Essays on Two-sided Market, Product Quality and Welfare

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By

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Certificate

Certified that the Thesis entitled

"Essays on Two-sided Market, Product Quality and Welfare" submitted by me for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my work carried out under the supervision of Prof. Tanmoyee Banerjee (Chatterjee) and Prof. Swapnendu Bandyopadhyay, Department of Economics, Jadavpur University.

And that neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere/elsewhere.

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Chapter 1: Introduction

1.1 Overview

The digital ecosystem has experienced a rapid growth in the past few decades across the globe and it has been one of the major steers behind any successful economy. The retail e-commerce which has grown to be an indispensable component of global retail industry, has seen a substantial volume of sales of $4.28 trillion in 2020 and its sale volume is expected to elevate to $5.4 trillion in 2022. [1] The e-commerce marketplace in an emerging country like India is projected to expand to $111.40 billion in 2025 from $46.2 billion in 2020. [2] The worldwide business landscape has experienced a massive transformation following the emergence of wireless handheld devices and internet. To see the evolution of digital platforms, we have to trace the path of history over 50 years back when the advent of early technological advancement like Electronic Data Interchange (EDI) in 1960s facilitated the introduction of present-day electronic commerce by allowing a computer-to-computer digital interchange of data instead of relying on traditional way of transferring data such as mailing and faxing.

Michael Aldrich's discovery of electronic shopping in 1979 by bridging a transaction-processing computer to a modified television through a telephone has paved the way for modern online shopping. In 1982, France introduced an online system, Minitel by connecting millions of telephone subscribers to a computer network. In the same year, Boston Computer Exchange created first online platform primarily as a market for people involved in selling of used computers. The early 1990s was marked by the inception of World-Wide-Web when Tim Berners-Lee developed the first web server and wrote the first ever web browser. In 1992, Book Stacks Unlimited by Charles M. Stack launched a commercial website (www.books.com) for

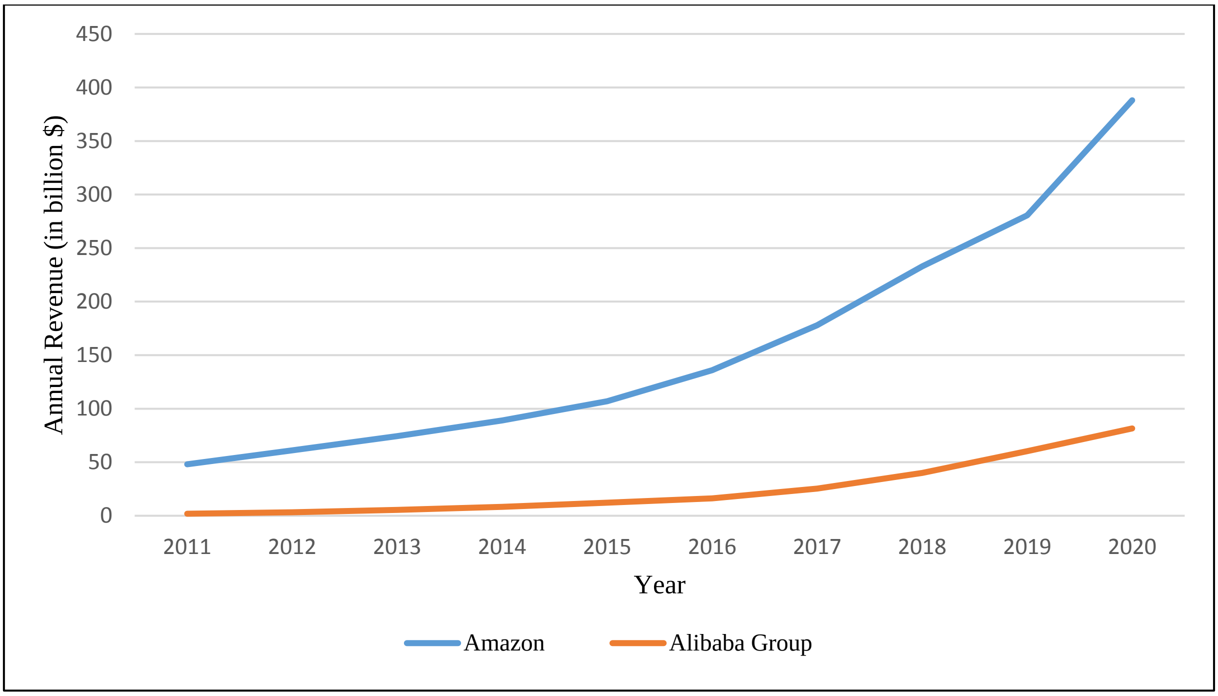
[1] Reported at https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/

[2] Reported at https://www.ibef.org/industry/ecommerce.aspx

digital selling of books. In late 1990s, Netscape founded a web browser under the code name Mozilla which turned out to be the primary Navigator browser before the development of present giant Google. The mid 90s was characterized by the massive growth in the commercial worldwide use of internet. The year 1995 celebrated the iconic inception in the history of online platform as today's tech-giant, Amazon and auction-web mammoth, eBay were launched. Amazon, founded by Jeff Bezos, started off its operations globally as an online bookstore and expanded to become one of the online retail giants in the globe by including electronics, appliances, apparel, toys, groceries, beauty and sports products and many more in its supply networks. The first ever digital auction site, eBay, launched by Pierre Omidyar, allowed one-to-one transactions. In 1998, the continued rise of e-commerce industry led to the development of PayPal, the first online payment system used to transfer money. In 1999, another e-commerce giant, Alibaba developed as an online platform and saw its profitability in 2001. In 1999, worldwide e-commerce sale reached to $150 billion (Terzi, 2016). In 2015, Amazon amounted for more than half of global e-commerce growth (Garcia, 2015). In 2017, worldwide retail e-commerce sale volume expanded to $2.304 trillion, a sharp 24.8 percent rise from the previous year (McNair & Pearl, 2018). In 2017, e-commerce sales across the world amounted to $29.367 trillion, comprising 25.516 trillion from business-to-business (B2B) sales and $3.851 trillion from business-to-consumer (B2C) transactions. [3] Figure 1.1 shows the annual revenue of Amazon and Alibaba group for the period of 2010-2020.

[3] Reported at https://unctad.org/press-material/global-e-commerce-sales-surged-29-trillion

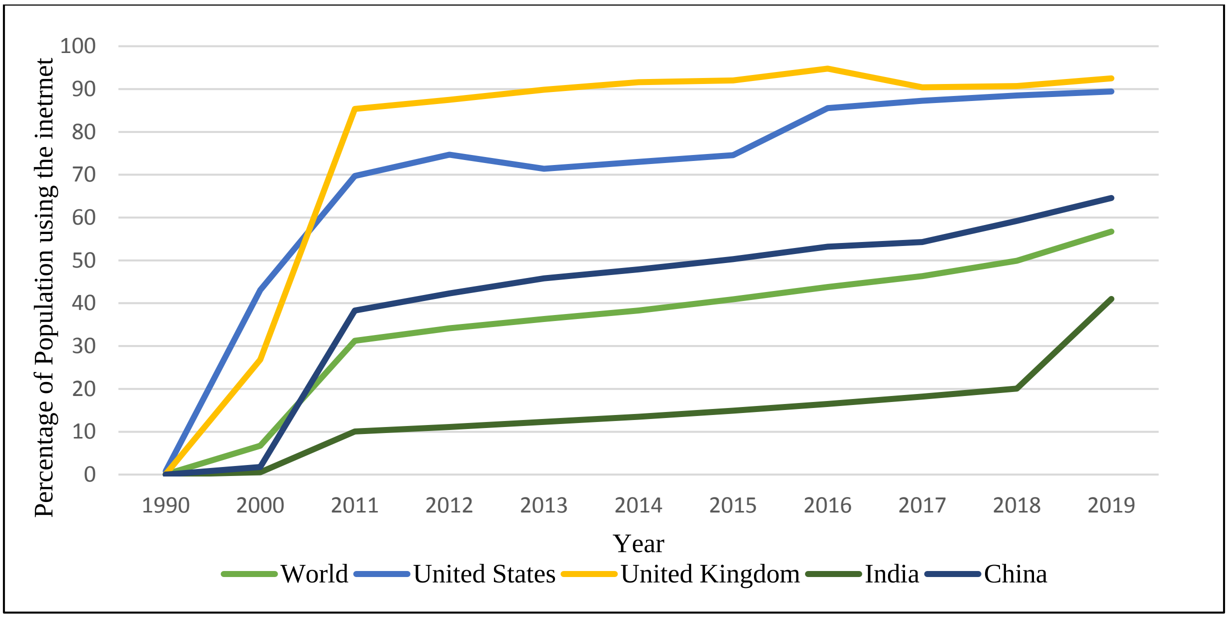
Figure 1.1: Annual Revenue of Amazon and Alibaba from 2011 to 2020



Source: Statista 2021

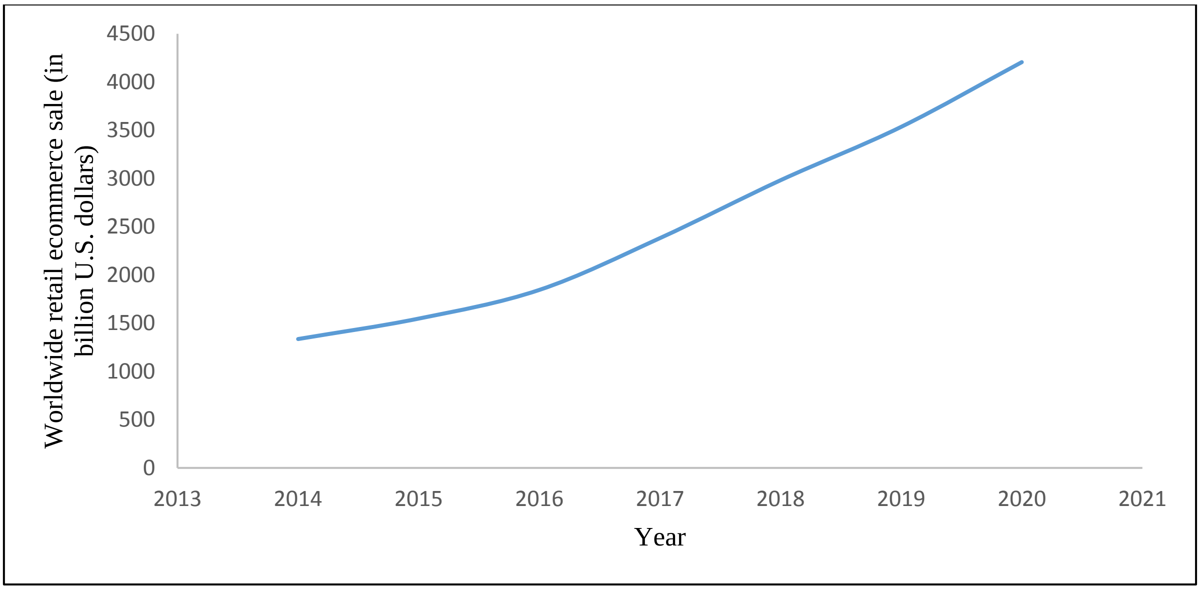
Online platforms rode a whimsical path since its inception. The substantial advancement in technology over the years has driven the global ecommerce growth. The success of digital platform is directly intertwined with the introduction of internet. This can be considered as one of the waves which pushed the growth of digital marketplaces to a soaring high. Figure 1.2 exhibits the percentage of population using internet for entire world and four countries, United States, India, United Kingdom & China. It is evident from the figure that the worldwide percentage estimate for internet use is rising since its arrival. With higher adoption of internet, as Figure 1.3 suggests, there originates a concomitant increase in worldwide annual e-commerce sales.

Figure 1.2: Percentage of population using internet for the period 1990-2019



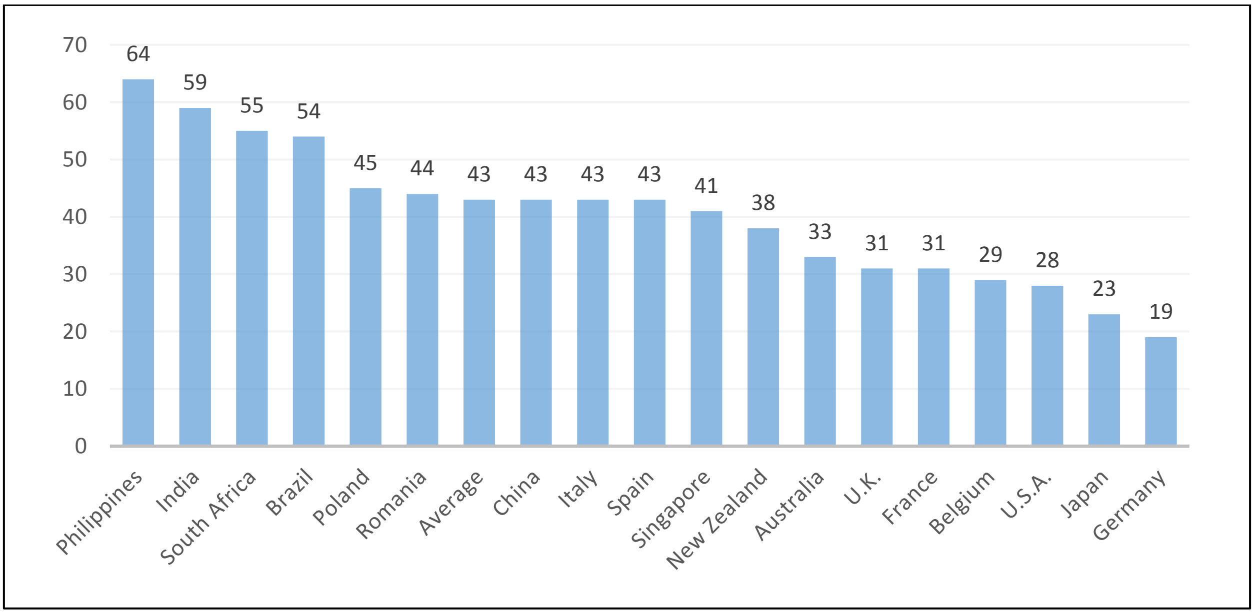
Source: World Development Indicators databases.

Figure 1.3: Retail ecommerce sales globally for the period 2014-2020



Other two waves that ecommerce faced in the past few decades, were the linking businesses to a secure network to conduct electronic transactions in the mid-90s and advent of wireless handheld devices that facilitated the online shopping with wireless internet. [4] In 2021, the figure of mobile device users across the world stood at 5.29 billion and more consumers purchase using mobile devices rather than through desktop and laptops. [5] Another wave originated in the recent past is due to the outbreak of Covid-19. The growth of ecommerce has boomed during the Covid-19 crisis as people across the world now find digital platform a more convenient way to shop and they spend more time using different social media. E-commerce share in the worldwide retail sales rose from 14% in 2019 to 17% in 2020 (UNCTAD, 2021). Figure 1.4 exhibits the percentage increase in the number of users aged from 16 to 64 devoting more time on social media use amid coronavirus lockdown. [6] Globally, on an average 43 percent people devoted more time on social media during covid-19 crisis with Philippines has topped the chart with 64 percent users.

Figure 1.4: Percentage rise in users for devoting more time on social media during covid-19



[4] Reported at https://venturebeat.com/2012/03/16/cash-in-on-mobile-the-third-wave-of-e-commerce/

[5] Reported at https://datareportal.com/global-digital-overview

[6] Source: https://datareportal.com/reports/more-than-half-the-world-now-uses-social-media

More generally, these online platforms are identified with the presence of two distinct groups of users whose ultimate gain originates by interacting with other group of the market through a common intermediary (Rochet & Tirole, 2003). Indirect network externalities or inter-group network effects are one of the defining attributes of two-sided markets which can be described as intermediary platforms catching two groups “on board” and facilitating interactions between members of two sides through the levy of appropriate fee on each side (Rochet & Tirole, 2006). In case of online streaming media, final users and content providers interact with each other. More is the volume of contents on media player, more worthy will be the media from consumers’ perspective and vice versa. More seller base will attract more final consumers in case of ecommerce market. Advertisers and viewers/users constitute the two sides of digital social media. There has been other examples of the platforms that have followed the two-sided market structure. These businesses possess some undeniable advantages that are not only contributed to achieve higher growth rate but to reach larger customer base over the years as well. [7] The one of the important facets of two-sided online platforms is the ease of doing businesses with unifying and integrated trade opportunities. One can simply connect and make businesses with other users residing on the other part of the world through internet platforms seamlessly. Secondly, two-sided internet platforms reach the accelerated growth path by removing physical barriers and developing a robust & blooming digital ecosystem. The third and most practical merit of two-sided platform stemming from first two advantages is the access to larger user base around the world.

This chapter provides a comprehensive outline of the thesis and builds a fundamental premise for the present study. Section 1.1 presents a primer to two-sided online market. Section 1.2 lays

[7] Around 4.55 billion people use social media across the globe in 2021, a considerable jump by 409 million from the previous year. Globally the rate at which number of social media users are climbing, stands at 9.9% per year. Reported at https://datareportal.com/global-digital-overview

down the broad objectives of our research. Section 1.3 delineates the methodology of the research design. Section 1.4 explains the contributions of the present study to the existing theory. Section 1.5 outlines the structure of the dissertation.

1.2 Objective of the research

The two-sided market has evolved over the years and become an indispensable part of market economy in a way that no one could have ever imagined. Despite the burgeoning works made theoretically and empirically in the last three decades on the business strategies of market economics with indirect network effects, two-sided market economics have experienced scant progress in this regard. The purpose of the present thesis focuses to fill the research gap in the theoretical aspect.

The theory builds on the rich volume of existing literature starting with the early and pioneering works by Rochet & Tirole (2003, 2004, 2006), Armstrong (2006), Caillaud & Jullien (2001, 2003). The present dissertation focuses on three broad issues that either have not been evaluated in the existing literature or have been investigated only in a limited extent. Three distinct theoretical models have been developed to study the following three research questions that to the best of our knowledge, are not examined before:

- Evaluating the effect of price discounts on the level of service quality, advertising level and profit of platform when two-sided monopoly platform gives out discounts on product sold and also uses advertising as a tool to transmit information about discount to buyers. The model endogenously decides the level of quality of service and advertising level as well. A comparative analysis has also been made to examine the difference of results between monopoly market equilibrium and social optimum.

  Offering concessions and deep discounts have been the lucrative stimuli for e-commerce platforms to capture larger market share. Many big e-retailers are adopting the pricing strategy with unexpected excessive discounts. Amazon's promotional event, Great Indian Sale, Big Billion Days by Flipkart are presented to customers with extremely high discounts in a view to attract more consumers and compete in the market. This specially spurs us on to intervene and investigate the effect of discounts on quality and profit of the platform.

- Analyzing the effects of two forms of taxations --- a tax imposed on platforms' revenues and an ad valorem tax on consumers' participation fees, in a vertically differentiated two-sided duopoly platforms where each platform expands the probability of matching between its registered agents on two sides with the help of an informative advertising technology. The study also highlights the effects of the strength of cross group externality on model variables.

  The growth of two-sided platform businesses is skyrocketed in the past few decades all over the globe because of the universal use of internet and different handheld devices. The lawmakers in different countries have shifted their focus in developing an effective regulatory atmosphere for this rapidly increasing markets in the form of tax implementation to ensure that these giant retail companies give fair proportion of their sales revenues to governmental coffers. [8] This is particularly necessary in continued growth of this industry and to protect this booming market from excessive financial and legal burden. This has driven us to step in and explore the issue of tax incidence on platform businesses.

- Understanding the contracting problem between a platform and a seller where seller holds a private information regarding his/her per unit cost for producing a product with certain level of quality. In particular, the study discusses the first-best and second-best choices of each type of seller for two standard forms of contract design, revenue-sharing

[8] Reported at https://lawshelf.com/videocoursesmoduleview/taxation-in-e-commerce-module-4-of-5

and cost-sharing contracts when service quality is endogenously settled. The model is then extended by introducing the advertisement in the platform framework. In this light, the study finds out the platform's profit-maximizing level of advertisement for complete and incomplete information cases under both revenue-sharing and cost-sharing contracts.

Above research subjects have been taken from various real-life instances of online platform which has particularly motivated us to adopt these specific three aforementioned concerning issues. The thesis intervenes into existing literature with three comprehensive models which will combine the real-life problems with the prevailing theories and divulge some key outcomes. Before spelling out the key findings of the thesis in a brief, a concise illustration of methodology has been produced in the next section.

1.3 Methodology

The dissertation employs a range of standard theoretic modelling framework of Industrial Organization to answer the above mentioned research questions of the present thesis. The sequential game structure has been used to solve the different stages of the game involving the decisions of economic agents operating either in monopoly or duopoly platform structure. The stage game is answered using Backward Induction and Sub-game Perfect Nash Equilibrium has been obtained in each theoretic structure, thereby helping us to carry out comparative static exercise in each model. Last but not the least, a numerical study comprising different parameter values has been performed in each chapter to substantiate the analytical findings derived in each analysis.

1.4 Contribution

Two-sided online platform possesses a great value to academics and policy practitioners for its expeditious growth trajectory since its arrival. Although there exists a host of literature explaining different issues related to platform, however, only few of them discuss about the recent trend in platform market and behavioural course of its economic agents. The present research casts light on the underexplored sphere of knowledge concerning two-sided markets and builds theoretical model setup to institute some valuable intuitions that greatly contribute to the large body of literature. We present a detailed analysis on each of these research questions on the ensuing chapters, however, here we highlight the crucial results.

- The analytical result suggests that the rising discount has a dampening effect on non-price components (here, quality of service) and volume of transactions for monopoly platform. This result bears a significant practical implication as the umpteen discount offers not only hurt the quality standards of platforms but also erodes the trust and confidence of customers on product and platform. [9]
- The theoretical result further indicates that tax incidence has negative effect on the level of informative advertising sent by duopoly platforms which attempt to increase the probability of finding sellers by buyers through the advertising technology. Most interestingly, tax on consumers is partially shifted to the sellers' side. Both taxes cause adverse impacts on platforms' profits and consumers' surpluses on both platforms. Numerical comparison between taxes on platforms and consumers based on certain parameter values establishes that a tax on platforms should always be preferred to a tax on consumers. Additionally, with the increase in the strength of cross-side externality, platforms increase the level of informative advertising.
- Finally, the study constructs a contract design that could help to mitigate the coordination problem between platform provider and seller where price per product is influenced by seller's product quality and platform's service quality. An inventive result reveals that the high type seller must provide product quality less than the first-

[9] Reported at https://dare2compete.com/blog/gd-topic-are-online-discounts-killing-e-commerce

best quality in presence of information asymmetry when service quality is endogenously determined. This result marks a complete departure from the one-sided model result which holds that high type seller should serve first-best quality when information asymmetry is present. We further set a comparative study between most commonly adopted form of contracts, revenue-sharing and cost-sharing. In particular, the study shows the diminishing effect of tax on product quality, service quality and profit of the platform. Additionally, the chapter finds that the platform sends more advertisement when it knows the exact type of seller.

The most prominent contribution of the present thesis is the development of comprehensive research models that could explicitly describe the latest events occurring in the domain of two-sided digital market.

1.5 Outline of the thesis

The thesis intervenes in the existing literature with three prevailing research proposals which have been discussed in the upcoming chapters. The ensuing chapters are organized as follows.

The present chapter sets out a concise discussion on the emergence of two-sided online platforms and backdrop of the research problems. It outlines the recent global trend of online platforms with carefully explaining the objectives of present thesis. Particularly, the significant theoretical findings of our study and their practical & economical relevance have been expounded. Next, the contribution of the thesis is thoroughly and extensively presented.

A rich volume of literature on the studies related to online platforms has been exhaustively surveyed in the Chapter 2 entitled *"Review of Literature"*. The key findings of each of these studies have been extracted and elaborated to describe the recent trends in two-sided platform market. The articles reviewed explore both the analytical and theoretical models relating to two-sided markets. Based on the existing findings, research gaps have been identified which embark the foundation of each of our research questions. On the basis of the detailed literature survey and research proposals, theoretic structure has been established and modeling framework is then advocated for each research objective. Each chapter uses these models to answer the research questions and analyze key findings.

Chapter 3 entitled *"Online Platform Quality, Discount and Advertising: A Theoretical Analysis"* sets forth the impact of umpteen discount deals given to consumers by platform by analyzing a similar framework adapted following Rochet and Tirole (2003). Specifically the chapter determines the optimal level of service quality and advertising undertaken by platform in presence of indirect network externality. A comparison between market equilibrium and social optimum is carried out as well.

Chapter 4 on *"A Theoretical Analysis on Two-sided Duopoly Platforms and Tax regimes"* focuses on another critical issue, tax incidence that has remarkable effect on platforms' business strategy. This chapter highlights the effect of tax on fees paid by buyers & sellers and the level of informative advertising sent by the duopoly platforms which seek to improve the matching between the two opposite sides. We use backward induction to interpret the optimum results. Importantly, this chapter produces a comparison between a tax levied on platforms' revenues and an ad valorem tax on consumers' access fees by conducting a numerical analysis for certain parameter values.

Chapter 5 entitled *"Interaction between online platform and seller: Deriving the impact of tax and advertising"* explores the contracting problem between a platform provider and a seller when information asymmetry is present. Given the burgeoning literature on contract problem of retailer and supply chain participants, this chapter unlike other works, interestingly connects platform's service quality into the contracting framework. In presence of information asymmetry, this, in a way, gives rise to optimal choices that mark off from the conventional one-sided choices. This chapter also introduces the effect of advertising in our modeling structure.

Chapter 6 concludes the thesis summarizing the crucial findings obtained in Chapters 3 to 5 on different relevant issues on two-sided platforms and sets off the avenues for future research endeavours. Bibliographical references is appeared thereafter.

Chapter 2: Review of Literature

The continuous evolution of Internet and emerging technological advancement have contributed to the development of newer form of business models. There are instances where more and more traditional markets are transforming them into online platforms and adopting two-sided market strategies. The widespread adoption of these strategies is not only for its cost-effective way of trading. But these businesses have other advantages as well. The two-sided online firm experiences a wider user base and can have a more comprehensive understanding about user preferences that the firm could use efficiently through its online services. Another stimulus recently spurred the growth of two-sided market is outbreak of Coronavirus disease 2019 (Covid-19). More and more people are approaching to online markets for their daily purchases for avoiding public gatherings and maintaining social-distancing.

Two-sided market is interpreted as a framework connecting two distinct sides through a common platform provider by appropriately imposing fees on both sides (Rochet and Tirole, 2004). The one of the distinguishing characteristics that set this kind of market apart from other forms of market structure is the indirect externalities or inter-group network effects (Rochet and Tirole, 2003; Caillaud and Jullien, 2003; Choi, 2010). This particularly implies members of one side earn benefit when other side member of the market joins. In case of any e-commerce platform, product suppliers and end consumers represent two distinct sides who consummate trade with each other. As more products are available in the retail platform, the more worthy the e-commerce platform becomes for final consumers and vice-versa. The other notable examples of two-sided platform include the social networking applications such as Facebook.com, LinkedIn, where final consumers and advertisers interact, the media sharing networks such as YouTube, Spotify where content creators and consumers connect with each other, the several auction sites (e.g., eBay, Yahoo) where sellers and consumers execute deals, video game consoles (e.g., PlayStation, Xbox) where game creators and consumers interconnect, etc. Two-sided online market is growing at a whopping rate and spreading its wings in different sectors across the globe. [10] In this backdrop, it is significantly pertinent to probe different issues relating to two-sided market which have not earned sufficient attention in the existing literature. Before going into the detailed analysis of those issues in the following chapters, the present chapter offers a succinct and concise overview of both the analytical and empirical literature concerning various themes related to two-sided markets for better understanding of functioning of this form of market structure. We essentially investigate the studies on those issues we have explored in the upcoming chapters.

2.1 Two-sided markets: A review

There are vast amount of literatures that resemble our work. The various dimensions of two-sided market have received importance in recent articles and those can be traced back with pioneering studies by Rochet and Tirole (2003, 2004, 2006), Armstrong (2006), Caillaud & Jullien (2001, 2003), Jullien (2011) who famously set forth the pivotal role of two-sided market in different sectors of economy. Rochet and Tirole (2003) are among the first to consider network externality and multi-sidedness together in their work. The work by Rochet and Tirole (2003) is majorly motivated by credit card industry, however can be considered as a general model appropriate to explain broader domain of two-sided markets. The model starts off with the paradigm of monopoly platform structure and then develops the concept of platform competition. The model builds up on a sequential game theoretic structure with a platform determining the per-transaction fees to be levied on two distinct groups of the market in the first stage followed by a second stage where members on the each side decide about joining the platform. The study advocates that monopoly platform's aggregate price is decided by an altered version of monopolistic form of Lerner condition and optimum allocation of prices

[10] In 2020, the retail e-commerce trading skyrocketed with a rate more than 25% globally. Reported at https://www.statista.com/topics/871/online-shopping/

between two groups is determined by the relative elasticity of demand. In case of competition, the optimum decision on price allocation is governed by a modified form of monopoly outcome. The study also introduces the case of non-profit intermediary platform. The Chapter 3 of the present thesis employs the modeling framework established by Rochet and Tirole (2003), however, with a significant innovation.

Rochet and Tirole (2004) identified and presented two distinct kind of pricing rule generating two forms of externalities. First is the platform's per-interaction or variable fees impacting the two group's willingness to interact and hence their net benefit from potential transactions. Second effect stemming from the interaction-independent membership or fixed fees impacts the members on two sides' existence decision on the platform and thus causes membership externalities. The platform's formation of usage and membership fees is pertinent only if both sides take usage and membership externalities into account while transacting on platform. In addition to this, Rochet and Tirole (2004) had also suggested a formal definition of two-sided market which says that when volume of transaction on a platform changes with the per-transaction charges on each side while total price remains constant, that platform follows two-sided market. Put it differently, pricing structure is important for two-sided market and platform has to optimally formulate it to bring two sides "on board". They integrates the model by considering both kinds of charges and provides the expression for optimal pricing structure which is simply a variant of Lerner rule. Together with this, comparison of results of two different models derived by considering either kind of externality has been emphasized. An extension of the model includes the payments made between end users.

Contributing to the strand of literature on two-sided market, Armstrong (2006) emphasized three separate frameworks (monopoly platform, competing platforms with agents are single-homing and the "competitive bottlenecks" framework where agents on one side participate on all intermediary platforms) of two-sided markets to discuss about the determinants of optimal prices. For doing this, he considered two groups interconnected by a platform (or, platforms). The three most important factors impacting the optimal prices are (i) the degree of cross-group network externalities, (ii) two forms of fees structure (lump-sum or per-interaction fees) and (iii) last but not least, the decisions of the agents on single-homing or multi-homing. In particular, positive indirect network effects induce platform to perform effectively on one side so that it could compete competently on the other side of the market and vice versa. This generates a downward influence on platform's prices to two groups relative to the case with no externality and thus reduces the profit of the platform. It can be seen that equilibrium fee charged to one side under monopoly platform is adjusted downward by amount of utility exerted on other side of the agents. In the model for duopoly platforms, it can be inferred from the optimal prices that platform will attract one side more intensely than other group when that side (i) is located to the more competitive part and/or (ii) generates higher utilities to the other side. The study also discusses the concept of two-part tariffs in the two-sided platform market.

The study by Caillaud and Jullien (2001) establishes the first attempt to examine the role of cross-subsidization, originating from the existence of third degree price discrimination and cross-group network externality, on the magnitudes of competition among cybermediaries. Cybermediaries are the newer form of intermediaries specialized largely on informational services, that is, these types of intermediaries process the information regarding their users and help both types of agents to find each other. The paper analyses the pricing decisions of monopoly and competing cybermediaries. In particular, competition between intermediaries with membership fees is first emphasized and then the effect of transaction fees along with access fees on competition is explored. A dominant-market equilibrium shows that with access charges and users participating on only one intermediary, one cybermediary appropriates all the trade in the entire market with positive level of profit. However, this profit disappears with introduction of transaction fees along with access fees or the possibility of multi-homing by agents.

Caillaud and Jullien (2003) modeled the imperfect competition between platform providers. They have introduced the concept of "chicken and egg" causing from the existence of indirect network effects in platform market. This, specifically, implies the platform should have a large seller base to target the customer pool but seller will join the platform only if there exists a huge market for registered buyers in that particular platform. They further spell out the notion of "divide and conquer" pricing strategy, that is, subsidizing one group of members (divide) and recuperating that cost by charging high on the other group (conquer).

There exists a wide range of literature on two-sided platforms concentrating on the simultaneous arrival of two distinct sides. However, Hagiu (2006) first argued the sequential courting of two sides as most type of two sided markets does not follow the stylized depiction of arrival of agents at the same time, while the courting of two groups on many markets is based on a sequential move game. He presented some examples as well for better understanding of this simultaneous problem of coordination. For application developers and video game consoles, platforms invite the seller way before buyers to make sure the enough seller support on the inauguration of platforms to the buyer market. It would be more realistic to consider one group to enter the platform before another group. The study departs from the earlier literature to consider the fact that platforms should focus on courting the sellers (or, chickens in connection with "chicken and egg" problem) first.

Contributing to the wide array of literature, Hagiu (2009) studied some crucial strategic elements affecting pricing structures on two sided markets. He observed that stronger liking for product diversity by consumers causes products to be less substitutable and that allows platforms to capture more profits from seller side compared to buyer side in monopoly framework. This evidently explains why video game consoles appropriate more profits from the game developers and application platforms secures larger surpluses from buyer side. The reason is the higher demand of buyers for more variety for videogames compared to applications. However, more preference for diversity produces larger market power for producers which causes intermediary's price reducing strategy on buyers less productive in competing platforms' framework. Rysman (2009) thoroughly delineates some major issues relating to two-sided markets such as pricing strategies, openness etc.

The study by Dukes & Liu (2016) discusses about the strategic design of search environment which is provided by an online platform as a way to reduce consumers' searching cost. The game has followed a sequence of stages. In the first period, the online platform determines its search environment followed by sellers' decision on setting prices. In the next stage, the consumer decides the number merchants to assess (or, breadth) and the total amount of characteristics of a particular product to analyze (or, evaluation depth). In the final step, the consumers make their purchase decision out of all evaluated products. The study optimally finds the consumers' evaluation breadth & depth and concludes that optimal search environment is set at a level leading to higher search cost which allows consumers' to evaluate not too many sellers, but again not too high causing them to analyze products at a partial depth.

There exists a rich volume of studies focusing on welfare aspects on two-sided markets. Choi (2010) examined the implications of tying on price competition and total welfare in two-sided platforms with the indirect network benefits. The work by Choi (2010) is mostly inspired by the latest antitrust issues where Microsoft prompted its members using its Windows Operating System to accept its Media Player as well and this act by Microsoft which damages other digital media players like RealNetworks, is anticompetitive. The paper stands in contrast to the literature concerning about the exclusive intermediation (i.e., participating in only one platform) by agents. Although Armstrong (2006) considers multi-homing by one group of agents in his competitive bottleneck framework. However, the assumption of single-homing by both groups or only one group lies in sharp contradiction with the recent structure of markets. For example, the users and content providers in digital media register in more than one platforms. Choi (2010) discussed the issue of tying by considering the multi-homing by both groups. The result indicates that tying causes more multi-homing by consumers and provides access of platform-specific contents to larger volume of consumers. As a consequence of this, tying enhances welfare with multi-homing.

Bolt & Tieman (2006) undertook the social welfare analysis to determine socially optimal price structure on two-sided markets. The study indicates that social welfare practice causes monopoly platform to earn negative profits, thereby creating a built-in cost recovery issue. This result lies in contrast with outcome obtained in one-sided literature which states that social welfare maximizing prices lead to zero economic profits. The reason is simple and lies in the positive impact of indirect network effects on two-sided industry. To attract users from both groups and increase the participation among users, social dictator sets prices to both groups less than the marginal cost, thereby leading to loss for monopoly platform.

Jeon & Rochet (2010) explore the effect of open access scheme of electronic journals on quality measures. The sequential move game starts with the journal deciding the minimum quality standard and the prices in first period. In the next period, authors determine the submission decisions on that journal followed by the journal’s accepting or rejecting decisions based on the referees’ decisions in the third stage and finally, readers choose whether to purchase the journal. Open access would be efficient policy for journal from social welfare perspective, otherwise open access lowers the quality below the welfare maximizing rate.

Ylikoski (2005) maps out the significant difference between two major forms of consumers’ searches – heuristic & analytical online searches by undertaking a field experiment on students sample from 149 subjects. The study affirms that during the process of acquiring information before purchasing, time limits and lack of knowledge & proficiency of consumers make the formal online searches unrealistic. Heuristic online searches --- the low-deliberation searches, exert a positive and major connection towards the variety of information used in internet searchers, in contrast to the analytical events which are generally pre-planned searches. Analysis of the article suggests that heuristic events dominate the internet searches of consumers whereas analytical searches produce more definite search results.

The review of above discussed seminal papers shows an overall understanding of price structure and behaviour of markets having indirect network benefits. It is important for all economic agents to take the effects of externality into account while deciding the price structure. These papers employ simple modeling framework based on the two-sided platforms by considering several different forms of market (i.e., monopoly platform and duopoly platforms).

A host of recent studies on two-sided markets has described several issues by framing simple theoretical model whereas analysis derived using empirical model receives little attention in the existing literatures. The following papers focus on the empirical investigation of different topics of two-sided markets. Brynjolfsson & Smith (2000) empirically investigated the internet retailers (may be referred as “frictionless” industry) and provided a comparative study between online and conventional platforms for two types of physical goods- books & CDs. By employing more than 8,500 observations on prices from the period February, 1998 to May, 1999 and applying various statistical tests, the study determines the pricing pattern for 41 online and conventional platforms. It proposes some highly relevant findings. Online retailers impose 9-16% lesser prices for books and CDs compared to conventional networks. This substantial difference in prices will make competition and survival difficult for conventional retail channels. Moreover, the prices for products change in lower increments for internet networks compared to conventional platforms. There exists considerable and significant price differences across the retail channels on Internet.

Landsman & Stremersch (2011) empirically investigated multi-homing—the possibility of participation on more than one platform by an agent, in the context of two-sided video game industry. The authors distinguishes between two categories of multi-homing—seller-level & platform-level multi-homing. Both types of multi-homing carry significant implications in boosting the sales level of a platform. By seller-level multi-homing, they imply the degree at which applications of a specific seller on a platform are present for buyers on its rival platforms and platform-level multi-homing signifies the degree to which applications present on a particular intermediary are also accessible on other platforms. The study also considers additional two factors—platform age and its market share which can have a major effects on deciding the impact of both types of multi-homing on platform sales. The intermediary age and its market share play a significant role in reducing the uncertainty among buyers about the platform adoption choice. The study finds that the (negative) impact of platform-level multi-homing is stronger than (positive) the applications available on the platform on sales volume. Moreover, this negative effect is more dominant for platforms with lower market share and emerging platforms than a full-grown platform and platforms having greater market share. Again with greater market share of a full-grown intermediary, more applications will multi-home. These outcome may influence the future behaviour of such market.

2.2 Two-sided markets and discounting

There has been a recent surge among global retailers to use “discount” (or, sometimes coupons) as a crucial part of their pricing strategy to court more consumers and thereby, expand the volume of interactions between two groups. The recognition that most of the two-sided platforms are engaging in offering hefty discount deals to consumers all through the year has triggered an upsurge of research in theory of two-sided markets.

One of the earlier groundbreaking studies on the principle of couponing (or, price discounting) by Narasimhan (1984) introduces coupons as a price discriminatory mechanism for particular group of customers. The implications concerning coupon use, differentiated elasticities among users & non-users of coupons, couponing across distinct brands have been analyzed using a theoretic model and then verified by employing a panel dataset. The decision for coupon use is particularly based on the price savings obtained for using coupons and cost associated with it (i.e., cost of time). The key findings reveal that the intensity to use coupons reduces with opportunity cost of time and the buyers who use coupons are more price elastic compared to low intense users of couponing.

The paper by Feng et al. (2021) investigates a monopoly two-sided platform provider's optimum prices for product and its profits in both promotional and non-promotional regimes when both platform provider and third-party seller offer identical products to customers by presenting a game-theoretic model. The stage game proceeds with monopoly platform provider's decision to develop its first-party product in the first stage followed by the determination of product prices announced by both platform and third-party seller & consumers making their buying decisions in the second stage. The study indicates that platform will impose a greater regular price in the promotional phase when the market expansion rate is small or commission level is low. Moreover, with low and moderate rate of market expansion and higher rate of commission, promotional initiative does not necessarily cause higher market demand for first-party product. In absence of promotional activities by third-party sellers, platform provider's promotional decisions benefit both the platform provider and third-party seller as long as redemption cost is lower or market expansion rate is higher. Then the model is expanded by introducing the third-party seller's promotional strategy. The study concludes that the promotional strategy of platform attains a win-win pay-off for both platform and the third-party seller irrespective of whether third-party seller endorses its product or not when the market expansion rate, redemption cost and fraction of price sensitive buyers fulfill certain restrictions.

Mela, Gupta & Lehmann (1997) empirically studied the long run impact of advertising and promotional activities on buyers' preference for brands by addressing panel data for over 1500 households for a period of $8\frac{1}{4}$ years on one packaged commodity in one market. They recognize two class of buyers – loyal (or, comparatively less sensitive to prices) and not-loyal (or, having more price-sensitivity) and conjecture that more and more buyers are turning more price and promotion responsive over time. Moreover, the dual impact of rise in price sensitivity of consumers and enlarging the volume of non-loyal buyers in respect to fall in advertising have powerful impact on consumers' preferences. Contrary, more promotional offers cause buyers to turn increasingly responsive to prices and promotions. Mela, Gupta & Lehmann (1997) indicated that "advertising" creates "good" impact on preferences as it helps in reducing the volume of non-loyal customers and making them less sensitive to prices and in the same logic, "promotional" activities possess a substantial "bad" impact on consumers' choices. A prime limitation of this study is that the entire analysis has been undertaken by considering only one product-group.

Dong, Liu & Zhao (2021) presented an empirical research to study the low-discount promotional strategies and guide in developing marketing policies by using a unique consumption dataset comprising the details of 4,465 customers for a period of 21 months on a mobile payment networking platform, Bestpay. The study focusses and analyzes the concept of "boomerang" effect causing from low-discount trap. The idea of "boomerang" effect has been originated from the disciplines of sociology and psychology, depicting the occurrence of individual's unpredicted way of reacting to any stimulus. The study confirms that the low-discount on non-essential products may display a negative impact on sales volume as low-discount results in reducing the consumers' buying intentions. Moreover, the boomerang effect lessens with rise in product price. Thus, customers' willingness to buy first diminishes with low discount, however, it again increases as discount rises, displaying a U-shape like curve for relationship between discount level and product sale volume. The study also identifies some factors (online learning, discounts within limited period etc) which could help to lessen the boomerang effect.

Balakrishnan, Foroudi & Dwivedi (2020) studied the effect of coupon use, membership services and peer influence on purchasing decision of customers and psychological behaviour by adopting a factorial experimental analysis to examine the proposed hypotheses. The empirical study with responses taken from 364 participants shows a rise in coupon value positively influence the purchase behaviour and impulsive buying by consumers as well as their repurchase objective. Digital coupon usage presents both the utilitarian benefit and psychological gain to online buyers and is an effective way to gain higher revenues.

The paper by Ieva, De Canio & Ziliani (2018) identifies and evaluates the factors leading to consumers' adoption of daily deal (known as deal-of-the-day or, DoD) websites' (such as Groupon) shopping by collecting the data through an online survey. The results obtained through empirical analysis reveal that consumer's shopping at daily deal sites is not only motivated by the utilitarian reasons; hedonic benefits of shopping at DoD sites play a considerable role. Put it differently, price saving is not the only prime driver of coupon use; emotions can be interpreted as one of the significant element deciding the purchase on DoD platforms. Thus, platforms should focus on hedonic, emotional and enjoyable interfaces along with price promotional strategy to court more new consumers and retain registered customers.

Together with this, authors indicate value consciousness of consumers and perceived risk for purchasing product deter customers from buying at DoD sites irrespective of age. However, deal proneness of customers encourages them to shop at DoD.

What emerges from reviewing the strand of literature on discounting is that exceptionally few theoretical study has been built concerning price discounting on two-sided markets and no study till date has incorporated the psychological benefit of discounting in the theoretic model in presence of advertising. Given this research gap in literature of two-sided market, the framework developed in Chapter 3 discusses the effect of discounting on non-price factors & profit of platform in presence of cross-group network externality by considering both monetary and psychological gain of discount in the structural model and thereby, adds considerable value to the literature pertaining promotional strategies of two-sided platform networking channels.

2.3 Two-sided markets and taxation

The rapid evolution of internet ecosystem has marked fundamental and institutional challenges to tax authorities. Bacache-Beauvallet and Bloch (2018) documented some key issues related to implementing taxes on digital transactions. The first element of difficulties is attributed to the nature of digital transaction which allows digital businesses more mobile across geographical boundaries. The transaction taking place among members of different jurisdictions imposes problem for collection of VAT/GST from different national borders. Most of the cases, big tech giants develop their businesses at a location to gain from lower tax rate and thus generate large volume of trading in big industrialized countries by paying only low corporate income taxes. Another element is the intangible kind of business form which could not be easily monetized (e.g., network effects, algorithms). Thus the tendency of tax evasion by most multinational firms and growing volumes of digital businesses with only small amount of tax collection have prompted fiscal authorities of different countries to develop fresh tax laws and update the existing ones. Faced with lower amount of tax collection from giant retailers, France, Italy, Hungary have proposed specific taxes on digital transactions. The issues related to taxation in internet economy have caught eyes of academics and policy makers, however, the volume of academic literature is scant. We analyze the issue of taxation on Chapter 4 titled "A Theoretical Analysis on Two-sided Duopoly Platforms and Tax regimes". The academic literature by Belleflamme & Toulemonde (2018), Goolsbee (2000), Kind et al. (2008, 2009) has considered the issue of taxation under two-sided platform.

Belleflamme & Toulemonde (2018) developed two-sided competing platforms model based on Hotelling product differentiation to derive the impact of different taxes on sub-game perfect outcome. The utility obtained by each agent of one group depends on the number of members participating on the opposite group, thus capturing the notion of "cross-group external effect". The paper explains two cases ---- symmetric and asymmetric tax situations. The stage-game consists of mainly two stages. In the first step, the each platform simultaneously decides the price to be charged on each side and given the access fees, members determine their joining decision on platform. For non-discriminating taxes, specific taxes are completely transferred to the side where these are imposed, keeping other side and platform unaltered. Transaction taxes upset both groups and benefit the intermediary whereas ad valorem taxes help fiscal authorities to seize a portion of platforms' profit. For discriminating taxes, members from untaxed side receive value from the tax.

Goolsbee (2000) runs an empirical work to examine the impacts of local taxation on consumers' decisions over purchasing from Internet. The study which employs an extensive data of 25,000 persons having online access suggests that taxation has prominent role on internet commerce. It advocates that the online commerce would dip significantly if sales taxes were to be imposed on internet. Not surprisingly, the degree of tax effect is so huge that applying existing taxes on the internet might lower the number of internet buyers by more than 24 percent.

Kind, Koethenbuerger, and Schjelderup (2008) studied the optimal provision of goods under two-sided market framework and compared the results obtained in specific and ad valorem taxes. They noticed that the provision of goods under perfect competition and monopoly is either under or over-supplied depending on the sign and strength of consumer group spillover effects. Particularly, when there exists positive spillover effects, the goods may be underprovided in the perfect competitive case. In contrast to the competitive case, a monopoly platform firm may oversupply both goods compared to social optimum. The note shows ad valorem and unit taxes can be imposed to reach the social optimum level of goods.

The article by Kind et al. (2009) presents a comparative analysis of ad valorem and unit taxes based on tax revenue and welfare implications under two-sided platform connecting two distinct sides. The analysis is based on a simple model of two-sided firm and argues that in contrast to the one-sided results, neither the tax revenue nor the welfare dominance for ad valorem taxes holds under two-sided market as unit taxes may yield higher tax revenue and welfare compared to ad valorem taxes for two-sided market. The note builds the idea that nature of an industry is more crucial than what has formerly been the perception.

The economic literature has a long tradition of examining impacts of taxation but the two-sidedness of a market has received scant attention in this regard. Moreover, to the best of our knowledge, the impact of two forms of taxes --- a tax levied on platforms’ revenues and an ad valorem tax on consumers’ access fees under two-sidedness of the market in the duopoly platforms has been first studied and incorporated in Chapter 4 of our study.

2.4 Two-sided markets and contract design: A review

The mode of contract between the participating agents has been a center point of debate in economic theory. When two parties involve in trading, there may exist some form of asymmetric information. The presence of asymmetric information leads member of both parties to commit on a contract in an attempt to mitigate the adversities they cause. The most popular application of contract concerning the existence of asymmetric information is known as principal-agent approach. There prevails a host of economic affairs that qualify to fit in the common structure of principal-agent framework. These applications include the contracting problem between platform and its seller, the owner & manager of a firm, employer & employee, insurance company & insured person, manufacturers & retailers and many more. Our discussion in this study emphasizes the contract design between a platform and a seller in the space of digital market. Platform providers share a proportion of their revenues with sellers in a way to attract them to platform businesses (Sur et al., 2019). Platform markets experience issues concerning the revenue sharing with sellers who claim to receive the unfair share of sales proceeds (Sur et al., 2019). The contract design has been studied extensively in existing literature, but most work mainly focuses on channel coordination of supply chain management. Issues of coordination in platform markets have gained only a few analysis in literature (Sur et al., 2019; Böhme, 2016; Babich et al., 2012; Zhang et al., 2019). One of the distinguishing quality of Chapter 5 titled "Interaction between online platform and seller: Deriving the impact of tax and advertising" is the discussion of issues of contract design in platform ecosystem. We now express and summarize the different aspects and various divergent perspectives on contract design as articulated by existing scholarly articles.

Sur et al. (2019) theoretically discussed the revenue sharing agreement between intermediary and service providers by employing a Stackelberg model. The study regards two platforms as the leaders of the game who first decide their revenue sharing fees and service developers as followers who determine the prices for their services in response to the fees fixed by platforms. The model analysis observes the existence of a stable unique equilibrium where both platforms and developers maximize their respective surpluses. According to them, the most challenging task the platforms face is to boost the size of markets.

Our work is well connected to the study by Böhme (2016) who highlights the issues related to second-degree price discrimination in the two-sided monopoly platform structure. The model assumes two types of agents on side 1 of the market based on their intrinsic benefits derived from participating at the platform. It starts with the benchmark case of full information where platform knows the type of the agent and monopolist optimally decides the contract variables by maximizing its own net surpluses. When incomplete information exists, platform maximizes its profit subject to participation and incentive compatibility constraints. The model with two different kinds of members on side 1 observes that platform access for high-demand type agents is unambiguously lower in incomplete information case than the full information situation. This marks the deviation of two-sided market results from one-sided framework. Then the model has been extended for the bundle-specific interaction.

The article by Babich et al. (2012) analyses a buyback contract formulation for a supplier-retailer structure where the retailer holds a private information regarding the demand state in the market. By offering the specific contract to retailer in accordance with the demand situation, the supplier tries to derive the hidden information from retailer about the demand condition. The authors calculate the optimal menu of contracts---a wholesale price (defined by w), buyback (denoted as b) & a lump-sum transfer (indexed as T) by maximizing supplier's profit subject to Participation and Incentive compatibility constraints. In case of no asymmetry in information, simple contract helps supplier to derive entire first-best profit by appropriating all the surpluses from retailer. However, in presence of asymmetry information, the supplier needs to give up a part of his/her profit to derive the private information from retailer. The study shows that under incomplete information, the supplier can formulate a contract in a way to appropriate surpluses from retailer and achieve the first-best profit.

The study by Xu et al. (2010) examines a supplier-manufacturer contracting problem where manufacturer secures major modules particularly from overseas suppliers (regarded as prime suppliers). But in the event of excess demand, manufacturer takes the help of local suppliers for fulfilling its urgent under-supplied orders. In particular, overseas suppliers provide better quality products than the local supplier who are regarded as backup or urgent suppliers in their model. However, the issue with local suppliers is that they have to put additional effort at the time of urgent orders and the production cost they bear during that time is unknown to the manufacturer. This asymmetric information about the production cost leads to the problem in contract designing for manufacturer. The study mainly considers two types of contracts---price-only agreements and contracts comprising of transfer payments & a lead time quotation. The course of the event starts with overseas supplier (denoted as S_1) determines the wholesale price. In the next stage, manufacturer gives orders to overseas supplier well in advance to receive the modules before the selling period. Finally, when there is excess demand above the normal order placed with S_1, the manufacturer places the urgent order with local suppliers (indexed as S_2). The study observes that manufacturer prefers to deal with local supplier as it can appear as a potential rival/competitor to S_1 and an efficient agreement leads to more surpluses for manufacturer. In case of price-only agreement, S_2 attempts to lower its costs by delaying the delivery and thus leads to inefficiency in contract designing. Moreover, this contract does not reveal the exact type of the supplier in contrast to the “transfer payments-lead time quotation” contract where the supplier discloses its true nature of cost condition, thereby leading to higher profit for manufacturer. The model also shows numerical study examining the effect of different parametric values on manufacturer’s profit.

The theoretical study by Zhang et al. (2019) analyses the interrelationship between e-retailer's contract design and manufacturer's quality choice by building a two-sided platform model in a platform-manufacturer structure. They largely explore two most commonly studied forms of contract--- revenue-sharing agreement and fixed-fee contract. The interrelationship has been examined for each form of contract for two cases, exogenously fixed product quality (benchmark model) and endogenously determined quality. The analytical model notes that with exogenous product quality, platform chooses the revenue-sharing contract. However, contract decision may get altered for endogenously chosen product quality. This variation in contract selection arises as revenue-sharing leads to lower price for manufacturer than the fixed-fee agreement while fixed fee causes better product quality for manufacturer. Therefore, platform adopts revenue-sharing (fixed-fee) agreement in response to larger (lower) heterogeneity in markets. Then the modeling framework has been extended for several other forms of structure (e.g., manufacturer competition, platform competition, generalized cost function).

There exists a rich volume of two-stage supply-chain literature explaining divergent issues in the space of contract designing. Ma et al. (2017) explained the contract choice in a two stage retailer-manufacturer supply chain by devising two forms of contract—wholesale price & two-part tariff contracts. Each contract choice is illustrated for two regimes---information symmetry & asymmetry framework. The model derives optimal contract variables where the market demand is affected by corporate social responsibility effort (CSR) exerted by manufacturer and marketing effort given by retailer. Under wholesale price agreement, the impact of CSR cost on profit of each agent on supply channel has been observed. The model shows that the impact of cost variation on retailer's profit is ambiguous where manufacturer's profit unambiguously rises with cost variation under wholesale price contract. Numerical analysis has been performed to exemplify the theoretical modeling setup. The study motivates the retailer to boost the manufacturer's CSR efforts through the proper implementation of contracts under supply chain in the presence of asymmetric information.

The paper by Ma et al. (2013) evaluates the two stage supply channel coordination where market demand is impacted by product quality enhancement effort exerted by manufacturer and marketing effort provided by retailer. Centralized and decentralized supply channel models have been demonstrated through a theoretical model. Three different types of decentralized contract---two-part tariff (TPT) contract, TPT along with quality-cost sharing model (CS-Q) & both quality and marketing cost sharing contract (CS-QM), have been discussed and the model shows that TPT alone cannot efficiently coordinate the members of supply chain (SC). A new form of contract, TPT along with sharing of both costs incurred for quality and sales effort, optimally coordinates the agents of SC. The model optimally determines the level of marketing effort, quality effort and supply channel profits.

From the above survey of scholarly articles on two-sided market economics, it can be inferred that some of the emerging and significant areas in digital platform either went completely unnoticed in the literature concerning two-sided platform or, earned insufficient attention in the existing literature. The persistent and continuous growth graph of platform industry has motivated us to evaluate three significant and comprehensive issues which have attracted the interest from both the policy-makers and academicians in recent years. By identifying the research gap in existing literature, we discuss three major subjects in the upcoming three chapters.

- Theoretical literature till date neither exercises the effect of discounts on non-price factors on platform market nor includes the psychological factor of discounts on modeling structure. The existing literature either frames the issue of discounts with the help of empirical analysis or provides limited attention in this regard, to the best of our knowledge. Chapter 3 titled as "Online Platform Quality, Discount and Advertising: A

Theoretical Analysis" takes care of the issue and considers the importance of psychological benefit of consumers along with the monetary gain from receiving discounts given by e-retailers in determining their utilities by building a theoretical framework. We then plan to derive the effect of discounts on price and other non-price factors by framing a simple model on two-sided market. To the best of our knowledge, no academic paper has included the psychological utility of discounts in their model and moreover, the literature pertaining discounts receives negligible status. Therefore, against the backdrop of platforms giving huge discounts to buyers, we opt for deriving the effect of discounts on other model variables. A welfare analysis has also been performed to compare it with the market equilibrium.

- There exists two distinct strands of literature focusing on two-sidedness of platform market and the effect of taxation on online buying behaviour. Although the academic literature revolving around the two-sided markets has advanced lately by considering the issues related to taxation on platform economy, no article till date has considered the two forms of taxation --- taxes levied on platforms' revenues and ad valorem taxes levied on consumers' access fees in a vertically differentiated two-sided duopoly platforms. Therefore, building from the above gap in existing literature, in Chapter 4, we consider these two taxes using a modeling framework. The model introduces a unique concept of an informative advertising technology which increases the probability of finding a registered seller by a registered buyer in a platform. Therefore, informative advertising sent by each platform raises the probability of successful interaction among its registered agents from two distinct groups. We develop a modeling framework to include the possibility of cross-group external effects present in each platform which charges per-transaction fees to sellers and fixed participation fees to its buyers. After determining the optimal levels of informative advertising and fees to be charged on both consumers & sellers for each platform under each tax regime, we derive a sensitivity analysis to observe the effect of each form of tax on model variables. The model compares the results obtained for both tax regimes for a same level of both taxes. Numerical experiment has been conducted to validate the analytical results. Moreover, the effect of strength of cross-side externality on model variables has been performed through a comparative static exercise.

- Platform coordination has been an important topic as members of platforms complain about receiving uneven share of sales proceeds. However, most literature pertaining channel coordination is emphasized on supply-chains giving little attention to platforms. Given this research gap and the important role of channel coordination in platform businesses, in Chapter 5, we aim to provide effective platform channel coordination using the contract design where per unit price is influenced by seller's product quality and platform's service quality. The issue with the platform is that it does not know the true nature of unit quality cost incurred for producing a product by seller. This results in asymmetry in information which induces platform to formulate a contract so that seller truthfully reveal its true type. For this purpose, we study two distinct form of contracts---revenue-sharing and cost-sharing contracts. A comparative analysis of two types of contract has also been presented. The seller-platform model has been extended to take into account the advertising in the platform setup. Therefore, Chapter 5 deals with the platform channel coordination in asymmetry information model under revenue-sharing and cost-sharing contracts with the existence of endogenous service quality which is not studied so far in any of the existing articles that have been reviewed.

- Finally, Chapter 6 marks the conclusion of the chapters and describes the key findings obtained in Chapters 3 to 5. It also presents the scope for future research relating to two-sided markets. Bibliographical references are introduced thereafter.

Chapter 3: Online Platform Quality, Discount and Advertising: A Theoretical Analysis[11]

3.1 Introduction

The revolutionary expansion of internet and World Wide Web across the globe in the past years have marked the evolution of online platform in digital marketplace. Another catalyst that has contributed to the rapid expansion of two-sided market, is the wireless handheld devices such as smartphones, tablets etc. Such technology has made possible a wider reach of internet, increasing the number of internet users. All these factors have propelled the growth of two-sided market in online marketplace. In 2017, retail e-commerce sale is estimated at $2.304 trillion across the globe, a 24.8% jump from the previous year. M-commerce sale worldwide is estimated at $1.357 trillion in 2017 and this amount of sale accounts for 58.9% of digital market. By 2021, m-commerce market is expected to be reached to 72.9% of overall e-commerce sales (McNair & Pearl, 2018). The outbreak of the novel coronavirus (Covid-19) has initiated a further progress towards e-commerce growth. In 2020, retail e-commerce sale volume across the globe advances a more than 25% growth rate. [12]

The literature pertaining to two-sided market has evolved with the studies of Parker and Van Alstyne (2000), Caillaud and Jullien (2001), Caillaud and Jullien (2003) and Rochet & Tirole (2003). Rochet and Tirole (2004) defined two-sided market as a market structure where intermediary provides a common platform to different groups of agents for making transaction with each other by charging appropriate price to each side. One of the defining characteristics of two-sided markets is the presence of indirect network externality or intergroup network

[11] This chapter is published in the IIMB Management Review (Publisher: Elsevier); https://doi.org/10.1016/j.iimb.2022.03.004

[12] Reported at https://www.statista.com/topics/871/online-shopping/

externality which is associated with the value created by the participation of other group users. Rochet & Tirole (2003) and Caillaud & Jullien (2003) assumed the existence of indirect externality in both sides and both directions of the platform. Under two-sidedness, indirect externality has an important implication as more members on a side help to attract members of other side and vice-versa. It is imperative that platform should internalize this externality in deciding the optimal pricing strategy. Credit and debit card, computer operating systems, television networks, media markets, shopping malls, video game console, online trading platforms are certain examples of such market structures. [13] Although these two-sided industries have different business standards but have adopted similar pricing strategies to get and maintain two sides on board.

There exists a plethora of studies focusing on the complexity of pricing structures in two-sided markets. Papers by Rochet and Tirole (2003, 2004, 2006), Armstrong (2006), Caillaud and Jullien (2003) provide valuable insights about workings of two-sided markets. Caillaud and Jullien (2003) proposed a model setup of imperfect competition with indirect network externality and also suggested "divide and conquer" strategy where one side of market is subsidised and profits are earned from other side by charging a higher price to that side. Rochet and Tirole (2003) advocated that the monopoly platform's total price is determined by a variant of monopolistic Lerner condition and optimal price structure is governed by relative magnitude of price elasticity of demand of both sides.[14]According to the literature, in two-sided markets with network externalities, distribution of total price between two distinct groups determines

[13] In case of video game, consumers and software developers constitute two groups that engage in trade with each other. Videogame platforms require gamers to induce software developers to design games to their platforms and games to attract gamers to buy and use their games console (Rochet and Tirole, 2006).

[14] Lerner index, defined as $\frac{(P-MC)}{P}$ identifies the intensity of market power which is measured by the divergence between firm's price level and its marginal cost of production at its profit-maximising level of output (Elzinga & Mills, 2011).

volume of transaction i.e., platform is not only concerned about total price but also optimal division of total price between two groups (Rochet and Tirole, 2004). Rochet and Tirole (2006) incorporated usage and membership externality and derived optimal pricing under two sidedness. Armstrong (2006) introduced the concept of "two-part tariffs" similar to Rochet and Tirole (2006). Two-part tariff comprises of a fixed fee and a marginal price for each member of other side participating in platform. Evans (2003) performed empirical analysis and advocated that differential pricing strategies are used to get multiple sides on board and price continues to play a vital role in maintaining customers on the platform. The need to get two sides on platform for a successful transaction gives rise to "chicken and egg" problem: agents of a side will be willing to join the platform if they see many members on other side of the same platform (Caillaud and Jullien, 2003). Hagiu (2006) solved the famous "chicken and egg" problem by developing a model where producers enter to platform before consumers. Hagiu (2009) showed that product variety is a key determinant of optimal pricing strategies. Many other researchers have studied two-sided market structure empirically in recent years and contributed to the existing literature (Rysman, 2007; Shankar & Bayus, 2003).

Platforms that follow growth-over-profit strategy, need to promote scale and demand proficiency through building strong network effects in the initial years of business development. Online retailing industry has adopted the traditional marketing strategy of coupon use to address new consumers and sustain old ones (Ravula, Bhatnagar & Ghose, 2020, Balakrishnan, Foroudi & Dwivedi, 2020, Ba et al., 2020, Feng et al., 2021). According to a recent report, 60% of online buyers across the globe look for any discounts or coupons before placing an order from online retailers. [15] Discounts can be taken as an incentive for consumers to participate in online transaction that can in turn induce sellers to engage in distribution side

[15] Reported at https://www.statista.com/topics/2162/digital-coupons-and-deals/

due to the existence of indirect network externality. Caillaud and Jullien (2003) advocated a "divide-and-conquer" kind of pricing rule to be followed by these platforms due to existence of strong cross-side network effects. Intermediaries devise a "cross subsidization" pricing strategy where one group is subsidised and other side of the market is charged a premium to finance the subsidy. The aim of this pricing rule is to produce indirect network effects: Money-side members will be attracted and encouraged to pay handsome fee if they see vast audience in subsidized side and in a similar way, platforms become more attractive to subsidy-side if there are more members in money-side (Eisenmann et al., 2006). It is more relevant for platforms to subsidise more price and quality sensitive side (Eisenmann et al., 2006). Adobe Acrobat PDF network charges nothing for accessing the software to its readers, the more price sensitive side but on the other hand, writers, the less price-sensitive side of the PDF network who are attracted by the presence of subsidy-side, pay a premium for the software (Eisenmann et al., 2006). If the PDF network reverses the pricing rule by charging readers, the more price-sensitive side and subsidising less price-sensitive side, then the network platform will break down (Eisenmann et al., 2006). Many e-commerce marketplaces follow this pricing approach by providing periodically run blockbuster discounts to their buyers, the more price-sensitive side to attract them which in turn helps to generate larger seller base and escalate the interactions between these two groups.[16] Promotional schemes work as a stimuli for consumers in their purchasing decisions and consequently, promote better interactions between businesses and consumers (Dong et al., 2021, Wu et al., 2020). Thus it has become a crucial strategy for earning additional profits and facing higher degree of competition in market (Dong et al., 2021, Wu et al., 2020, Balakrishnan, Foroudi & Dwivedi, 2020). There exists a rich wealth of real-life examples where we can find that platforms have used price discounting to stimulate

[16] Any strategy of price cut or discount to sellers will not boost sellers' sentiments to participate in platform as they are less sensitive to prices. So, any concession to sellers will have negligible impact on other variables. (see Appendix 3.1)

purchase and generate traffic to platforms. Amazon.com comes up with “Great Indian Sale” where it gives its customers a great amount of discount.[17] Although Amazon has launched many exclusive brands in recent years but these private label brands built by Amazon make up a very small portion in Amazon’s overall business and contribute only 0.2 percent in Amazon’s total revenue. [18] “Big Billion Days” started by Flipkart.com is nothing but a promotional tool to give deep discounts on products in order to trigger sale volume. [19] Price and special promotions involving price discounts help to attract customers to retail store and increase store traffic (Lichtenstein and Bearden, 1989, Grewal et al., 1998). This crucial strategy of providing deep discounts adopted by platform to attract buyers has a serious impact on pricing structure. It is important for platforms to disseminate the information of discounts to consumers. Advertisement channels play an important role in this regard. There is growing volume of real life examples where platforms involve in aggressive advertising revealing price discounts by using different advertising instruments (newspaper, emails, text messages, webpage etc.). Price discounting strategies adopted by Amazon.com, Flipkart.com are featured in newspaper advertising, emails, text messages, webpage to bring consumers’ attention to different types of discount schemes.[20] Narasimhan (1984) theoretically and empirically investigates the determinants responsible for consumers’ decision on coupon usage and suggests that the trade-off between price savings and cost associated with coupon usage along with some household

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[17] Source: https://www.indiatoday.in/technology/features/story/5-deals-you-need-to-check-out-during-amazon-great-indian-festival-1609115-2019-10-14

[18] Source: https://www.cnbc.com/2017/12/20/amazons-private-label-brands-sold-almost-450-million-in-2017.html

[19] Source: https://economictimes.indiatimes.com/small-biz/startups/newsbuzz/flipkart-announces-dates-for-big-billion-days-sale-heres-what-to-expect/articleshow/71093373.cms?from=mdr

[20] The businesses in general and digital marketing in particular target individual consumer in a direct and cost effective way to reach consumers with discount offers through the extensive usage of emails (Sahni *et al.*, 2016). Not only emails, platforms adopt many other advertising technologies to draw recipients’ attention to different price discounting deals.

variables play a crucial role in determining coupon usage. The paper by Mela, Gupta & Lehmann (1997) which is close to our study, empirically investigates the long term impacts of promotional activities (both price and non-price) and advertising strategy on pattern of buyers' choice of brands by analyzing a specific data set comprising the purchasing behaviour of over 1500 households on one product-group in one market for $8\frac{1}{4}$ years. Their study conjectures that more and more buyers become price and promotional sensitive over the years and together with this, less advertising and more promotional deals cause buyers to become more price and promotion responsive. Dong, Liu & Zhao (2021) proposed an empirical study to discuss the role of low-discount promotional events on consumers' purchasing behaviour by analyzing a specific consumption dataset of 4,465 customers for a period of 21 months on Bestpay platform and reflect the idea of "boomerang" effect causing from low-discount trap. This, particularly, indicates that at the low-discount range, consumers are not willing to purchase the non-essential products and this specific behaviour of consumer reduces the sale volume; however, with increase in discount, sale volume also increases. This reaction pattern of purchase volume in response to discount level produces a U-shaped like curve (Dong et al., 2021). Ieva, De Canio & Ziliani (2018) determined and analyzed the drivers leading to purchases at daily deal websites by conducting an online survey. The study shows that hedonic and emotional factors along with price promotions influence the purchasing behaviour of customers at daily deal sites. Value consciousness of buyers and perceived risk demotivate buyers to shop at DoD (deal-of-the-day) and on the other hand, deal proneness of customers encourages them to shop (Ieva, De Canio & Ziliani, 2018). Balakrishnan, Foroudi & Dwivedi (2020) empirically validated the effect of coupon use on consumers' purchase decision & find that a rise in coupon value directly influences the impulsive buying by consumers as well as their repurchase behaviour and consequently, adds psychological utility to the consumers. Most researches on price discount (or, price promotions) to date have concentrated mainly on the empirical findings and thus, a strong theoretic structure is required to explain the effects of price discount on other measures of platforms in presence of advertising by considering the psychological aspect of couponing among consumers. Moreover, no literature till date has considered the psychological benefit of coupon use in theoretic model. Building from the above research gaps in the previous literature related to two-sided markets, this chapter presents a simple two-sided market model with the presence of indirect network effects and advertising by incorporating both the monetary and psychological gain of discounting. Present chapter is motivated by the previously discussed real-life evidences and delves into a theoretical framework to determine the profit maximizing level of prices and advertising of a monopoly platform that offers discounts to buyer side in presence of strategic design of aggressive advertisement. Our study theoretically observes that discount not only affects price charged on buyers but also the price paid by sellers, although discount adds utility to buyers' side only while purchasing the product from sellers. We also introduce the quality of service provided by platform as a variable in the model since the results from empirical analysis demonstrate that service quality has strong effect on consumers' behavioural intentions and delivering service quality is an important strategy to survive in competitive world (Zeithaml et al., 1996; Parasuraman et al., 1985). Present chapter contributes to the existing literature by analysing the issues related to discount offers, informative advertising and service quality provided by a two-sided monopoly platform and attempts to find how prices and non-price elements such as service quality, advertising levels and volume of transaction are affected by change in amount of discount offered to buyers.

Several authors like Jullien (2005), Rysman (2009), Parker and Van Alstyne (2005), Hagiu (2004), Choi (2010), Jeon and Rochet (2010), Affeldt (2011), Njoroge et al. (2014) and Ribeiro (2016) discuss the issues of social welfare in the respect of two-sided market. [21] Following

[21]Jullien (2005) analyzed efficient pricing to produce welfare in two-sided market. Rysman (2009) discussed about the interchange fee in the context of social welfare. Parker and Van Alstyne (2005) showed that consumer welfare improves as network firm charges price to

these studies, we also analyze the provision of service quality and level of advertisement if social planner exists in monopoly platform setup and compare the results obtained in two regimes. A noticeable result is that monopoly platform sets a higher service quality compared to social optimality but the comparison with advertisement is ambiguous. The analysis of this study intends to fill the gap in the literature and can have major implications in describing marketing strategy in two-sided markets.

The rest of the paper is organized as follows. Section 3.2 outlines the theoretical model set up and key concepts under monopoly market equilibrium followed by the comparative static analysis. Section 3.3 presents analysis of social optimum. In section 3.4, comparison of results under two regimes is discussed. Section 3.5 gives concluding remarks. Appendix contains proofs and computations.

3.2 Theoretical framework

3.2.1 The model setup

We present a very simple model of two-sided markets following the one developed by Rochet and Tirole (2003), however, with significant departure. We extend the Rochet and Tirole (2003) model set up to include the effect of discount offerings given to buyers by platform on service quality, level of advertising and volume of transaction in platform. The analysis of two-sided

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consumers and content-providers in presence of positive complementarities. Hagiu (2004) documented trade-off between three factors responsible for establishing welfare in proprietary platforms and those are deadweight loss generated through monopoly pricing, extent of business-capturing effect due to product diversity and incorporation of indirect-network effect. Choi (2010) investigated the impact of tying on social welfare when agents are allowed to multi-home. Jean and Rochet (2010) performed social welfare analysis for academic journals. Affeldt (2011) analyzed social welfare in case of tying and bundling exercise in two-sided market. Njoroge et al. (2014) performed welfare analysis under neutral and non-neutral network cases. Ribeiro (2016) evaluated welfare in two-sided market in presence of asymmetry of customer density on either side of the city.

market under monopoly structure in section 3.2.1 will be used to compare the results under welfare analysis derived in section 3.3.

The model setup consists of three groups of agents. The potential value from transaction is generated by the interaction between two distinct groups of the market whom we denote as buyers (indexed by B) and sellers (indexed by S). Such interactions between these two end-users are mediated by a monopoly platform. Indirect network externality is present in such market structure as members of a side are concerned about the number of members of other side participating in the platform. To deliver services, the platform charges a fixed membership fee A_i and a per transaction usage fee a_i ($\forall$ i $\in$ {B, S}) to end-users of each side. Buyer side of the platform derives satisfaction from the quality of service (QoS) provided by platform while making a transaction in that platform and this satisfaction adds to the utility of buyer. We define QoS as a composite index for day to day service standard provided by platform which includes impartial and non-discriminatory return and repayment policy, packaging policy, cancellation policy, delivery services given by platform to its buyers. We assume QoS to be endogenous to the system and this is indexed by 's'. Furthermore, the monopoly platform offers periodic discounts to buyers and it is indexed by d where $0 < d < 1$. The discount provides positive value to buyers and this is being added to their utility functions when buyers engage in transaction and purchase products from sellers.

Platforms use advertisement to bring consumers' notice to different discounting schemes. Advertising in our model is informative in nature and endogenous to the system. We assume that a fraction λ of buyers receives advertising signal sent by platform proposing the amount of discount "d". Only those buyers who receive advertising signal, participate in platform and get involved in transaction in that platform. Following Grossman and Shapiro (1984), the expenditure of advertising to attain a reach of λ fraction of buyers is assumed to be lump-sum and quadratic in nature. The cost of ensuring that a fraction λ of buyers receives information about discount through advertisement given by platform becomes a convex function of λ. We assume there is no other way to make transaction between these two groups, they can only transact through the platform. Every user who joins the platform ends up making a transaction in platform. We first focus on the joining decision of members of two distinct groups.

A. Buyers

Buyer's heterogeneity is observed in terms of the willingness to pay which is indexed by Θ_B where Θ_B denotes additional valuation for a representative buyer for making a transaction with each additional seller in platform. Θ_B is uniformly distributed over the continuum $[0, \bar{\Theta}]$. We assume that buyers receive positive utility from discounts in two forms: first, from the monetary benefit of paying less for acquiring the product which is recorded in the utility function of buyers by subtracting the amount of discount from usage fee per transaction and second, from the psychological satisfaction for getting the product at a reduced cost. During price promotional deal, consumers expect to perceive a price "gain" and respond positively (Kalwani et el., 1992). Price promotion shows higher psychological benefit associated with acquiring favourable financial terms of price deal (i.e., positive perceived transaction value) which in turn, affects the value of obtaining the product (i.e., a higher net gain by lowering financial cost) (Grewal et al.,1998). Alexander, Tripp & Zak (2015) empirically show coupon use (or, discounting) promotes psychological responses. Price saving is not the prime incentive for coupon use; hedonic measures and emotions can be regarded as one of the key elements for influencing buyers' purchasing behaviour at deal-of-the-day (DoD) platforms (Ieva, De Canio & Ziliani, 2018, Balakrishnan, Foroudi & Dwivedi, 2020). In line with these studies, the present chapter aims to capture the psychological benefit along with the monetary gain associated with price discount in our structural framework. Thus, price discount adds positive value to consumer's utility in two ways. This psychological benefit of discount appears in utility function as a multiplicative term with service quality and this psychological satisfaction together with service quality of platform will decide how much consumers will be prepared to pay for accessing platform services. When platforms provide no discount to buyers (i.e., d =0), only service quality of the platform will decide willingness to pay for the representative consumer.

Therefore, the net surplus for a representative buyer from making a transaction in platform that is supported by N_S sellers is,

$$U_B = [\Theta_B\, s\,(1 + d) - (a_B - d)]\, N_S - A_B \qquad (3.1)$$

There exists indirect network externality since buyers are interested in purchasing variety of products, so the net surplus from transaction for buyer raises with the increase in the number of sellers supported by platform. Each buyer enters into transaction with each seller for once. So, the total number of transaction buyer will make, is equivalent to total number of sellers participated in the same platform. The buyers who extract non-negative net surpluses (i.e. $U_B \geq 0$) from transaction, will join the platform. In this context, following Rochet and Tirole (2004) we define P_B as "per-interaction price" which is paid by buyers for participating in platform and engaging in interaction with members of other group. It is defined as

$$P_B = a_B + \frac{A_B}{N_S} \qquad (3.2a)$$

Therefore, the "per-interaction price" charged by platform on buyers comprises of usage fee per transaction paid by buyers and the average of fixed membership fee of buyers (i.e., total membership fee divided by the number of interactions made with other group). The number of buyer joining a platform will depend on this "per-interaction price" (Rochet and Tirole, 2004). Thus, the spectrum of buyers who are willing to participate in platform can be obtained as,

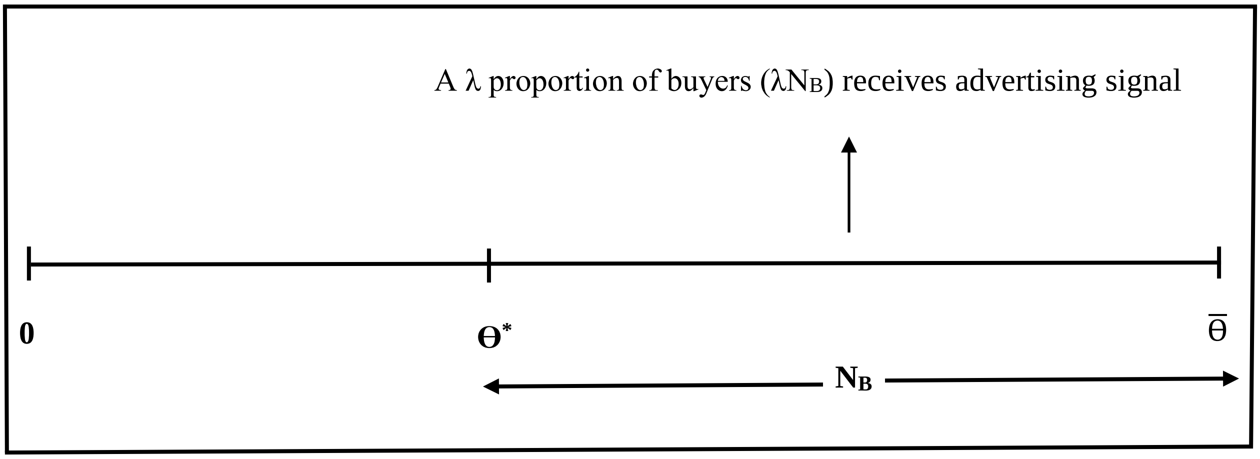
$N_B = [1 - \frac{(P_B - d)}{\bar{\Theta} s(1+d)}]$; where $\Theta^* \left(= \frac{P_B - d}{s(1+d)}\right)$ to be the marginal consumer who is indifferent between joining and not joining the platform.

The spectrum of buyers in the domain $\Theta^* \leq \Theta_B \leq \bar{\Theta}$ will be willing to participate in platform and engage in transaction with sellers. But buyers in the interval $0 \leq \Theta_B \leq \Theta^*$ will not be prepared to join the platform. So, the market segment for buyers is not fully covered as buyers in the range $0 \leq \Theta_B \leq \Theta^*$ will neither join platform nor involve in transaction with sellers. Among the buyers willing to participate in platform, only a fraction λ receives advertisement sent by platform. According to our assumption, those buyers who are exposed to advertisement, will only join the platform.

Therefore, the expected number of buyers who will ultimately join the platform can be derived as,

$$\lambda N_B = \lambda \left[1 - \frac{(P_B - d)}{\bar{\Theta} s(1+d)}\right] \tag{3.3}$$

Figure 3.1: Consumer Spectrum under Advertising in Platform



Source: Based on the theoretical model done by author

B. Sellers

Intragroup heterogeneity for seller is based on additional profit of π_S from entering into transaction with each buyer in the platform where π_S is uniformly distributed over the continuum $[0,\bar{\pi}]$. Net profit of a representative seller from making transaction in platform which is adopted by (λN_B) buyers is,

$$\Pi_S = (\pi_S - a_S)\lambda N_B - A_S \tag{3.4}$$

The buyers (λN_B) receive advertising message from platform and decide to connect to the platform. A seller enters into transaction with each buyer, so total number of transaction for a representative seller is (λN_B). Here also, the presence of indirect network externality is noticed since seller's profit from transaction is increasing with the adoption of more buyers.

"Per-interaction price" for sellers (P_S) is a price charged on sellers for availing platform services & making transaction with buyers and can be documented as the sum of per transaction usage fee and average of fixed membership fee paid by sellers (Rochet and Tirole, 2004).

Therefore,

$$P_S = a_S + \frac{A_S}{\lambda N_B} \tag{3.2b}$$

Then expected number of sellers joining the platform can be obtained as,

$$N_S = [1 - \frac{P_S}{\bar{\pi}}] \tag{3.5}$$

Where π^* (=P_S) to be the marginal seller who is indifferent between joining and not joining the platform.

The market for sellers is also partially covered as sellers in the range $0 \leq \pi_s \leq \pi^*$ will not be interested in participating in platform as those sellers derive negative surpluses from making transaction in platform.

The number of buyers and sellers (derived in the expressions (3.3) and (3.5) respectively) that the platform expects to cater vary negatively with "per-interaction prices" paid by buyers and sellers respectively.

3.2.1.1 Market equilibrium under monopoly platform

We consider that both distinct groups are served by a monopoly platform. This section analyses the optimal pricing structure of a monopoly platform.

The profit of the monopoly platform is given by,

$$\Pi_P = A_B\lambda N_B + A_S N_S + (a_B + a_S - d)\lambda N_B N_S - \frac{\alpha}{2}s^2 - \frac{\beta}{2}\lambda^2 \tag{3.6}$$

The first two terms of (3.6) represent the revenue earned by platform from both sides through fixed membership fees. The third term constitutes the net revenue earned by platform through the imposition of per transaction usage fee on both sides where 'd' is the amount of discount per transaction provided by platform and $\lambda N_B N_S$ is the total volume of transaction. The fourth term represents lump-sum quadratic quality cost borne by platform for providing services to buyers' side. The last term exhibits the cost of advertisement incurred by platform.

Incorporating the expression of "per-interaction price" from equations (3.2a) and (3.2b) and setting the values of N_B and N_S from equations (3.3) and (3.5), equation (3.6) can be rewritten as,

$$\Pi_P = \lambda\,(P_B + P_s - d)\,[1 - \frac{(P_B - d)}{\bar{\theta}s(1+d)}](1 - \frac{P_S}{\bar{\pi}}) - \frac{\alpha}{2}s^2 - \frac{\beta}{2}\lambda^2 \tag{3.7}$$

Using the backward induction, in this step we determine the profit maximizing prices announced by platform for both sides. We derive First Order Conditions of profit-maximisation with respect to P_B and P_S assuming the existence of interior solution.

$$\frac{\partial \Pi_P}{\partial P_B} = \lambda\left(1 - \frac{P_S}{\bar{\pi}}\right)\left[\left\{1 - \frac{(P_B - d)}{\bar{\theta}s(1+d)}\right\} - \frac{(P_B + P_S - d)}{\bar{\theta}s(1+d)}\right] = 0 \tag{3.8}$$

$$\frac{\partial \Pi_P}{\partial P_S} = \lambda\left\{1 - \frac{(P_B - d)}{\bar{\theta}s(1+d)}\right\}\left[\left(1 - \frac{P_S}{\bar{\pi}}\right) - \frac{(P_B + P_S - d)}{\bar{\pi}}\right] = 0 \tag{3.9}$$

We have checked Second Order Sufficient Condition for profit maximization problem and all conditions have been satisfied. [22] We derive the profit maximizing prices as,

$$P_B = \frac{[2\bar{\theta}s(1+d)+3d-\bar{\pi}]}{3} \tag{3.10}$$

$$P_s = \frac{[2\bar{\pi}-\bar{\theta}s(1+d)]}{3} \tag{3.11}$$

The expected number of users participated in platform on each side can be obtained as,

$$\lambda\, N_B = \lambda\, \frac{[\bar{\theta}s(1+d)+\bar{\pi}]}{3\bar{\theta}s(1+d)} \tag{3.12}$$

$$N_S = \frac{[\bar{\theta}s(1+d)+\bar{\pi}]}{3\bar{\pi}} \tag{3.13}$$

Using (3.10), (3.11), (3.12) and (3.13) in equation (3.7), the platform's profit can be derived as,

$$\Pi_P = \lambda \frac{[\bar{\theta}s(1+d)+\bar{\pi}]^3}{27\bar{\theta}\bar{\pi}s(1+d)} - \frac{\alpha}{2}s^2 - \frac{\beta}{2}\lambda^2 \tag{3.14}$$

Next, we consider the choice of service quality and advertisement by the monopolist. Π_P is maximized with respect to s and λ to derive optimum amount of quality of service (QoS) and advertisement provided by the monopoly platform.

First Order Condition with respect to 's' and λ can be obtained as,

$$\frac{\partial \Pi_P}{\partial s} = \lambda \frac{(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}s(1+d)-\bar{\pi})}{27\bar{\theta}\bar{\pi}s^2(1+d)} - \alpha s = 0 \tag{3.15}$$

$$\frac{\partial \Pi_P}{\partial \lambda} = \frac{[\bar{\theta}s(1+d)+\bar{\pi}]^3}{27\bar{\theta}\bar{\pi}s(1+d)} - \beta\lambda = 0 \tag{3.16}$$

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22 $\frac{\partial^2 \pi_P}{\partial P_B^2} = -\frac{2}{\bar{\theta}s(1+d)} < 0$; $\frac{\partial^2 \pi_P}{\partial P_S^2} = -\frac{2}{\bar{\pi}} < 0$ and $|H| = \frac{3}{\bar{\theta}\bar{\pi}s(1+d)} > 0$

Or, $\lambda = \frac{[\bar{\theta}s(1+d)+\bar{\pi}]^3}{27\beta\bar{\theta}\bar{\pi}s(1+d)}$

Equation (3.15) can be simplified as, $\lambda\,\Phi(s) = \alpha\, s$

Where, $\Phi(s) = \frac{(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}s(1+d)-\bar{\pi})}{27\bar{\theta}\bar{\pi}s^2(1+d)}$

Here $\Phi(s) > 0$ for $s > \frac{\bar{\pi}}{2\bar{\theta}(1+d)} = s_{min}$. Thus equilibrium quality will be always higher than s_{min}.

Second Order Condition (S.O.C) for profit maximization with respect to service quality $(= \frac{\partial^2 \pi_P}{\partial s^2})$ requires $\alpha > \lambda\Phi'(s)$ and that for level of advertisement is, $-\beta < 0$. [23] [24]

Replacing the value of λ in (3.15), we have,

$$\frac{\partial \Pi_P}{\partial s} = \frac{(\bar{\theta}s(1+d)+\bar{\pi})^5(2\bar{\theta}s(1+d)-\bar{\pi})}{27^2\beta\bar{\theta}^2\bar{\pi}^2 s^3(1+d)^2} - \alpha s = 0 \tag{3.17}$$

$$\text{Or, } \frac{s^2\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^5(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s})}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2} = \alpha \tag{3.18}$$

$$\text{Let, } \delta(s) = \frac{s^2\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^5(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s})}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2} \tag{3.19}$$

where $\delta'(s) > 0$ (See Appendix 3.2)

After replacing equation (3.19), equation (3.18) can be simplified as, $\delta(s) = \alpha$.

Figure 3.2 depicts the determination of equilibrium service quality (s^*) and advertising (λ^*) diagrammatically by plotting equations (3.15) and (3.16).

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[23] $\Phi'(s) = \frac{2}{27\bar{\theta}\bar{\pi}(1+d)}[\frac{\bar{\pi}^3}{s^3} + \bar{\theta}^3(1+d)^3] > 0$ & $\Phi''(s) = \frac{2}{27\bar{\theta}\bar{\pi}(1+d)}[-\frac{3(\bar{\pi})^3}{s^4}] < 0$

[24] $|H| = \beta(\alpha - \lambda\Phi'(s)) - \Phi(s)^2$; If α and β would be sufficiently large then $|H| > 0$.

The profit of platform can be written as,

$$\Pi_P = \frac{1}{2}\frac{[\bar{\theta}s^*(1+d)+\bar{\pi}]^6}{27^2\beta\bar{\theta}^2\bar{\pi}^2 s^{*2}(1+d)^2} - \frac{\alpha}{2}s^{*2} \quad (3.20)$$

Figure 3.2: Determination of Service Quality and Advertisement under Monopoly Platform

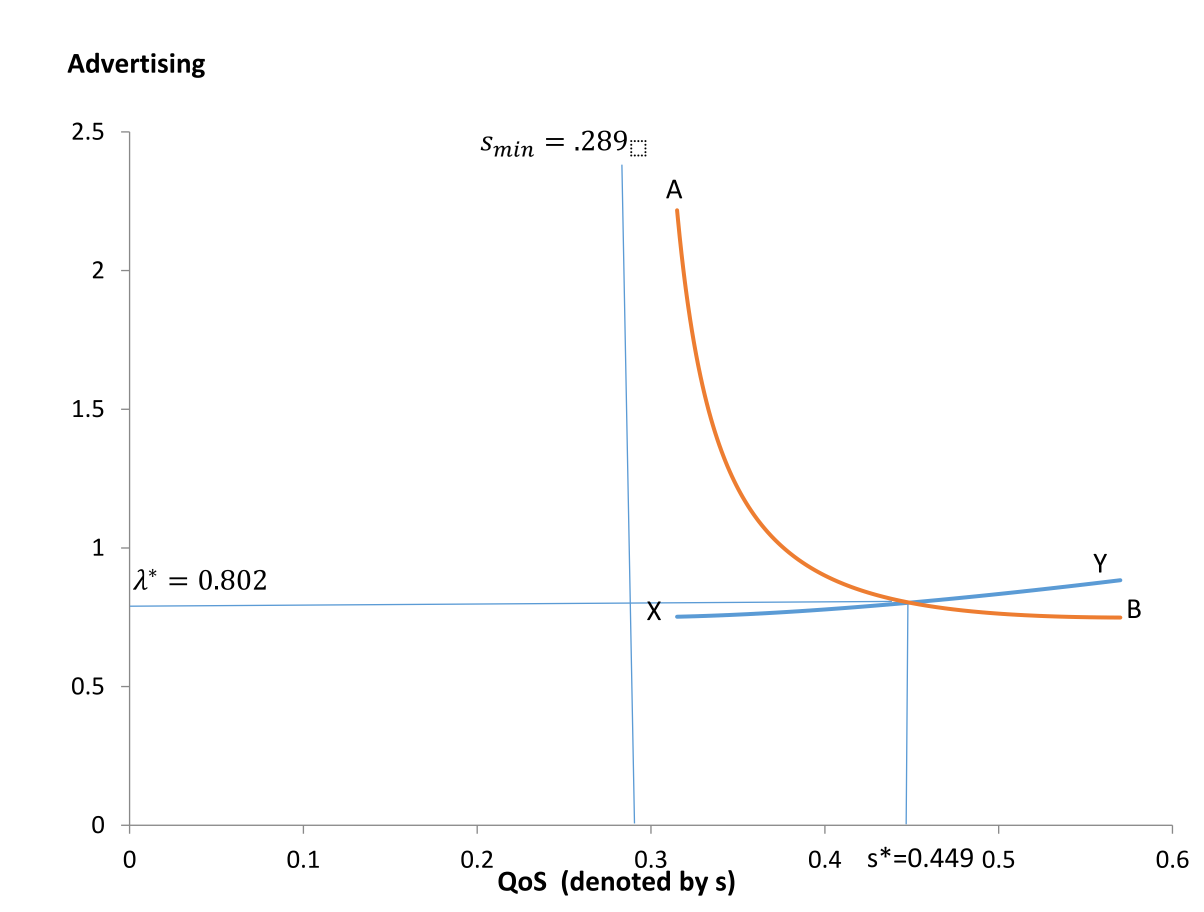

Figure 3.2 shows the determination of equilibrium level of service quality and advertising outlay for the following parameter values: α=1; $\bar{\theta} = 4$; d = 0.3; β=1; $\bar{\pi} = 3$. Along 'AB' curve we have $\frac{\partial \Pi_P}{\partial s} = 0$ and along XY curve we have $\frac{\partial \Pi_P}{\partial \lambda} = 0$. We observe that equilibrium value for QoS is s*=0.449 and advertising outlay $\lambda^* = 0.802$

Source: Numerical analysis based on the theoretical model on monopoly platform

$$P_B^* = \frac{[2\bar{\theta}(1+d)s^*+3d-\bar{\pi}]}{3} \text{ and } P_S^* = \frac{[2\bar{\pi}-\bar{\theta}(1+d)s^*]}{3} \quad (3.21)$$

The total volume of transaction on the monopoly platform can be obtained as,

$$V^* = \lambda^* N_B^* N_S^* = \frac{[\bar{\theta}(1+d)s^* + \bar{\pi}]^5}{243\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2 {s^*}^2} \tag{3.22}$$

Next, subsection will analyze and discuss the findings and results of the model.

3.2.2 Analysis and results under monopoly platform

From profit maximizing outcomes derived in last subsection, we get following propositions. We employ the comparative static exercise to see the responsiveness of equilibrium due to change in per transaction discount (d).

Proposition 1 shows the change in service quality, level of advertisement and volume of transaction in response to an increase in discount provided by monopoly platform.

Proposition 1:

- **(i)** *An increase in discount will reduce service quality of monopoly platform unambiguously.*
- **(ii)** *An increase in discount will lower the level of advertisement of monopoly platform.*
- **(iii)** *A rise in discount will reduce volume of transaction in monopoly platform.*
- **(iv)** *A rise in discount will increase profit of monopoly platform.*

(Proof is given in the Appendix 3.3)

Platform gives discount to buyers so that more buyers join the platform (Ravula, Bhatnagar & Ghose, 2020, Balakrishnan, Foroudi & Dwivedi, 2020, Ba et al., 2020, Feng et al., 2021). This in turn attracts more sellers because of the presence of indirect network externality. But offering discounts and incurring service quality outlay both are costly to platform. So, whenever platform is increasing its discount, its cost of providing discount to buyers increases. To reduce its overall cost, it lowers its quality of service (QoS) in response to an increase in discount. So, more discount-centric strategy of monopoly platform can pose an adverse impact on non-price components such as quality of service of platform. This research finding bears a significant practical implication as the umpteen price discount not only hurts the quality standards of platforms but also erodes trust and confidence of users on product and as well as platform. [25]

Consumer acquisition is an indispensable part of platform's growth strategy and pivotal for successful interactions with sellers. Discount strategy adopted by platform acts as a device for expanding user base which is the prime concern for any platform. Moreover, platform uses advertising signals to expand its reach to buyers so that buyers could get information about discount and get attracted to participate to the platform. The initial direct effect of rising discounts on advertisement is always positive. But as more number of consumers enter the platform, it causes a huge increase in discount burden of platform. This burden of discount may outweigh its profit if platform goes on increasing the level of advertisement. Thus a profit-maximizing monopoly platform optimally decides regarding the advertisement level which may actually fall with discount. So, our model depicts a counter-intuitive relationship between these two variables.

Increase in discount by monopoly platform causes a negative impact on both service quality and level of advertisement. Both the forces of falling level of advertisement and service quality may pose an opposing impact on consumer acquisition where the interest of platform lies in. This in turn affects the volume of transaction on platform in a negative way. So, an increase in discount hurts volume of transaction in monopoly platform.

The monopoly platform raises discounts by compromising the service-quality aspect of platform. This will work in two directions. Reduced quality and level of advertisement are causing "crowding out" of consumer base which in turn lowers the volume of transaction on

[25] Reported at https://dare2compete.com/blog/gd-topic-are-online-discounts-killing-e-commerce

platform. This appears to be cost-increasing part of platform. But on other side, platform is incurring lower cost for providing deteriorating quality of service and lower amount of advertisement. This seems to be the cost-reducing side of platform. Cost-reducing factors outweigh the loss in consumer base which platform is facing because of the fall in the level of service quality and level of advertisement in response to increase in discount, resulting in higher profit.

Further we observe the effect of rising discount on per-interaction fees charged on buyers and sellers. It can be shown that an increase in discount will unambiguously increase per-interaction fee paid by sellers but the effect of rise in discount on the per-interaction fee charged on buyers is ambiguous. [26] Increase in discount helps to attract more buyers and this expanded buyer base will interact with sellers which serves the purpose of monopoly platform. Witnessing huge members on the buyers' side, sellers will be prepared to pay a higher premium to connect to them. So, platform recovers the enhanced cost of offering discounts by increasing per-interaction price of sellers. However, the platforms may lower or raise the per-interaction price paid by buyers in response to increase in discount.

3.3 Welfare analysis

In this section, we study the welfare implications if a social planner exists in monopoly market structure. Here, we take the price settings similar to the structures derived in the monopoly case under section 3.2.1.1. We only derive quality of service (QoS) and level of advertising under social welfare analysis and investigate the variation of the results obtained in sections 3.2 and 3.3.

In the last section, the network platform enjoys monopoly power in deciding QoS, s and level of advertisement, λ. Monopoly platform maximizes its own profit without considering the well-

[26] For details, see Appendix 3.3

being of other agents. However, the objective of social planner is completely different from that of monopolist. He will choose that level of advertisement and QoS which will ensure the welfare of society as a whole. Maximizing social welfare will raise economic well-being of all groups of agents.

In our model, total social welfare generated through platform services comprises of net buyers' surplus, net sellers' surplus and monopolist profit, conditional upon buyers' and sellers' participation in the platform.

So, the social welfare can be described as,

$$W = \frac{\lambda}{\bar{\theta}\bar{\pi}}\int_{\pi^*}^{\bar{\pi}} d\pi \int_{\theta^*}^{\bar{\theta}} [\theta_B s\,(1+\,d) - (P_B - d)]d\theta + \frac{\lambda}{\bar{\theta}\bar{\pi}}\int_{\theta^*}^{\bar{\theta}} d\theta \int_{\pi^*}^{\bar{\pi}} (\pi_S - P_S)d\pi \quad + $$

$$\frac{\lambda}{\bar{\theta}\bar{\pi}}\,(P_B\; + P_S\; - d)\int_{\pi^*}^{\bar{\pi}} d\pi \int_{\theta^*}^{\bar{\theta}} d\theta - \frac{\alpha}{2}s^2 - \frac{\beta}{2}\lambda^2 \tag{3.23}$$

The first two terms of equation (3.23) represent buyers' net surplus and sellers' net profit respectively. All the subsequent terms depict the profit of monopoly platform. By simplifying the expression (3.23) and setting values of P_B, P_S similar to monopoly price structure (derived in (3.10) and (3.11)) we obtain social welfare as a function of QoS (s) and level of advertisement (λ) (See Appendix 3.4).

$$W(s,\lambda) = \frac{2\lambda}{27}\frac{[\bar{\theta}s(1+d)+\bar{\pi}]^3}{\bar{\theta}\bar{\pi}s(1+d)} - \frac{\alpha}{2}s^2 - \frac{\beta}{2}\lambda^2 \tag{3.24}$$

Social optimum level of QoS and level of advertisement have been determined by maximizing social welfare expressed by (3.24). First Order Conditions for welfare maximization with respect to s and λ yield,

$$\frac{\partial W}{\partial s} = \frac{2\lambda}{27}\frac{(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}s(1+d)-\bar{\pi})}{\bar{\theta}\bar{\pi}s^2(1+d)} - \alpha\, s = 0 \tag{3.25}$$

$$\frac{\partial W}{\partial \lambda} = \frac{2[\bar{\theta}s(1+d)+\bar{\pi}]^3}{27\bar{\theta}\bar{\pi}s(1+d)} - \beta\,\lambda = 0 \tag{3.26}$$

Or, $\lambda_W = \frac{2[\bar{\theta}s(1+d)+\bar{\pi}]^3}{27\beta\bar{\theta}\bar{\pi}s(1+d)}$

Replacing the value of λ_W in the equation (3.25), we have,

$$\frac{\partial W}{\partial s} = \frac{4(\bar{\theta}s(1+d)+\bar{\pi})^5(2\bar{\theta}s(1+d)-\bar{\pi})}{27^2\beta\bar{\theta}^2\bar{\pi}^2s^3(1+d)^2} - \alpha\, s = 0$$

$$\text{Or,} \quad \frac{4s^2\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^5(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s})}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2} = \alpha \qquad (3.27)$$

After replacing the equation (3.19), equation (3.27) can be simplified as, $\delta(s) = \frac{\alpha}{4}$.

The socially optimal level of service quality and advertising outlay are determined by solving (3.25) and (3.26) and depicted in Figure 3.3.

Figure 3.3: Determination of Service Quality and Advertisement outlay under Social Planner

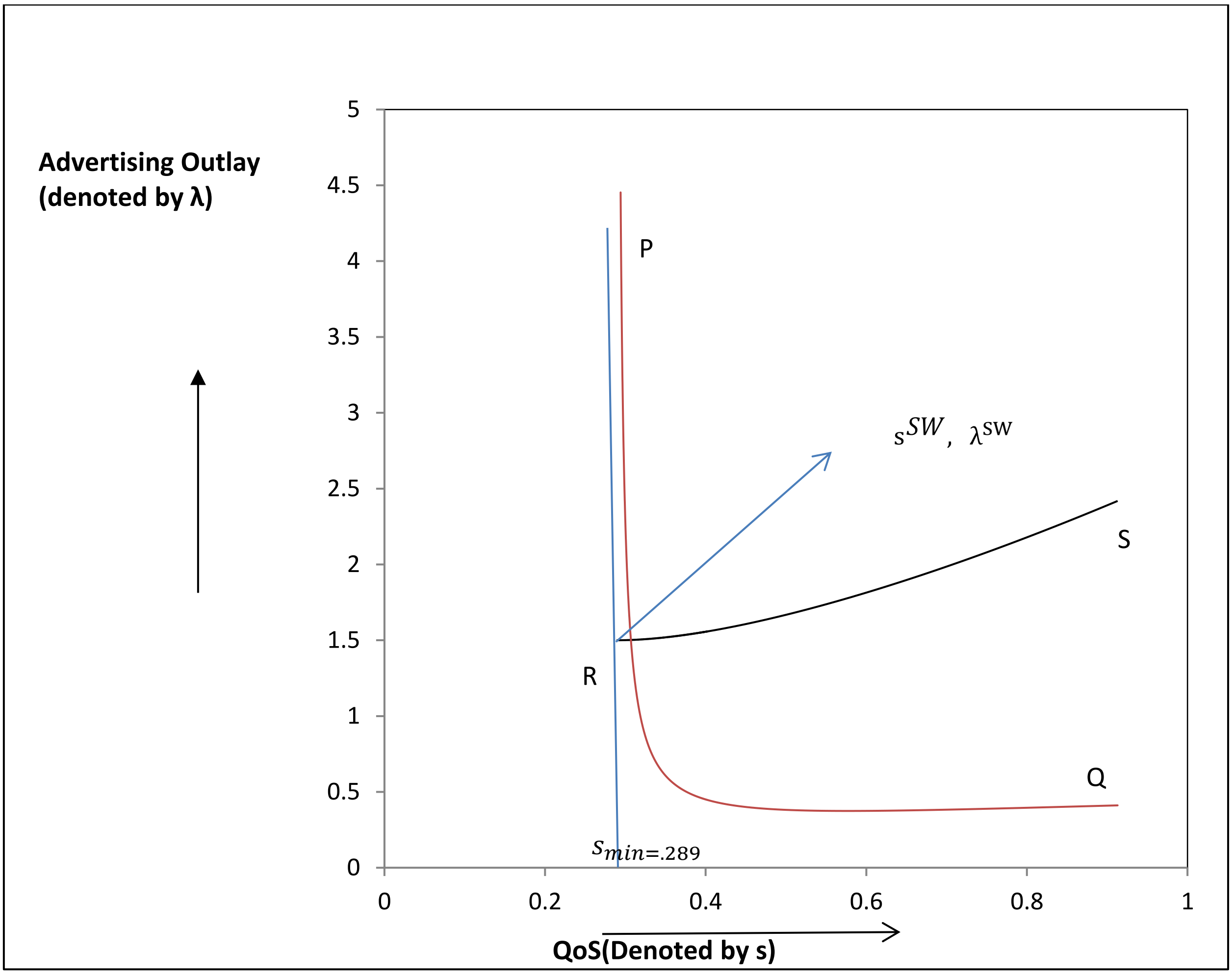

Figure 3.3 shows the determination of socially optimal level of service quality and advertising outlay for the following parameter values: α=1; $\overline{\Theta} = 4$; $d = 0.3$; β=1; $\bar{\pi} = 3$. Along 'PQ' curve we have $\frac{\partial W}{\partial s} = 0$ and along 'RS' curve we have $\frac{\partial W}{\partial \lambda} = 0$

Source: Numerical analysis based on the theoretical model on social planner

3.4 Comparison between socially optimum and monopoly market outcome under two-sided platform

Results derived in section 3.2 and section 3.3 show that the socially optimum structure does differ from the monopoly market equilibrium. In this section, we will study the divergence of results between two regimes derived under section 3.2 and 3.3. To analyze the scenario, we compare quality of service provided to buyers and level of advertising messages sent by platform under two regimes.

Proposition 2:

(i) *Monopoly platform provides higher amount of quality of service compared to social optimum.*

(ii) *A comparison between level of advertising by monopoly platform and social planner is ambiguous under two-sided market.*

Proof:

(i) A comparison between equation (3.18) and (3.27) shows that

$$\delta(s^*) = 4\delta(s^{SW}) = \alpha \tag{3.28}$$

where $\delta(s) = \frac{s^2\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^5(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s})}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2}$ and $\delta'(s) > 0$; s^* is the equilibrium level of QoS under monopoly and s^{SW} is the socially optimal level of quality of service (QoS). Thus, the validity of equation (3.28) requires, $s^* > s^{SW}$, unambiguously. (Figure 3.4 shows a graphical representation of this proof). Q.E.D.

(ii) A comparison between equation (3.16) and (3.26) gives the following result:

$$\frac{\lambda^*}{\lambda^{SW}} = \frac{1}{2}\left(\frac{s^{SW}}{s^*}\right)\left(\frac{[\bar{\theta}s^*(1+d)+\bar{\pi}]^3}{[\bar{\theta}s^{SW}(1+d)+\bar{\pi}]^3}\right) \tag{3.29}$$

From the earlier part of the proof we have $s^* > s^{SW}$. Thus, in equation (3.29) in R.H.S, the first term in the parenthesis $\frac{s^{SW}}{s^*} < 1$ but the second term under parenthesis $\frac{[\bar{\theta}s^*(1+d)+\bar{\pi}]^3}{[\bar{\theta}s^{SW}(1+d)+\bar{\pi}]^3} > 1$.

Thus, $\frac{\lambda^*}{\lambda^{SW}} \lesseqgtr 1$. Q.E.D. ■

A noticeable result obtained in our model unambiguously shows that welfare-maximizing service quality (s^{SW}) lies below the profit-maximising service quality (s^*) as shown in Figure

3.4. However, the comparison with advertising outlay is ambiguous. The monopoly platform may actually undertake a lower advertising outlay compared to the social planner as shown in our numerical analysis for certain parameter values. [27] The objective of social planner is to expand platform's reach to buyers as much as possible by maintaining platform's profitability. From our numerical analysis, it is clear that number of buyers joining the platform is higher under social welfare since $\lambda^{SW} N_B^{SW} > \lambda^* N_B^*$. [28] So, greater number of buyers under social welfare will help to attract more sellers which will benefit both sides as more members on seller side will provide vast varieties of products to buyers and more buyers will give sellers larger market of buyer to capture. Since the welfare maximizing authority is more inclined to maximize the overall surplus of the economy, they may prefer to include more number of buyers and sellers in the market, instead of investing on improved service quality. Whereas the profit maximizing monopolist chooses to serve a small segment of the market and serves them high service quality to extract more amount of surplus from them. Mela, Gupta & Lehmann (1997) conjectures the "good" impact of advertising on buyers' preference for brands. Our study supports the finding developed by Mela, Gupta & Lehmann (1997) as social dictator increases the advertising outlay (as found in our numerical study) which courts more buyers and consequently more sellers, thereby producing more social surplus. Thus, our analysis

[27] Our numerical example with the parameter values: α=1; $\overline{\theta} = 4$; $d = 0.3$; β=1; $\bar{\pi} = 3$ shows that $\lambda^{SW} > \lambda^*$

[28] $\frac{\lambda^* N_B^*}{\lambda^{SW} N_B^{SW}} = (\frac{\lambda^*}{\lambda^{SW}})(\frac{\left[\overline{\theta}(1+d)+\frac{\bar{\pi}}{S^*}\right]}{\left[\overline{\theta}(1+d)+\frac{\bar{\pi}}{S^{SW}}\right]})$; From our numerical analysis, $\lambda^{SW} > \lambda^*$. Thus, in R.H.S, the first term in the parenthesis $\frac{\lambda^*}{\lambda^{SW}} < 1$ and the second term under parenthesis $\frac{\left[\overline{\theta}(1+d)+\frac{\bar{\pi}}{S^*}\right]}{\left[\overline{\theta}(1+d)+\frac{\bar{\pi}}{S^{SW}}\right]} < 1$ since $s^* > s^{SW}$. So, $\frac{\lambda^* N_B^*}{\lambda^{SW} N_B^{SW}} = 0.4241 < 1$

brings out an interesting dynamics of a two-sided market through the comparison between monopoly and social planner in the context of two-sided market.

Figure 3.4: Comparison of service quality provision under social planner with monopoly

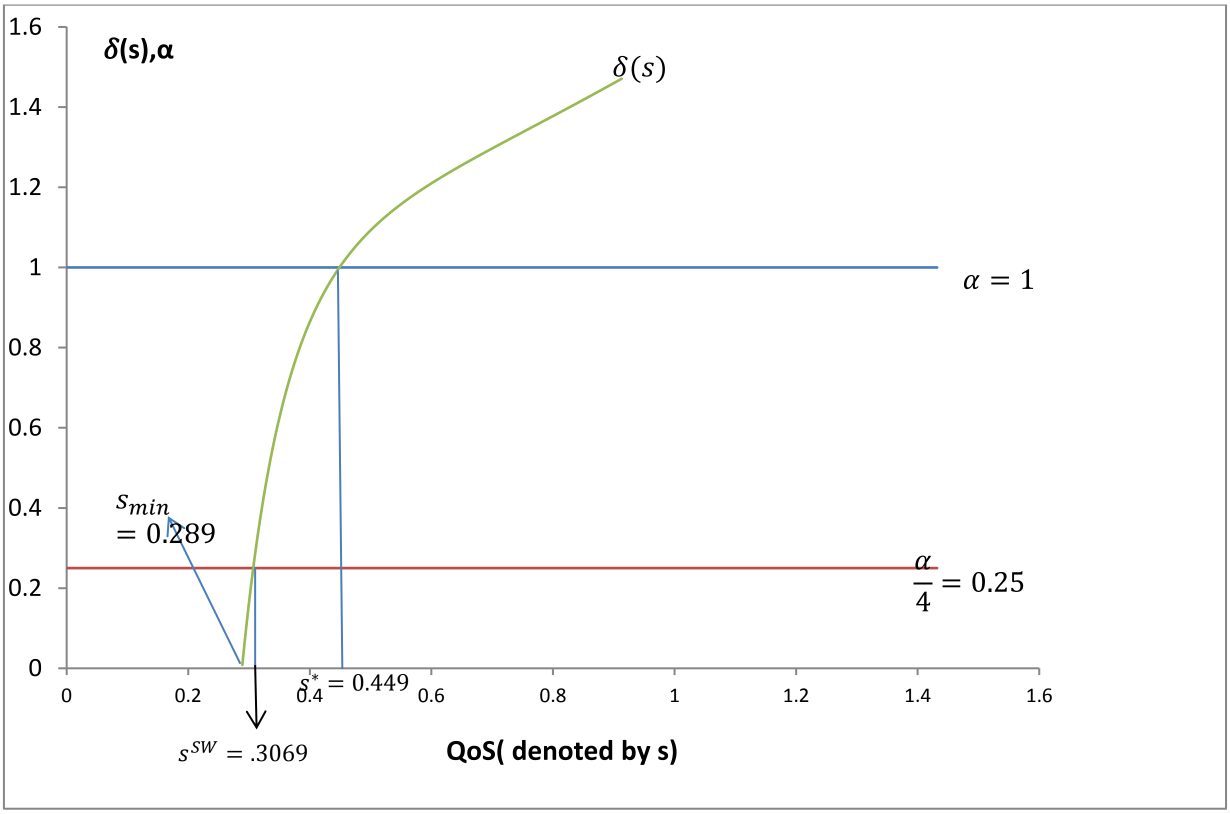

Figure 3.4 compares the determination of socially optimal level of service quality to that of monopoly case for the following parameter values: α=1; $\overline{\Theta} = 4$; d = 0.3; β=1; $\bar{\pi} = 3$. We observe that the socially optimal level of QoS is $s^{SW} = 0.3069$ whereas monopoly level of QoS is s*= 0.449. *Source: Numerical analysis based on the theoretical model*

3.5 Concluding remarks

The existence of two-sided market has disrupted the operating mechanism of the traditional market. It causes new challenges every day to businesses operating as intermediaries and facilitating direct trading between buyers and sellers. As motivated by different real life examples and empirical evidences on aggressive advertising revealing discount offers, the present chapter analyses the effect of discounts offered to buyers on service quality and extent of advertisement of monopoly platform by developing a structure of two-sided markets with indirect network effects similar to Rochet and Tirole (2003). The implications for management concerning the use of blockbuster discounts in monopoly market environment are quite clear. The major concern for managers should be reaching out to a broader section of market and the provision of deep discount serves the purpose. Due to the presence of indirect network externality in two-sided market, discount offers have considerable impact on optimal pricing structure of the platform for both sellers' and buyers' sides, where discount is provided to only buyers. Managers of industries employing two-sided market model should account for the indirect network externality when performing, implementing and evaluating any business strategy. A successful executive will strive to extract the benefits of network effects and design suitable incentive framework that will take care the interests of both sides.

The study theoretically shows that the policy of price discount by the monopoly platform actually enhances the profit, even when high discount induces the platform to reduce the service quality and expenditure on informative advertising. The price discount offers increase the cost burden of the platform which is in turn adjusted by lower provision of service quality and low level of advertising. Giving deep discounts will discourage such businesses in improvement of quality which in turn gives trade-off opportunities to consumers. It has now become a well-known tradition when consumers many times receive damaged or defective product, wrong items and delayed refund payment during the promotional sale period. Consumers who value quality more than price and promotional deals will start to devalue the quality and lose trust on platform services. Quality conscious buyers will not only be lured by huge price-discounts; rather they give more importance to the quality aspect compared to discount deals. Thus platform may lose some valued customers if it continues to exert lower service standard for giving discounts. Moreover, offering discounts constantly can lose its importance. Dependence on discounts to increase revenues can raise problems of platform's profitability, consumer satisfaction, integrity of services and reputation of platform which can actually undercut business. These detrimental effects of discounts will have a long-term impact on business and be difficult to correct. Delivering products with huge discounts can be a powerful way to steer sale volume and widen buyer base but a destructive instrument when platforms exercise this strategy without fully comprehending its negative sides. So, a manager should be mindful enough to create profit possibilities for business and promote incentive plan to benefit members of both sides. The study also deals with social optimum analysis and shows that from the point of view of the social planner the overprovision of QoS is not socially desirable.

While the study has certain merits to review, some of the following limitations prevail. First, we have studied discount policy in a monopoly platform framework. But e-commerce sites and other digital markets we see in existence have more than one competing platforms engaged in price competition. It will be interesting to extend our study to more than one platform. Second, tax authorities of many countries are now trying to levy taxes on online transactions mediated by tech-giants. Some sections of US levied “Netflix Tax” on streaming media (Bajo-Buenestado and Kinateder, 2019). France implemented “YouTube Tax” on online videos (Bajo-Buenestado and Kinateder, 2019). It will be intriguing to see how results shape up under various tax regimes and whether tax cut gives similar kind of results as discounts. Third, consumer information is appeared to be a strong weapon used by intermediation service networks to acquire user market. Before participating in a transaction on a platform, users need to “sign-up” to be able to access platform services by providing some personal information. So, platforms use this user information as a device to improve their services. Also, after making a purchase consumers can leave feedbacks on the online platforms. Sometimes, potential buyers use these feedbacks to judge the quality of the services of the platform. This can be incorporated in the model and it can exhibit interesting findings that could be valuable for literature. Further, we have assumed sellers to be homogenous in this model. However, heterogeneity among the sellers may have interesting impact on the pricing decision of platform. This can be another possible extension of our paper. An intensive advertising technique can have negative effects on the consumers as well. Because of the privacy implications of advertisement, policymakers should not only empower consumers but also spell out laws that could protect consumers (Boerman et al., 2017). In our study the negative impact of advertisement on the consumer utility level has not been taken into account. This can be another possible avenue to extend our model.

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Appendices to Chapter 3

Appendix 3.1.

Case of discount given to less price-sensitive side, sellers

Let us assume that per transaction discount or any certain kind of concession, “d” has been offered only to sellers, the less price-sensitive side of the market by platform. Net surplus of a representative seller from making interactions with each member on other side of the platform is,

$$\Pi_S = [\pi_S - (a_S - d)]\lambda N_B - A_S$$

Net surplus of a representative buyer from engaging into transaction with each seller is,

$$U_B = [\theta_B s - a_B] N_S - A_B$$

Profit of monopoly platform can be written as,

$$\Pi_P = \lambda (P_B + P_s - d) [1 - \frac{P_B}{\bar{\theta}s}](1 - \frac{P_{s-d}}{\bar{\pi}}) - \frac{\alpha}{2} s^2 - \frac{\beta}{2}\lambda^2$$

First Order Conditions (F.O.C.) for profit-maximization with respect to P_B and P_s will give profit-maximizing per-interaction prices. Those can be obtained as,

$P_B = \frac{[2\bar{\theta}s - \bar{\pi}]}{3}$ and $P_s = \frac{[2\bar{\pi} + 3d - \bar{\theta}s]}{3}$

So, platform's profit is,

$$\Pi_P = \lambda \frac{[\bar{\theta}s + \bar{\pi}]^3}{27\bar{\theta}\bar{\pi}s} - \frac{\alpha}{2}s^2 - \frac{\beta}{2}\lambda^2$$

F.O.C. for profit-maximisation with respect to service quality(s) and level of advertisement (λ) will yield profit-maximising level of QoS and advertisement which will not depend on amount of discount.

Thus, offering discount to sellers' side will hardly have any impact on other variables of the model.

Appendix 3.2.

Derivation of Slope of $\delta(s)$ function

From (3.19), we have,

$$\delta(s) = \frac{s^2\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^5 \left(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s}\right)}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2}$$

Differentiating with respect to s, we have,

$$\delta'(s) = \frac{1}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2}\Bigg[2s\left\{\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right\}^5\left(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s}\right)$$

$$+ s^2\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^5\left(\frac{\bar{\pi}}{s^2}\right)$$

$$+ 5s^2\left\{\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right\}^4\left(-\frac{\bar{\pi}}{s^2}\right)\left(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s}\right)\Bigg]$$

$$=\frac{1}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2}\ [2s\left\{\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right\}^5\left(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s}\right)+\ \bar{\pi}\left\{\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right\}^4\{-10\bar{\theta}(1+$$

$$d)+\qquad\qquad \frac{5\bar{\pi}}{s}+\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\}]$$

$$=\frac{\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^4}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2}[\{2s\bar{\theta}(1+d)+2\bar{\pi}\}\left(2\bar{\theta}(1+d)-\frac{\bar{\pi}}{s}\right)+\frac{6\bar{\pi}^2}{s}-9\bar{\theta}\bar{\pi}(1+d)]$$

$$=\frac{\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^4}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2}\ [4s\bar{\theta}^2(1+d)^2+\frac{4\bar{\pi}^2}{s}-7\bar{\theta}\bar{\pi}(1+d)]$$

$$=\frac{\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^4}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2 s}\ [4\bar{\pi}^2+4s^2\bar{\theta}^2(1+d)^2-7\bar{\theta}\bar{\pi}(1+d)s\ ]$$

$$=\frac{\left(\bar{\theta}(1+d)+\frac{\bar{\pi}}{s}\right)^4}{27^2\beta\bar{\theta}^2\bar{\pi}^2(1+d)^2 s}\ [4\{\bar{\theta}(1+d)s-\bar{\pi}\}^2+\bar{\theta}\bar{\pi}(1+d)s]\quad >0$$

Appendix 3.3.

Proof of Proposition 1(i)

From (3.17), we get,

$$\frac{\partial\Pi_P}{\partial s}=\ \frac{(\bar{\theta}s(1+d)+\bar{\pi})^5(2\bar{\theta}s(1+d)-\bar{\pi})}{27^2\beta\bar{\theta}^2\bar{\pi}^2 s^3(1+d)^2}-\alpha\ s=0$$

Or, $\frac{(\bar{\theta}s(1+d)+\bar{\pi})^5(2\bar{\theta}s(1+d)-\bar{\pi})}{27^2\beta\bar{\theta}^2\bar{\pi}^2 s^4(1+d)^2}-\alpha=0$

Or, δ(s) = α

Differentiating totally with respect to “d” gives

$$\delta'(s)\ \frac{ds}{dd}+\frac{\partial\delta(s)}{\partial d}=0$$

Or, $\frac{ds}{dd}=\ -\ \frac{\frac{\partial\delta(s)}{\partial d}}{\delta\prime(s)}$

Now,

$$\frac{\partial\delta(s)}{\partial d} = \frac{1}{27^2\beta\bar{\Theta}^2\bar{\pi}^2 s^4}\left[\frac{5(\bar{\Theta}(1+d)s+\bar{\pi})^4(2\bar{\Theta}(1+d)s-\bar{\pi})(\bar{\Theta}s)}{(1+d)^2} + \frac{(\bar{\Theta}(1+d)s+\bar{\pi})^5 2\bar{\Theta}s}{(1+d)^2} - \frac{2(\bar{\Theta}(1+d)s+\bar{\pi})^5(2\bar{\Theta}(1+d)s-\bar{\pi})}{(1+d)^3}\right]$$

$$= \frac{(\bar{\Theta}(1+d)s+\bar{\pi})^4}{27^2\beta\bar{\Theta}^2\bar{\pi}^2 s^4(1+d)^3}[5\bar{\Theta}s(1+d)(2\bar{\Theta}(1+d)s-\bar{\pi}) + 2\bar{\Theta}s(1+d)(\bar{\Theta}(1+d)s+\bar{\pi}) - 2(\bar{\Theta}(1+d)s+\bar{\pi})(2\bar{\Theta}(1+d)s-\bar{\pi})]$$

$$= \frac{(\bar{\Theta}(1+d)s+\bar{\pi})^4}{27^2\beta\bar{\Theta}^2\bar{\pi}^2 s^4(1+d)^3}[(2\bar{\Theta}(1+d)s-\bar{\pi})\{5\bar{\Theta}(1+d)s-\bar{\Theta}(1+d)s-\bar{\pi}\} + (\bar{\Theta}(1+d)s+\bar{\pi})\ \{2\bar{\Theta}s(1+d)-2\bar{\Theta}(1+d)s+\bar{\pi}\}]$$

$$= \frac{(\bar{\Theta}(1+d)s+\bar{\pi})^4}{27^2\beta\bar{\Theta}^2\bar{\pi}^2 s^4(1+d)^3}[(2\bar{\Theta}(1+d)s-\bar{\pi})\{4\bar{\Theta}(1+d)s-\bar{\pi}\} + \bar{\pi}(\bar{\Theta}(1+d)s+\bar{\pi})]$$

Since $\frac{ds}{dd} = -\frac{\frac{\partial\delta(s)}{\partial d}}{\delta\prime(s)}$ then we have,

$$\frac{ds}{dd} = -\frac{\frac{(\bar{\Theta}(1+d)s+\bar{\pi})^4}{27^2\beta\bar{\Theta}^2\bar{\pi}^2 s^4(1+d)^3}[(2\bar{\Theta}(1+d)s-\bar{\pi})\{4\bar{\Theta}(1+d)s-\bar{\pi}\}+\bar{\pi}(\bar{\Theta}(1+d)s+\bar{\pi})]}{\frac{\left(\bar{\Theta}(1+d)+\frac{\bar{\pi}}{s}\right)^4}{27^2\beta\bar{\Theta}^2\bar{\pi}^2(1+d)^2 s}[4\{\bar{\Theta}(1+d)s-\bar{\pi}\}^2+\bar{\Theta}\bar{\pi}(1+d)s]}$$

$$= -\frac{s}{(1+d)}\frac{[8\,\bar{\Theta}^2(1+d)^2s^2-5\,\bar{\Theta}\,\bar{\pi}(1+d)s+2\bar{\pi}^2]}{[4\{\bar{\Theta}(1+d)s-\bar{\pi}\}^2+\bar{\Theta}\bar{\pi}(1+d)s]}$$

$$= -\frac{s}{(1+d)}\frac{[2\{2\bar{\Theta}\,(1+d)s-\bar{\pi}\}^2+3\bar{\Theta}\,\bar{\pi}(1+d)s]}{[4\{\bar{\Theta}(1+d)s-\bar{\pi}\}^2+\bar{\Theta}\bar{\pi}(1+d)s]}$$

The denominator of above expression is always positive as $\delta'(s) > 0$. The numerator which is the sum of a squared term and a positive quantity, is positive.

Therefore, $\frac{ds}{dd} < 0$. Q.E.D. ■

Proof of Proposition 1(ii)

We have, $\lambda = \frac{[\bar{\theta}s(1+d)+\bar{\pi}]^3}{27\beta\bar{\theta}\bar{\pi}(1+d)s}$

Differentiating with respect to d, we have,

$$\frac{d\lambda}{dd} = \frac{3(\bar{\theta}s(1+d)+\bar{\pi})^2}{27\beta\bar{\theta}\bar{\pi}(1+d)s}[\bar{\theta}s + \bar{\theta}(1+d)\frac{ds}{dd}] + \frac{(\bar{\theta}s(1+d)+\bar{\pi})^3}{27\beta\bar{\theta}\bar{\pi}}[-\frac{1}{s^2(1+d)}\frac{ds}{dd} - \frac{1}{s(1+d)^2}]$$

$$= \frac{(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}(1+d)s-\bar{\pi})}{27\beta\bar{\theta}\bar{\pi}(1+d)^2s^2}[s + (1+d)\frac{ds}{dd}]$$

$$= \frac{(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}(1+d)s-\bar{\pi})}{27\beta\bar{\theta}\bar{\pi}(1+d)^2s^2}[s - \frac{(8\,\bar{\theta}^2(1+d)^2s^2-5\,\bar{\theta}\,\bar{\pi}(1+d)s+2\bar{\pi}^2)}{\left[\frac{4\bar{\pi}^2}{s}+\bar{\theta}(1+d)\{4s\bar{\theta}(1+d)-7\bar{\pi}\}\right]}]$$

$$= \frac{(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}(1+d)s-\bar{\pi})}{27\beta\bar{\theta}\bar{\pi}(1+d)^2s^2}\frac{[(\bar{\pi}^2-4\,\bar{\theta}^{\,2}(1+d)^2s^2)+\bar{\pi}(\bar{\pi}-2\bar{\theta}(1+d)s)]}{\left[\frac{4\bar{\pi}^2}{s}+\bar{\theta}(1+d)\{4s\bar{\theta}(1+d)-7\bar{\pi}\}\right]}$$

$$= -\frac{s(\bar{\theta}s(1+d)+\bar{\pi})^2(2\bar{\theta}(1+d)s-\bar{\pi})}{27\beta\bar{\theta}\bar{\pi}(1+d)^2s^2}\frac{[(4\,\bar{\theta}^{\,2}(1+d)^2s^2-\bar{\pi}^2)+\bar{\pi}(2\bar{\theta}(1+d)s-\bar{\pi})]}{[4\{\bar{\theta}(1+d)s-\bar{\pi}\}^2+\bar{\theta}\bar{\pi}(1+d)s]}$$

The numerator of the above expression is positive since $s > \frac{\bar{\pi}}{2\bar{\theta}(1+d)} = s_{min}$ and denominator is always positive since $\delta'(s) > 0$.

Therefore, $\frac{d\lambda}{dd} < 0$. Q.E.D. ■

Proof of Proposition 1(iii)

Volume of transaction is termed as V. We have,

$$V = \lambda N_B N_S = \lambda\frac{[\bar{\theta}s(1+d)+\bar{\pi}]^2}{9\bar{\theta}\bar{\pi}(1+d)s}$$

$$\frac{dV}{dd} = \frac{d\lambda}{dd}\frac{[\bar{\theta}s(1+d)+\bar{\pi}]^2}{9\bar{\theta}\bar{\pi}(1+d)s} + \frac{\lambda(\bar{\theta}s(1+d)+\bar{\pi})(\bar{\theta}s(1+d)-\bar{\pi})}{9\bar{\theta}(1+d)\bar{\pi}s^2}\frac{ds}{dd} + \frac{\lambda(\bar{\theta}s(1+d)+\bar{\pi})(\bar{\theta}s(1+d)-\bar{\pi})}{9\bar{\theta}(1+d)^2\bar{\pi}s}$$

$$= \frac{d\lambda}{dd}\frac{[\bar{\theta}s(1+d)+\bar{\pi}]^2}{9\bar{\theta}\bar{\pi}(1+d)s} + \frac{\lambda(\bar{\theta}s(1+d)+\bar{\pi})(\bar{\theta}s(1+d)-\bar{\pi})}{9\bar{\theta}(1+d)^2\bar{\pi}s^2}[s + (1+d)\frac{ds}{dd}]$$

From the conditions $P_B>0$, we have $\overline{\theta}(1+d)s > \frac{(\overline{\pi}-3d)}{2}$ and $P_S > 0$, we get $\overline{\theta}(1+d)s < 2\overline{\pi}$; so, the value of $\overline{\theta}$ for a particular value of s will fall within the range $\frac{(\overline{\pi}-3d)}{2} < \overline{\theta}(1+d)s < 2\overline{\pi}$. Now, $\frac{dV}{dd} < 0$ if $(\overline{\theta}s(1+d)-\overline{\pi}) > 0$. This condition will get satisfied if the ultimate range of $\overline{\theta}$ for a particular value of s is, $\overline{\pi} < \overline{\theta}(1+d)s < 2\overline{\pi}$. Any value of $\overline{\theta}$ falling within this range will automatically satisfy, $s > \frac{\overline{\pi}}{2\overline{\theta}(1+d)} = s_{min}$.

Therefore, $\frac{dV}{dd} < 0$. Q.E.D.■

Proof of Proposition 1(iv)

Monopoly platform's profit can be written as,

$$\Pi_P = \frac{1}{2}\frac{[\overline{\theta}(1+d)s+\overline{\pi}]^6}{27^2\beta\overline{\theta}^2\overline{\pi}^2s^2(1+d)^2} - \frac{\alpha}{2}s^2$$

Differentiating with respect to d, we get,

$$\frac{d\Pi_P}{dd} = \frac{\partial\Pi_P}{\partial d} + \frac{\partial\Pi_P}{\partial s}\frac{ds}{dd}$$

$$= \frac{1}{2}\frac{1}{27^2\beta\overline{\theta}^2\overline{\pi}^2s^2}\left[\frac{6[\overline{\theta}(1+d)s+\overline{\pi}]^5\overline{\theta}s}{(1+d)^2} - \frac{2[\overline{\theta}(1+d)s+\overline{\pi}]^6}{(1+d)^3}\right] \text{ [From F.O.C., } \frac{\partial\Pi_P}{\partial s} = 0\text{]}$$

$$= \frac{[\overline{\theta}(1+d)s+\overline{\pi}]^5(2\overline{\theta}(1+d)s-\overline{\pi})}{27^2\beta\overline{\theta}^2\overline{\pi}^2s^2(1+d)^3} > 0. \text{ Q.E.D. ■}$$

Also, we observe the effect of discount on per-interaction fees charged on both sides.

From (3.11), we have, $P_s = \frac{[2\overline{\pi}-\overline{\theta}s(1+d)]}{3}$

Differentiating with respect to d, we get,

$$\frac{dP_S}{dd} = \frac{\partial P_S}{\partial d} + \frac{\partial P_S}{\partial s}\frac{ds}{dd}$$

$$= -\frac{\overline{\theta}s}{3} - \frac{\overline{\theta}(1+d)}{3}\frac{ds}{dd} = -\frac{\overline{\theta}}{3}\left[s + (1+d)\frac{ds}{dd}\right]$$

Since $\left[s+(1+d)\frac{ds}{dd}\right]=-\frac{s[(4\,\bar{\theta}^2(1+d)^2s^2-\bar{\pi}^2)+\bar{\pi}(2\bar{\theta}(1+d)s-\bar{\pi})]}{[4\{\bar{\theta}(1+d)s-\bar{\pi}\}^2+\bar{\theta}\bar{\pi}(1+d)s]}<0, \frac{dP_S}{dd}>0$

From (3.10), $P_B=\frac{[2\bar{\theta}s(1+d)+3d-\bar{\pi}]}{3}$

Differentiating with respect to d, we get,

$$\frac{dP_B}{dd}=\frac{\partial P_B}{\partial d}+\frac{\partial P_B}{\partial s}\frac{ds}{dd}$$

$$=\frac{2\bar{\theta}s+3}{3}+\frac{2\bar{\theta}(1+d)}{3}\frac{ds}{dd}$$

$$=1+\frac{2\bar{\theta}}{3}\left[s+(1+d)\frac{ds}{dd}\right]$$

$$=1-\frac{2\bar{\theta}s}{3}\frac{[4\,\bar{\theta}^2(1+d)^2s^2+2\bar{\theta}\bar{\pi}(1+d)s-2\bar{\pi}^2]}{[\{4\,\bar{\theta}^2(1+d)^2s^2-7\bar{\theta}(1+d)\bar{\pi}s+4\bar{\pi}^2\}]}$$

Therefore, $\frac{dP_B}{dd}\gtreqless 0$; thus, the effect of increase in discount on price paid by buyers is ambiguous.

Appendix 3.4.

Derivation of Equation (3.24)

From (3.23), Social welfare can be written as,

$$W=\frac{\lambda}{\bar{\theta}\bar{\pi}}\int_{\pi^*}^{\bar{\pi}}d\pi\int_{\theta^*}^{\bar{\theta}}[\theta_B s\,(1+d)-(P_B-d)]d\theta+\frac{\lambda}{\bar{\theta}\bar{\pi}}\int_{\theta^*}^{\bar{\theta}}d\theta\int_{\pi^*}^{\bar{\pi}}(\pi_S-P_S)d\pi$$

$$+\frac{\lambda}{\bar{\theta}\bar{\pi}}(P_B+P_S-d)\int_{\pi^*}^{\bar{\pi}}d\pi\int_{\theta^*}^{\bar{\theta}}d\theta-\frac{\alpha}{2}s^2-\frac{\beta}{2}\lambda^2$$

$$=\frac{\lambda}{\bar{\theta}\bar{\pi}}\int_{\pi^*}^{\bar{\pi}}d\pi\int_{\theta^*}^{\bar{\theta}}\theta_B s\,(1+d)d\theta+\frac{\lambda}{\bar{\theta}\bar{\pi}}\int_{\theta^*}^{\bar{\theta}}d\theta\int_{\pi^*}^{\bar{\pi}}\pi_S\,d\pi-\frac{\alpha}{2}s^2-\frac{\beta\lambda^2}{2}$$

$$=\frac{\lambda}{\bar{\theta}\bar{\pi}}s(1+d)\left(\frac{\bar{\theta}^2}{2}-\frac{\theta^{*2}}{2}\right)\int_{\pi^*}^{\bar{\pi}}d\pi+\frac{\lambda}{\bar{\theta}\bar{\pi}}\frac{1}{2}(\bar{\pi}^2-\pi^{*2})\int_{\theta^*}^{\bar{\theta}}d\theta-\frac{\alpha}{2}s^2-\frac{\beta\lambda^2}{2}$$

$$= \frac{\lambda}{2\bar{\Theta}\bar{\pi}}(\bar{\pi} - \pi^*)(\bar{\Theta} - \Theta^*)[s(1+d)(\bar{\Theta} + \Theta^*) + (\bar{\pi} + \pi^*)] - \frac{\alpha}{2}s^2 - \frac{\beta\lambda^2}{2} \quad (3.A1)$$

Putting, $\Theta^* = \frac{P_B - d}{s(1+d)}$ and $\pi^* = P_S$ in (3.A1), we have,

$$W(P_B, P_S, s, \lambda) = \frac{\lambda}{2\bar{\Theta}\bar{\pi}}\left(\bar{\Theta} - \frac{P_B - d}{s(1+d)}\right)(\bar{\pi} - P_S)\left[s(1+d)\left(\bar{\Theta} + \frac{P_B - d}{s(1+d)}\right) + (\bar{\pi} + P_S)\right] - \frac{\alpha}{2}s^2 - \frac{\beta\lambda^2}{2}$$

The above equation will define social welfare as a function of four endogenous variables (P_B, P_S, s and λ) of our model.

Setting values of P_B, P_S similar to monopoly price structure (derived in (3.10) and (3.11)), we obtain social welfare as a function of QoS (s) and level of advertisement (λ).

So, above equation can be expressed as,

$$W(s, \lambda) = \frac{\lambda}{2\bar{\Theta}\bar{\pi}}\left[\bar{\Theta} - \frac{(2\bar{\Theta}s(1+d) + 3d - \bar{\pi})}{3s(1+d)} + \frac{d}{s(1+d)}\right]\left[\bar{\pi} - \frac{2\bar{\pi} - \bar{\Theta}s(1+d)}{3}\right]\left[s(1+d)\left(\bar{\Theta} + \frac{(2\bar{\Theta}s(1+d) + 3d - \bar{\pi})}{3s(1+d)} - \frac{d}{s(1+d)}\right) + \left(\bar{\pi} + \frac{2\bar{\pi} - \bar{\Theta}s(1+d)}{3}\right)\right] - \frac{\alpha}{2}s^2 - \frac{\beta\lambda^2}{2}$$

$$\text{Or, } W(s, \lambda) = \frac{2\lambda}{27}\frac{[\bar{\Theta}s(1+d) + \bar{\pi}]^3}{\bar{\Theta}\bar{\pi}s(1+d)} - \frac{\alpha}{2}s^2 - \frac{\beta\lambda^2}{2}$$

Chapter 4: A Theoretical Analysis on Two-sided Duopoly Platforms and Tax regimes

4.1 Introduction

Two-sided platforms are economically endowed with the significant task of connecting agents from two distinct sides that derive utilities from their interaction with each other, causing cross-side network effects to play a pivotal role in this respect. The economic literature pertaining to two-sided platforms (Caillaud and Jullien, 2003; Rochet and Tirole, 2003, 2006) demonstrates exclusive and distinct characteristics that mark these businesses off from traditional industries. The indirect network effect or cross-group effect which originates from improved trading possibilities of a group with the participation of an additional member in the cross-group, is typically an indispensable facet of the platform framework (Choi, 2010; Poddar et al., 2022). Many economically significant businesses operate under the paradigms of platform markets with network externalities. For instance, e-commerce marketplaces have two distinct sides, buyers and sellers on board, and two sides derive benefits by transacting with each other. Other examples of two-sided platforms are --- digital media, operating systems, and online portals to name a few.

With the advent of digital technology and the rapid adoption of the internet, the number of people buying digitally continues to soar each year. [29] Over 2 billion buyers traded online across the globe in 2020. As the platform markets skyrocketed in the past few years, it has also welcomed some challenges in the recent past. One key deliberation is concerned with the incidence of tax on platform members, which is also the essence of the present study. The titans of the online businesses like "GAFAM" are charged with the payment of lower level of taxes

[29] Reported at https://www.statista.com/topics/871/online-shopping/

even when all these internet platforms clocked stunning growth over the years.[30] Locating their businesses on lower-taxed regions and heavy reliance on elements of intangibles (search algorithms, network effects, etc) --- made these industries to escape fiscal scrutiny (Bacache-Beauvallet & Bloch, 2018). Given the perplexity of imposition of taxes on platform businesses, some countries voiced for alternative tax structures to regulate the tax evasion tendency of digital platforms. Several parts of US articulated a "Netflix Tax" on streaming media; France announced "YouTube Tax" on streaming videos in 2016; In India, "Goods and Services Tax" covered online transactions as well since 2017 (Bajo-Buenestado & Kinateder, 2019). Not surprisingly, taxes on internet platforms are the epicenter of discussions and controversial debates in the existing literature and among academicians and policy-makers.

Taxes on internet platforms may pose a divergent impact from traditional markets because of the presence of the elements of self-reinforcing force of network externalities and the competitive structure of platform economies. To comprehend the competitive game of online platforms and their reactions on fees change in presence of taxes levied on their businesses, the present study emphasizes the effects of taxation on fees of both sides, profits of the platforms, and social welfare for the duopoly asymmetric two-sided platforms. For this purpose, we develop a vertical differentiation model between competing platforms where each platform boards two sides of members (here, buyers and sellers) and charges a fee to each side. Unlike the pioneering contributions by Caillaud and Jullien (2003), Rochet and Tirole (2003) – primarily conducted their analysis based on symmetric platforms, we consider an asymmetric structure of the platforms for a deeper and more robust analysis of the impact of the tax structure. To reflect reality, we allow for the multi-homing by one group of agents (here, sellers).

[30] GAFAM indicates Google, Amazon.com, Facebook, Apple and Microsoft.

Given the difficulty of the modeling structure, we carry two different forms of tax analysis. First, the effect of the introduction of ad valorem tax on platform revenue has been discussed on platforms' fees, consumer surplus, and profits of platforms. In our second analysis, we consider the tax levied on access fees paid by consumers. Finally, we focus on the effects of tax incidence on both regimes to find the more distortive tax form by comparing social welfare on two tax structures. To the best of our knowledge, no literature discusses the comparative analysis of the distortionary effects of these two forms of taxes in an asymmetric competing platform ecosystem. Our study aims to fill this critical research gap in the academic literature by broadening our understanding of taxation in duopoly platform structure. Another element that sets our analysis apart from the existing literature concerning taxation is the consideration of a technology used by each platform that shares the information about the sellers to its customers. Informative advertising supplied by each platform enables a buyer to find information about sellers and drives the buyer to trade with only those sellers. The modeling structure establishes the following findings which can have a major contribution to the literature on platform economies. First, each platform lowers the equilibrium level of informative advertising sent to buyers in response to an increase in both kinds of taxes. Second, each platform reciprocates by lowering the fees charged to buyers to mitigate the effects of tax levied on buyers. Whereas the high-quality platform (referred to as Platform 1) lowers the participation fee on buyers in case of tax levied on platforms, the low-quality platform (referred to as Platform 2) shifts some degree of the tax burden to its buyers since it lowers the informative advertising less than the Platform 1 in response to an increase in tax rate. Therefore, rather than announcing a fee hike, Platform 1 believes in lowering the level of informative advertising by a greater amount. Third, an increase in tax imposed on consumers raises the per-transaction fee paid by sellers. Fourth, both tax structures produce detrimental effects on platforms' profits and consumers' surpluses for two platforms. We then conduct a numerical analysis based on certain values of parameters and derive that social welfare achieved in the case of tax levied on consumers is less than that for the case of a tax on platforms. Therefore tax on consumers generates a higher degree of unfavorable and adverse impacts on society as a whole. Next, sensitivity analysis is also conducted to examine the effect of the strength of cross-group interaction on model variables.

The issue of taxation on two-sided platforms receives scant status in the existing literature. However, few scholarly articles that existed in the literature, explained tax effects in different setups and settings than our analysis. The work by Belleflamme and Toulemonde (2018) analyses different kinds of taxes on competing platforms. Following the model developed by Armstrong (2006), it shows specific taxes are completely shifted to the taxed side; other group and platforms remain unaffected whereas transaction taxes affect both sides negatively and platforms positively. According to them, only ad valorem taxes help tax authority to take a fraction of the platform’s income. They also extend their analysis to investigate the effects of asymmetric taxes on agents of both sides and platforms’ profits. Bajo-Buenestado and Kinateder (2019) present a monopoly platform model and evaluate the cases of ad valorem taxes imposed on platform and end-users to derive that the existence of price distortions (like taxes) for a monopoly platform makes lump sum access fees and usage fees not replaceable for each other. Bacache-Beauvallet (2018) studies the consequences of digital marketing on tax competition and compares origin-based and destination-based taxation. Kind and Koethenbuerger (2018) assess the impact of taxation on digital media platforms. Favorable sales taxes motivate the circulation of printed newspapers and books, however, this is not the case for digital newspapers since a reduction in VAT causes sales volume to dip. The study by Kind, Koethenbuerger and Schjelderup (2008) investigates the optimal supply and taxation of goods in presence of two-sidedness of the markets for both the monopoly and competitive market structures.

The rest of the paper is arranged as follows. Before illustrating the effects of two distinct forms of taxation and their social welfare impacts on Section 4.3, we present the theoretical framework of the model in Section 4.2. Section 4.4 analyses the effect of the strength of (positive) interactions with sellers for buyers on model variables of our framework. Section 4.5 discusses the summary of results and provides concluding remarks. Mathematical computations are part of the Appendix.

4.2 Theoretical Framework

Consider two vertically differentiated duopoly two-sided platforms indexed by $i = 1, 2$ that generate value by getting two distinct groups of members who need each other's participation on the same board. For concreteness, we define two groups of agents (let's assume a digital marketplace as a two-sided platform) as buyers, *B* and sellers, *S*. Platforms compete to gain market share on each side. "Service quality" which refers to the daily service performance executed by a platform (like delivery service, replacement or exchange service, etc), is used to characterize the vertically differentiated element of platforms. If s_i be the service quality of the ith platform $i \in (1,2)$, we assume $s_1 > s_2$. With a larger value of service quality representing the higher level of quality, platforms realizing different levels of service quality help to serve heterogeneous consumers having different levels of willingness-to-pay. Next, we allow for multi-homing by sellers where buyers can at most participate and engage in trading on one platform. This line of assumption is very much common in recent times where sellers can join more than one platform to realize the benefit of interacting with a vast pool of cross-group agents on various platforms while a buyer purchases the product from only one platform. Finally, the mass of members on the jth side participating in the ith platform is denoted by N_i^j. Following Anderson Jr. et al., (2014), we assume platforms charge access fees to consumers and per-transaction fees to sellers.

In the next two subsections, we discuss two different forms of tax structure: tax (denoted by "τ") imposed on platforms' revenue and ad valorem tax, "t" levied on access fees paid by consumers. For the sake of simplicity, each tax rate is considered to be symmetric across platforms.

- *Buyers*

Buyers' valuations for service quality differ in their willingness to pay, v, therefore, a set (potential) buyers are represented by the distribution of v. The type, v is uniformly distributed on the interval $[\underline{v}, \bar{v}]$ where the number of buyers is normalized to 1. We can think of a platform environment where a buyer cannot evaluate all the sellers participated on the same platform on its own, rather the buyer only enters into a transaction with the sellers whose information has been channeled to them by the platform with the help of an advertising technology. We here consider informative advertising (indexed by λ_i) containing registered sellers' particulars sent by the i^th^ platform to its buyers, which help each buyer to find a seller with probability $\lambda_i \in [0,1]$, given both agents participated on the same platform. More specifically, if there exists N_i^S number of sellers on the i^th^ platform, then the buyer on the same platform receives information and benefits from at most $\lambda_i N_i^S$ number of sellers, sent by the advertising technology, λ_i by that particular platform. When the platform sends no advertising (i.e., $\lambda_i = 0$), the buyer receives no information about any seller operating on the platform, thus get no benefit in this regard. When $\lambda_i = 1$, a buyer can evaluate all the sellers participated on the same platform. Next, we consider there prevail cross-side network externalities and introduce a parameter that captures the valuation of interaction for a buyer with an additional seller. Denote the strength of cross-side effects for buyers by μ which is multiplied by the mass of sellers evaluated by the buyers. If P_i^B be the access fee (or lump sum participation fee) paid by buyers to the i[th] platform, then the (expected) utility for a representative buyer of type v is represented as,

$$U_i^B = vs_i - P_i^B + \mu\lambda_i N_i^S \tag{4.1}$$

Let v^* be the buyer who is indifferent between joining platforms 1 and 2. The total number of buyers participating in platform 1 is provided by the probability that buyers' utility from joining Platform 1 is greater than the utility derived from Platform 2 (i.e., $N_1^B = pr(U_1^B > U_2^B)$). The rest of the buyers will join Platform 2. Therefore, the (expected) number of buyers purchasing from platforms 1 and 2 respectively are given by,

$$N_1^B = \frac{1}{(\overline{v}-\underline{v})}\left[\overline{v} - \frac{(P_1^B - P_2^B) - \mu\{\lambda_1 N_1^S - \lambda_2 N_2^S\}}{(s_1 - s_2)}\right] \ \& \ N_2^B = \frac{1}{(\overline{v}-\underline{v})}\left[\frac{(P_1^B - P_2^B) - \mu\{\lambda_1 N_1^S - \lambda_2 N_2^S\}}{(s_1 - s_2)} - \underline{v}\right]$$

- *Sellers*

To reflect the actual market situation on the platform ecosystem, we particularly concentrate on an equilibrium where a set of sellers multi-home. Each seller's profit is influenced by the number of buyers participating on the platform. The availability of every additional buyer creates additional profit, π which represents the intragroup heterogeneity on the seller's side. The type of seller, π is uniformly distributed over the range $[0,1]$. Here, λ_i is the probability that the seller is found and evaluated by a consumer with the help of advertising technology sent by i[th] platform and thus it stands for probability of successful interaction of seller with the opposite group. The decision for multi-homing by sellers entirely depends on the per transaction fee, P_i^j which a seller (or, side *j*) needs to pay to the i[th] platform on each successful interaction with side –*j* (or buyers) (with $i \in (1,2), i \neq -i$). Therefore, (expected) profit of a representative seller under multi-homing is represented by,

$$\Pi_{Multi-homing}^S = (\pi - P_1^S)\lambda_1 N_1^B + (\pi - P_2^S)\lambda_2 N_2^B$$

We start by assuming $P_1^S > P_2^S$. As long as, $\pi \geq P_1^S > P_2^S$, the seller will join and benefit from interacting with buyers on both the platforms, thus they multi-home. Whenever, $P_2^S < \pi < P_1^S$, the seller will only sell through the platform 2. For $\pi < P_2^S < P_1^S$, the seller will not join on any platform. If mass of sellers is normalized to 1, then (expected) number of sellers participating in platforms 1 and 2 respectively is defined as,

$$N_1^S = (1 - P_1^S) \quad ; \qquad N_2^S = (1 - P_2^S) \tag{4.2}$$

Substituting N_1^S and N_2^S from equation (4.2), the (expected) number of buyers purchasing from platforms 1 and 2 respectively are obtained as,

$$N_1^B = \frac{1}{(\overline{v} - \underline{v})}\left[\overline{v} - \frac{(P_1^B - P_2^B) - \mu\{\lambda_1(1-P_1^S) - \lambda_2(1-P_2^S)\}}{(s_1 - s_2)}\right] \ \& \ N_2^B = \frac{1}{(\overline{v} - \underline{v})}\left[\frac{(P_1^B - P_2^B) - \mu\{\lambda_1(1-P_1^S) - \lambda_2(1-P_2^S)\}}{(s_1 - s_2)} - \underline{v}\right] \tag{4.3}$$

- *Platforms*

Following Anderson Jr. et al., (2014), we consider two separate revenue flows earned by each platform: a lump-sum subscription fee paid by buyers independent of the number of interactions made with members of other group and a per transaction fee paid by sellers on the successful sale of each content or product to consumers. The profit of the i[th] platform supported by N_i^S sellers and N_i^B buyers, can be written as,

$$\Pi_i^P = P_i^B N_i^B + P_i^S N_i^B(\lambda_i N_i^S) - \frac{\beta \lambda_i^2}{2} \ for\ i \epsilon (1,2) \tag{4.4}$$

The first term of equation (4.4) is the revenue of the platform collected by charging an access (subscription) fee, P_i^B to total N_i^B of buyers boarding on the i[th] platform. The second term represents the revenue earned by receiving a usage (per transaction) fee, P_i^S from sellers on each successful interaction with buyers on the same platform. Only those sellers whose information is channeled to buyers using informative advertising, λ_i, involve in the interaction with members of other group. Each platform incurs a lump sum (fixed) increasing cost for developing/installing an advertising technology, $\frac{\beta\lambda_i^2}{2}$, where β being the advertising cost-coefficient.

We solve the sub-game perfect equilibrium of the two-stage game which proceeds as follows. First, each platform simultaneously sets the level of optimal advertising technology. Next, both platforms determine the fees to be charged on both sides of the platform markets. Given the optimal advertising technology and fees charged by platforms, agents on both groups make their participation decision.

4.3 Competition between duopoly two-sided platforms: Cases of different tax structures

In this section, we show the effects of two separate forms of taxation on platform fees, profits and consumer surplus to get the most distortive form of taxation between taxes on consumers and taxes on platforms.

4.3.1 Taxes imposed on platform revenue

First, we consider an ad valorem tax, τ that has been imposed on platform revenue. Here we deal with symmetric taxes as nondiscrimination between platforms sets the founding-stone for taxation (Belleflamme & Toulemonde, 2018). Under this taxation, the decision problem of each platform changes to,

$$\underbrace{Max}_{\lambda_i, P_i^S, P_i^B} \quad \Pi_i^P = (1-\tau)\left[P_i^B N_i^B + P_i^S N_i^B\left(\lambda_i N_i^S\right)\right] - \frac{\beta\lambda_i^2}{2} \quad for\ i \epsilon (1,2)$$

where N_i^S and N_i^B are given by equations (4.2) & (4.3) respectively.

To obtain equilibrium fees paid by both sides on each platform, we solve an equation system of four first-order conditions (FOCs) for profit maximization written as follows:

$$\frac{\partial \Pi_1^P}{\partial P_1^B} = \frac{(1-\tau)}{(\overline{v}-\underline{v})}\left[\overline{v} - \frac{(P_1^B - P_2^B) - \mu\{\lambda_1(1-P_1^S) - \lambda_2(1-P_2^S)\}}{(s_1 - s_2)}\right] - \frac{(1-\tau)}{(\overline{v}-\underline{v})(s_1-s_2)}[P_1^B + \lambda_1(1-P_1^S)P_1^S] = 0$$

$$\frac{\partial \Pi_1^P}{\partial P_1^S} = \frac{(1-\tau)\lambda_1(1-2P_1^S)}{(\overline{v}-\underline{v})}\left[\overline{v} - \frac{(P_1^B-P_2^B)-\mu\{\lambda_1(1-P_1^S)-\lambda_2(1-P_2^S)\}}{(s_1-s_2)}\right] - \frac{(1-\tau)\mu\lambda_1}{(\overline{v}-\underline{v})(s_1-s_2)}[P_1^B + \lambda_1(1-P_1^S)P_1^S] = 0$$

$$\frac{\partial \Pi_2^P}{\partial P_2^B} = \frac{(1-\tau)}{(\overline{v}-\underline{v})}\left[\frac{(P_1^B-P_2^B)-\mu\{\lambda_1(1-P_1^S)-\lambda_2(1-P_2^S)\}}{(s_1-s_2)} - \underline{v}\right] - \frac{(1-\tau)}{(\overline{v}-\underline{v})(s_1-s_2)}[P_2^B + \lambda_2(1-P_2^S)P_2^S] = 0$$

$$\frac{\partial \Pi_2^P}{\partial P_2^S} = \frac{(1-\tau)\lambda_2(1-2P_2^S)}{(\overline{v}-\underline{v})}\left[\frac{(P_1^B-P_2^B)-\mu\{\lambda_1(1-P_1^S)-\lambda_2(1-P_2^S)\}}{(s_1-s_2)} - \underline{v}\right] - \frac{(1-\tau)\mu\lambda_2}{(\overline{v}-\underline{v})(s_1-s_2)}[P_2^B + \lambda_2(1-P_2^S)P_2^S] = 0$$

A few steps of computations delivers the equilibrium fees as,

$$P_1^B = \frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3} + \frac{\mu(\lambda_1-\lambda_2)(1+\mu)}{6} - \frac{(1-\mu^2)(2\lambda_1+\lambda_2)}{12}; \quad P_1^S = \frac{1}{2}(1-\mu) \tag{4.5}$$

$$P_2^B = \frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3} - \frac{\mu(\lambda_1-\lambda_2)(1+\mu)}{6} - \frac{(1-\mu^2)(\lambda_1+2\lambda_2)}{12};^{3} \quad P_2^S = \frac{1}{2}(1-\mu) \tag{4.6}$$

A classic outcome developed in this model indicates that both the platforms will charge the same per-transaction fees to sellers. Thus, the same number of sellers will serve both platforms and multi-home. Moreover, the presence of (positive) cross-group network effect allows the per transaction fee to adjust in the downward direction. Next we focus on deriving the optimal level of informative advertising for platforms by employing the two first order conditions of profit maximization for both platforms: $\frac{\partial \Pi_1^P}{\partial \lambda_1} = 0$; $\frac{\partial \Pi_2^P}{\partial \lambda_2} = 0$. A simple computation brings us with the equilibrium level of informative advertising defined as $(\lambda_1^{\tau *}, \lambda_2^{\tau *})$. Thus, we obtain,

$$\lambda_1^{\tau *} = \frac{(1-\tau)(1+\mu)^2}{12\beta}\left[\frac{24\beta(2\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}\right] \;\&\; \lambda_2^{\tau *} = \frac{(1-\tau)(1+\mu)^2}{12\beta}\left[\frac{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}\right] \tag{4.7}$$ [31,32]

[31] We assume, $\overline{v} > 2\underline{v}$

[32] The second order sufficient condition requires, $\Delta_\tau = \{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\} > 0$. This condition interprets that vertical differentiation should outweigh the strength of cross-group externality. Otherwise, both platforms cannot exist together in the equilibrium.

We see that the high-quality platform will serve a greater level of informative advertising to its buyers compared to its rival low-quality platform since $\lambda_1^{\tau *} > \lambda_2^{\tau *}$.

By replacing the equilibrium pair of advertising technology represented by (4.7) in equation systems (4.5) & (4.6), we finally derive the equilibrium fees on both platforms as $(P_1^{B^{\tau *}}, P_1^{S^{\tau *}}, P_2^{B^{\tau *}}, P_2^{S^{\tau *}})$. We can now derive the equilibrium level of profits on both platforms as:

$$\Pi_1^{P^{\tau *}} = \frac{(1-\tau)}{(\bar{v}-\underline{v})(s_1-s_2)}\left[\frac{(2\bar{v}-\underline{v})(s_1-s_2)}{3} + \frac{(\lambda_1^{\tau *}-\lambda_2^{\tau *})(1+\mu)^2}{12}\right]^2 - \frac{\beta\lambda_1^{\tau * 2}}{2}$$

$$\Pi_2^{P^{\tau *}} = \frac{(1-\tau)}{(\bar{v}-\underline{v})(s_1-s_2)}\left[\frac{(\bar{v}-2\underline{v})(s_1-s_2)}{3} - \frac{(\lambda_1^{\tau *}-\lambda_2^{\tau *})(1+\mu)^2}{12}\right]^2 - \frac{\beta\lambda_2^{\tau * 2}}{2}$$

4.3.1.1 Sensitivity Analysis: The incidence of tax levied on platforms

The unique sub-game perfect equilibrium under this tax structure expresses some compelling characteristics of the model variables in response to an increase in tax which are to be collected in Proposition 1 through the help of a comparative static exercise. The detailed proofs are in Appendix.

Proposition 1(i): The equilibrium level of informative advertising channeled to buyers decreases unambiguously with an increase in τ for both platforms.

With a higher level of τ, platforms now need to forgo a higher portion of their revenues earned from all participants. This immediate direct impact of an increase in the tax rate on platforms forces each platform to lower its investment on advertising technology and consequently, it serves a lower level of information to buyers in response to an increase in the tax rate.

Moreover, the high-quality platform 1 induces the level of informative advertising about sellers directed to buyers to fall to a higher rate than the low-quality platform.

Proposition 1(ii): The high-quality platform charges a lower access fee, $P_1^{B^{\tau *}}$ *to its buyers, however, the subscription fee charged to buyers by the low-quality platform* $P_2^{B^{\tau *}}$ *increases with tax levied on the platform when* $\mu > 0.7143$.

To hold the results obtained on Proposition 1(ii), a parametric restriction on μ is imposed which indicates that the strength of cross-side effects for buyers must be sufficiently higher than a threshold level of 0.7143. To obtain the impact of tax on equilibrium fees, we need to focus on two channels. The first and instantaneous impact would be to raise the subscription fees paid by buyers to mitigate the platforms' own burden of paying a tax. On the other hand, lowering each platform's investment on $\lambda_i^{\tau *}$ (with $i\epsilon(1,2)$) in response to an increase in tax allows each platform to lower its fee on buyers, a second effect originating through the lowered investment on advertising technology. The ultimate effect on equilibrium fees relies on the strength of these separate effects.

For the high-quality platform 1, the effect of lowering fees to buyers grows so powerful that it ultimately outweighs the immediate impact of raising fees in response to an increase in the tax rate. However, for the low-quality platform 2, we derive an interesting observation. With platform 2 lowers the investment on informative advertising, $\lambda_2^{\tau *}$ less than the high-quality platform, it pays the platform 2 to pass on a fraction of tax to buyers by raising $P_2^{B^{\tau *}}$. Thus low-quality platform will shift the burden of tax to some extent to its buyers through the increase in the subscription fee. On the other hand, the high-quality platform chooses to set a significantly lower level of advertising instead of announcing a fee hike.

As the per interaction fees paid by sellers are independent of tax rate therefore a change in tax rate produces no effect on equilibrium usage fees.

Proposition 1(iii): The equilibrium profit of each platform unambiguously falls with an increase in the tax rate.

Now when we possess a complete mapping of equilibrium informative advertising and fee changes, let us derive how these effects translate into the platform's profit changes. The direct effect of tax on profit is undoubtedly negative as platforms now have to pay a tax on their revenue earnings. In addition, a fall in investment on informative advertising to some extent recuperates the loss in profit margin. However, on the other hand, a lower level of information sharing discourages a successful interaction between two cross-groups as well. As the profit-diminishing effects are stronger making the overall effect on profit clearly negative. Moreover, the fall in access fee charged by platform 1 in response to the increase in tax rate further lowers platform 1's profit share.

Proposition 1 (iv): The consumer surplus of buyers on Platform 1 varies negatively with the tax rate, however, the effect on consumer surplus on Platform 2 is ambiguous.

The decline of the information sharing about sellers in response to an increase in tax rate reduces the consumer surplus attained by buyers of Platform 1 as they will now get less information and the probability for a successful interaction diminishes. However, no such unambiguous result can be obtained for Platform 2. To illustrate the effect on consumer surplus for Platform 2, we evaluate a numerical analysis depending on the parameter values: $\overline{v} = 4, \underline{v} = 1, s_1 = 3, s_2 = 1, \mu = 0.8, \beta = 0.5$ & $\tau \in (0.001,0.1)$. The numerical study identifies a negative relationship between the consumer surplus of buyers on platform 2 and the tax rate, as expected.

For the graphical illustration of all results, refer to Figures 4.1-4.10.

Diagram Panel 4.A: The effect of tax under both tax regimes

Fig. 4.1 Informative advertising for platfrom 1 for both tax regimes

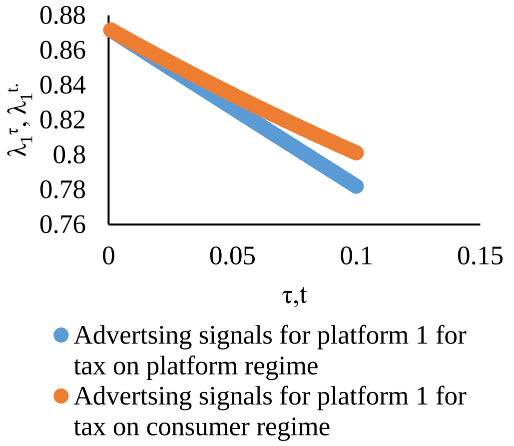


Fig. 4.2 Informative advertising for platfrom 2 for both tax regimes

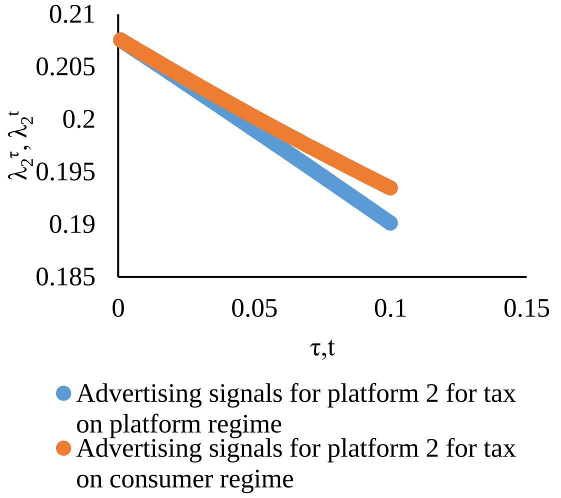


Fig. 4.3 Participation fee charged on consumers for platform 1

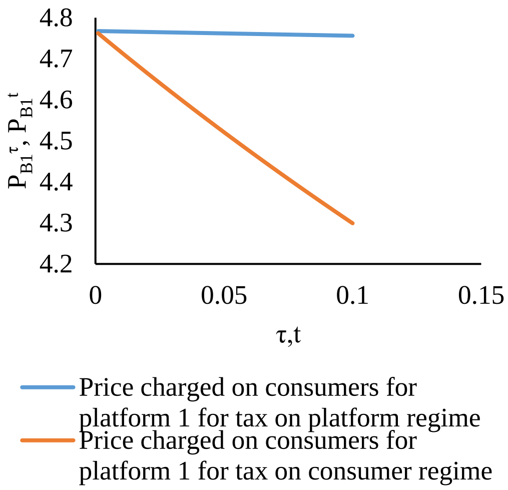


Fig. 4.4 Participation fee charged on consumers for platform 2

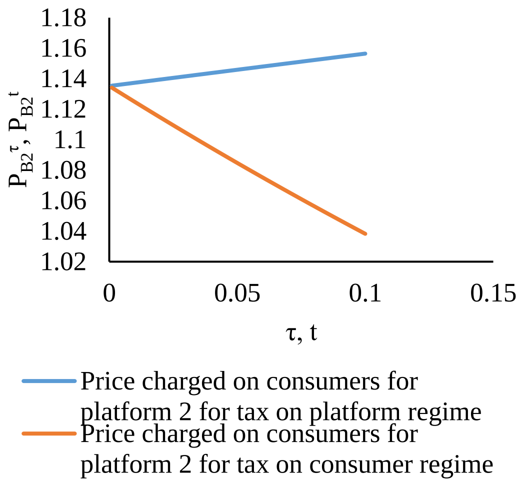


Fig. 4.5 Per transaction fee charged on sellers for both platforms for both tax regimes

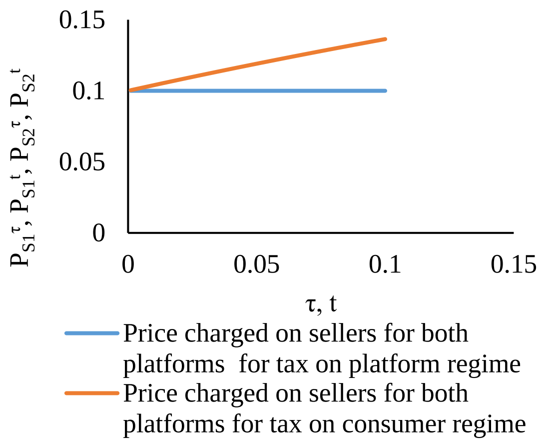


Fig. 4.6 Profit of Platform 1 for both tax regimes

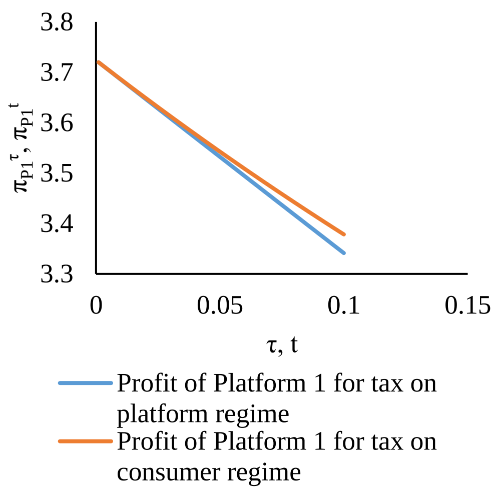


Fig. 4.7 Profit of Platform 2 for both tax regimes

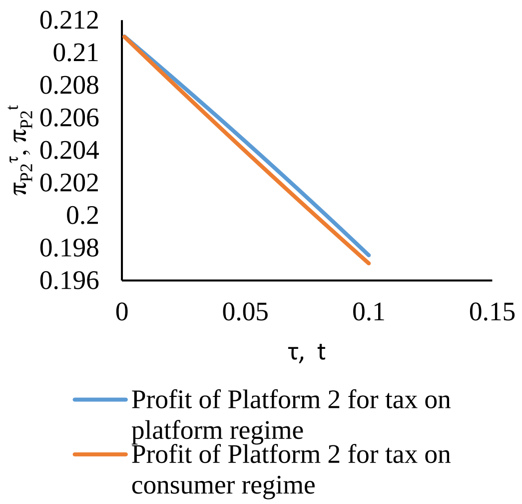


Fig. 4.8 Consumer surplus on Platform 1

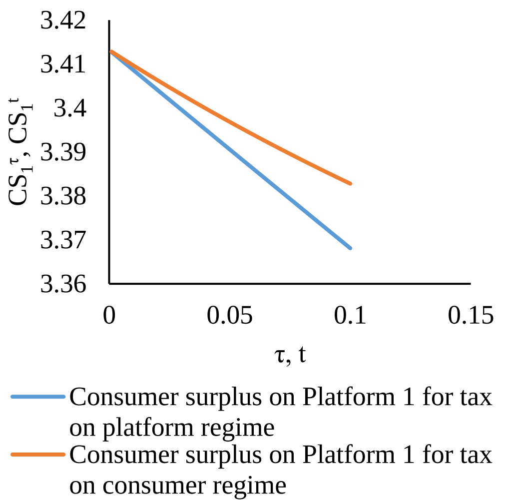


Fig. 4.9 Consumer surplus on Platform 2

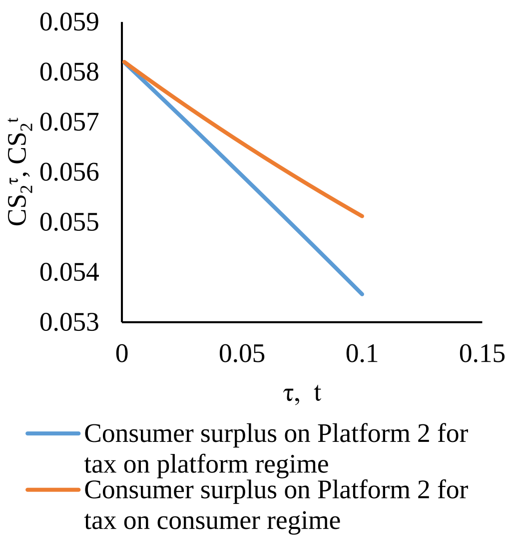
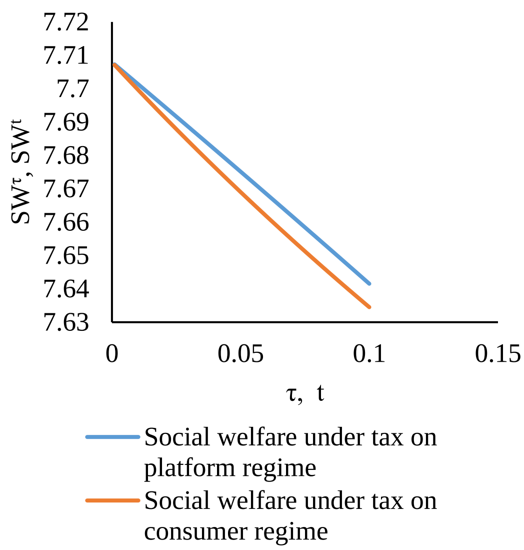


Fig. 4.10 Social welfare under two tax regimes



Source: Based on theoretical model done by authors

4.3.2 Taxes imposed on consumers

Next we consider an ad valorem (symmetric) tax, "t" levied on access fee paid by buyers to each platform. Under this particular form of tax structure, representative buyer's utility transforms to,

$$U_i^B = vs_i - P_i^B(1+t) + \mu\lambda_i N_i^S \qquad for\ i\epsilon(1,2)$$

Solving the stage-game with backward induction, we first derive the number of buyers that each platform boards as,

$$N_1^B = \frac{1}{(\overline{v}-\underline{v})}\left[\overline{v} - \frac{(1+t)\,(P_1^B-P_2^B)-\mu\{\lambda_1(1-P_1^S)-\lambda_2(1-P_2^S)\}}{(s_1-s_2)}\right] \ \& \qquad (4.8a)$$

$$N_2^B = \frac{1}{(\overline{v}-\underline{v})}\left[\frac{(1+t)\,(P_1^B-P_2^B)-\mu\{\lambda_1(1-P_1^S)-\lambda_2(1-P_2^S)\}}{(s_1-s_2)} - \underline{v}\right] \qquad (4.8b)$$

Then, platform's optimization problem is,

$$\underbrace{Max}_{\lambda_i, P_i^S, P_i^B} \quad \Pi_i^P = \left[P_i^B N_i^B + P_i^S N_i^B\left(\lambda_i N_i^S\right)\right] - \frac{\beta\lambda_i^2}{2} \quad for\ i\epsilon(1,2)$$

where N_i^S and N_i^B are given by equations (4.2) & (4.8) respectively.

The equilibrium fee for each side on each platform can be derived from system of four first-order conditions for profit maximization and these are written as follows,

$$\frac{\partial\Pi_1^P}{\partial P_1^B} = \frac{1}{(\overline{v}-\underline{v})}\left[\overline{v} - \frac{(1+t)\left(P_1^B-P_2^B\right)-\mu\{\lambda_1\left(1-P_1^S\right)-\lambda_2\left(1-P_2^S\right)\}}{(s_1-s_2)}\right] - \frac{(1+t)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[P_1^B + \lambda_1(1-P_1^S)P_1^S\right] = 0$$

$$\frac{\partial\Pi_1^P}{\partial P_1^S} = \frac{\lambda_1(1-2P_1^S)}{(\overline{v}-\underline{v})}\left[\overline{v} - \frac{(1+t)\left(P_1^B-P_2^B\right)-\mu\{\lambda_1\left(1-P_1^S\right)-\lambda_2\left(1-P_2^S\right)\}}{(s_1-s_2)}\right] - \frac{\mu\lambda_1}{(\overline{v}-\underline{v})(s_1-s_2)}\left[P_1^B + \lambda_1(1 - P_1^S)P_1^S\right] = 0$$

$$\frac{\partial\Pi_2^P}{\partial P_2^B} = \frac{1}{(\overline{v}-\underline{v})}\left[\frac{(1+t)\left(P_1^B-P_2^B\right)-\mu\{\lambda_1\left(1-P_1^S\right)-\lambda_2\left(1-P_2^S\right)\}}{(s_1-s_2)} - \underline{v}\right] - \frac{(1+t)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[P_2^B + \lambda_2(1-P_2^S)P_2^S\right] = 0$$

$$\frac{\partial\Pi_2^P}{\partial P_2^S} = \frac{\lambda_2(1-2P_2^S)}{(\overline{v}-\underline{v})}\left[\frac{(1+t)\left(P_1^B-P_2^B\right)-\mu\{\lambda_1\left(1-P_1^S\right)-\lambda_2\left(1-P_2^S\right)\}}{(s_1-s_2)} - \underline{v}\right] - \frac{\mu\lambda_2}{(\overline{v}-\underline{v})(s_1-s_2)}\left[P_2^B + \lambda_2(1 - P_2^S)P_2^S\right] = 0$$

We obtain the profit maximizing fees by solving above four equations as,

$$P_1^B = \frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3(1+t)} + \frac{\mu(\lambda_1-\lambda_2)(1+\frac{\mu}{1+t})}{6(1+t)} - \frac{\left\{1-\frac{\mu^2}{(1+t)^2}\right\}(2\lambda_1+\lambda_2)}{12}\ ;\ P_1^S = \frac{1}{2}\left[1-\frac{\mu}{(1+t)}\right] \tag{4.9}$$

$$P_2^B = \frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3(1+t)} - \frac{\mu(\lambda_1-\lambda_2)(1+\frac{\mu}{1+t})}{6(1+t)} - \frac{\left\{1-\frac{\mu^2}{(1+t)^2}\right\}(\lambda_1+2\lambda_2)}{12}\ ;\ P_2^S = \frac{1}{2}\left[1-\frac{\mu}{(1+t)}\right] \tag{4.10}$$

To derive the equilibrium level of informative advertising to be supplied by each platform, we have to solve the first-order conditions for profit maximization for each platform with respect to λ_i.

The profit-maximizing levels of informative advertising provided by two platforms take the following forms,

$$\lambda_1^{t*} = \frac{(1+\frac{\mu}{1+t})^2}{12\beta}\left[\frac{24\beta(2\overline{v}-\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}\right] \; \& \; \lambda_2^{t*} = \frac{(1+\frac{\mu}{1+t})^2}{12\beta}\left[\frac{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}\right] \quad (4.11)$$ [33]

Substituting the equilibrium pair of advertising technology $(\lambda_1^{t*}, \lambda_2^{t*})$ from (4.11) to the system of fee equations (4.9) & (4.10), we finally obtain profit-maximizing equilibrium fees $({P_1^B}^{t*}, {P_1^S}^{t*}, {P_2^B}^{t*}, {P_2^S}^{t*})$.

We next get the equilibrium level of profits earned by both platforms.

$${\Pi_1^P}^{t*} = \frac{(1+t)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3(1+t)} + \frac{(\lambda_1^{\tau*}-\lambda_2^{\tau*})(1+\frac{\mu}{1+t})^2}{12}\right]^2 - \frac{\beta{\lambda_1^{\tau*}}^2}{2}$$

$${\Pi_2^P}^{t*} = \frac{(1+t)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3(1+t)} - \frac{(\lambda_1^{\tau*}-\lambda_2^{\tau*})(1+\frac{\mu}{1+t})^2}{12}\right]^2 - \frac{\beta{\lambda_2^{\tau*}}^2}{2}$$

4.3.2.1 Sensitivity Analysis: The incidence of tax levied on consumers

The stage game solution brings us some unique relationships between model variables and tax rate which are summarized in Proposition 2. Proofs are in Appendix.

Proposition 2 (i): The equilibrium level of informative advertising supplied by each platform, $(\lambda_1^{t*}, \lambda_2^{t*})$ *decreases unambiguously with an increase in the tax rate. And, equilibrium access fee charged to buyers decreases as well in the tax rate when* $(t+1) < 1.4\mu$.

The parametric condition which is required to satisfy the findings presented in Proposition 2(i), indicates that the degree of cross-side effects, μ for buyers with participation of each additional seller should be sufficiently higher than the tax imposed on buyers' access fees.

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[33] The second order sufficient condition requires, $\Delta_t = \left[36\beta(\overline{v}-\underline{v})(s_1-s_2) - (1+t)\left(1+\frac{\mu}{1+t}\right)^4\right] > 0$

Tax levied on consumers discourages them to participate and purchase from the platform as they need to bear the additional burden in terms of tax payment. Thus to compensate them for utility-loss arising due to an increase in the tax rate, platform 1 lowers the amount of participation fee paid by buyers. However, a lower amount of participation fee reduces the profit margin of the platform earned on the buyers' side and thus, platforms react by lowering their investment on the level of informative advertising supplied to recover from losses.

Note that low-quality platform 2 reduces the level of informative advertising less than that of the high-quality platform. Although the direct effect of an increase in tax on consumers leads to a reduction in participation fees, however, as platform 2 reduces the level of informative advertising at a lower rate than platform 1, it may cause platform 2 to reconsider its immediate act of lowering fee and ultimately it may raise the post-tax level of ${P_2^B}^{t*}$. Therefore, we mathematically cannot ascertain the change in direction of ${P_2^B}^{t*}$ with tax rate. With the help of a numerical analysis depending on the parameter values: $\overline{v} = 4, \underline{v} = 1, s_1 = 3, s_2 = 1, \mu = 0.8, \beta = 0.5$ & $t \in (0.001,0.1)$, we derive a negative association between ${P_2^B}^{t*}$ & t, as expected.

Proposition 2 (ii): The per-transaction fee paid by the seller increases with the tax levied on consumers for each platform.

As the tax applies on the buyers' side, the two platforms reduce the consumers' access fees. However, to compensate for their loss of revenues, the platforms in turn increase the per-transaction fees paid by sellers. Thus the platforms pass on the burden of tax to some extent to agents on the cross-side.

Proposition 2 (iii): The equilibrium profit level falls with tax for both platforms.

To explain the impact of the tax rate on profit, we need to consider the informative advertising and fee changes originating from the tax change. Reduction of the participation fee by each platform in response to an increase in tax to arrest the fall in participation by buyers causes a fall in profit margin made by the platform on buyers' side. Moreover, an increase in per transaction fee paid by sellers discourages their participation and eventually, the interaction with the cross-side (here, buyers) which in turn negatively affects the participation of buyers' side through the act of cross-group externality. On the other hand, a fall in the investment on the level of informative advertising improves the platform's profit margin to some extent. The profit-reducing effects appear to be stronger to make the overall effect of tax on profit negative for the two platforms.

The increase in tax straight away decreases buyers' utility as buyers now have to account for the additional tax burden when they pay subscription fees to platforms. A fall in the informative advertising in response to an increase in tax further lowers consumer surplus. These two channels can be considered to be the consumers' surplus-reducing effects. However, another effect originating through fee changes improves consumer surplus as the platform reacts by lowering the participation fee in response to an increase in tax. These two opposite forces make the overall effect on consumer surplus ambiguous. When the negative direct effects overpower the positive force, we can expect to derive a negative relationship between them. The numerical analysis based on the parameter values: $\overline{v} = 4, \underline{v} = 1, s_1 = 3, s_2 = 1, \mu = 0.8, \beta = 0.5$ & $t \in (0.001, 0.1)$ presents a clear negative association between consumer surplus and the level of the tax rate for both platforms. Refer to Figures 4.1-4.10, for graphical demonstration of results presented in Proposition 2. The reactions of each model variable with respect to a change in tax rate under both tax regimes which have been explained thoroughly in Proposition 1 and 2, are summarized in Table 4.1. The numerical study further upholds the results presented in Table 4.1. (See Appendix 4.B for Table 4.1)

4.3.3 Numerical comparison between two tax regimes

Given the complexity of the model, we analyze the welfare aspect of each tax structure with the help of a numerical study. In case of tax levied on consumers, platforms serve higher degree of informative advertising to consumers than the platform tax regime for the same level of both taxes, as indicated by Figures 4.1 & 4.2 and that in turn raises the consumer surplus under consumer tax regime more than the tax on platform regime due to the presence of cross network externality effect. Therefore, from Figures 4.8 and 4.9, we observe the consumer surplus is unambiguously higher for similar level of taxes under consumer tax regime compared to the tax on platform regime. However, Figure 4.7 depicts a completely opposite result in terms of the profit of platform 2. The profit of the platform is higher under the case of tax levied on platform compared to the other tax regime. Moreover, in case of tax on consumers, each platform passes on the burden of tax on sellers in terms of higher per transaction fee and thus, reduces the profit earned by sellers whereas the per transaction fees paid by sellers are left unaffected under tax on platform regime. When we are considering the overall social welfare effect, the profit effect dominates the consumer surplus effect such that the social welfare for the same level of taxes will be unambiguously lower in case of tax on consumer regime than on platform tax regime.

If we interpret social welfare for k[th] tax regime, SW^k $\left(k \in (\tau, t)\right)$ as the sum of consumers' surplus on each platform, sellers' surplus on two platforms, each platform's profit and tax revenue then from Figure 4.10, it is quite clear that for identical set of parameters and same level of both taxes, higher level of social welfare is attained in case of tax on platforms. Taking the values of parameters as $\overline{v} = 4, \underline{v} = 1, s_1 = 3, s_2 = 1, \mu = 0.8, \beta = 0.5, \tau = 0.1, t = 0.1$, we have $SW^\tau = 7.641532 > 7.634504 = SW^t$. Thus, from the social welfare perspective, tax on platforms should always be favored to tax on consumers.

4.4 Deriving the effect of the strength of cross-group externality

The co-efficient of cross-group externality exerted by sellers on buyers defined as μ portrays a significant role in our two-sided market model as a buyer of each platform receives an additional benefit with an additional seller's evaluation. Recall our utility function for buyers on the i[th] platform (represented by equation (4.1)), $U_i^B = vs_i - P_i^B + \mu\lambda_i N_i^S$. This section is devoted to find the impact of μ on informative advertising supplied by each platform, fees paid by buyers and sellers to each platform. Combining all these effects, we conclude our next Proposition. For a numerical example, we let $\overline{v} = 4, \underline{v} = 1, s_1 = 3, s_2 = 1, \beta = 0.5$ and we define $\mu \in [0.2,0.9]$. The numerical evaluation further confirms the results derived in Proposition 3.

Proposition 3 (i): The level of informative advertising supplied by each platform increases unambiguously with μ.

The intuition is pretty simple and straightforward. As the strength for cross-side external effects (μ) increases, buyers care about reaching to more sellers participated on the platform. Platforms reciprocate by increasing the level of informative advertising about sellers sent to buyers. The more information buyers get about sellers, the more utilities will be derived by them and consequently, it expands their participation on the platforms. Therefore, an increase in the degree of cross-side effects pays each platform to higher the level of informative advertising.

Proposition 3 (ii): The per-transaction fee paid by sellers on each platform diminishes with μ.

Now comes the effect of μ on per-transaction fees. Buyers tend to bother more about the number of sellers present on the platform in response to an increase in μ. Thus, to attract more sellers on board, each platform charges a lower per-transaction fee to sellers. Hence, an increase in μ eventually pushes $P_i^{S^*}$ down.

Proposition 3 (iii): The participation fee paid by buyers on platform 1 increases with μ, however, for platform 2, the relationship is ambiguous.

As μ increases, buyers obtain additional utility with each additional seller participation. Thus, they will be more interested to connect to a large number of sellers. The high-quality platform exploits this opportunity to gain additional profit by charging higher access fees to buyers when μ is high. However, this is not the case for the low-quality platform. As consumers having lower willingness-to-pay join the low-quality platform, platform 2 cannot therefore easily charge a higher access fee to its buyers. Moreover, platform 2 lowers its fee to buyers in response to an increase in μ, as indicated by our numerical study. For graphical presentation of the effect of μ on model variables, refer to Figures 4.11-4.16.

Diagram Panel 4.B: The effects of strength of cross-group externality, μ

Fig. 4.11 Informative advertising by platform 1

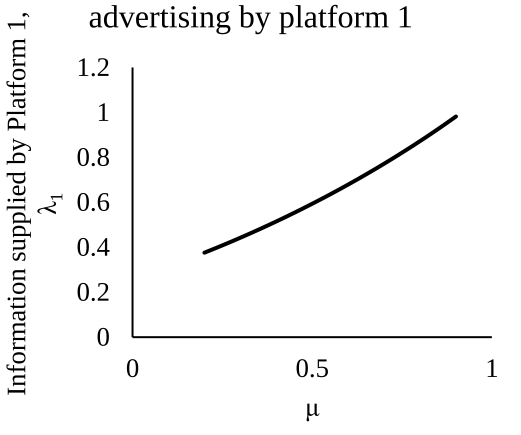


Fig. 4.12 Informative advertising by platform 2

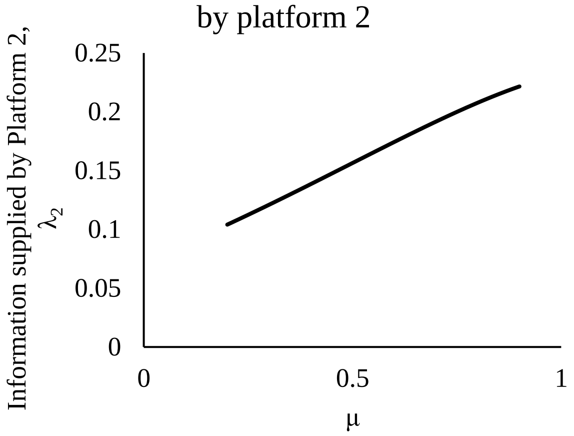


Fig. 4.13 Participation Fees charged on buyers by platform 1

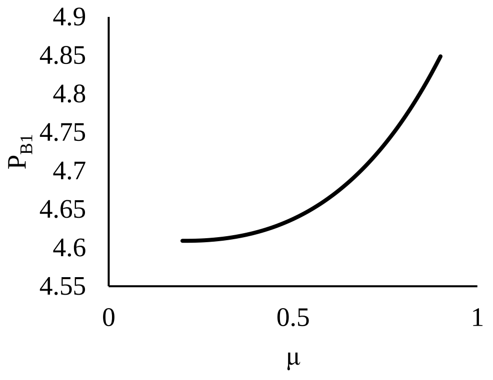


Fig. 4.14 Participation fees charged on buyers by platform 2

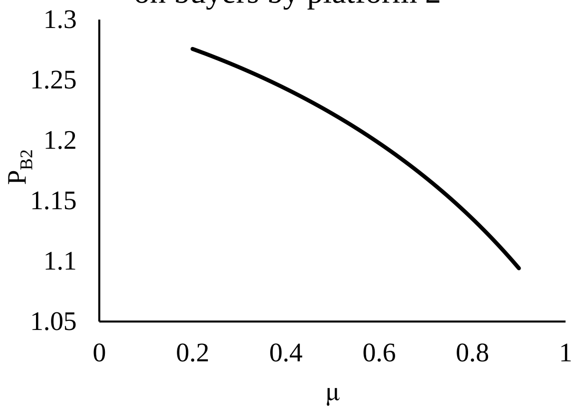


Fig. 4.15 Per-transaction fee for sellers on platform 1

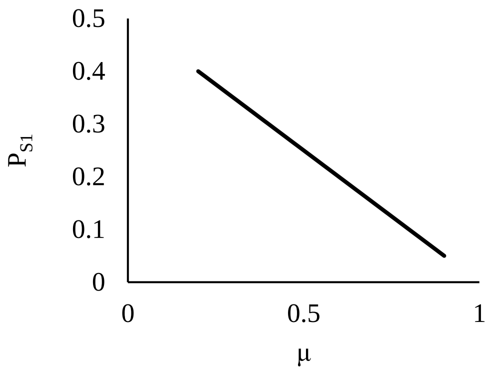
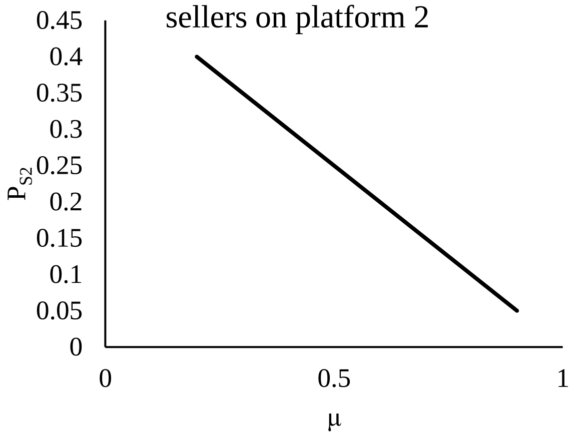


Fig. 4.16 Per-transaction fee for sellers on platform 2



Source: Based on theoretical model done by authors

4.5 Conclusion

The literature pertaining to taxation on competing two-sided markets is scarce. In this present article, we project the effect of two separate forms of taxation (i.e., a tax levied on platform & consumers) on agents of each platform in a simple two-sided duopoly market setting. Another element that sets apart our work from the existing literature is the presence of a technology used by each platform to disseminate informative advertising which inevitably increases the probability of finding a registered seller by a buyer on the same platform. For both forms of taxes, each platform lowers the level of informative advertising sent to its buyers which in turn automatically deteriorates the surpluses obtained by consumers. For tax on consumers, the tax burden to some extent transfers to other side agents in the form of higher per-transaction fees.

A numerical example is also conducted and it produces the same theoretical results as obtained in our model setting. The sensitivity analysis to show the effect of cross-side externality on different agents is also presented.

Though the present study produces some plausible characteristics of two-sided markets, it contains some limitations as well. First, multi-homing on the buyer side can be considered in a more general framework. Second, it will be interesting to review our observation for asymmetric taxation among platforms.

Appendices to Chapter 4

Appendix 4.A: Proofs and computations

1) *Proof of Proposition 1*

(i) $\lambda_1^{\tau *} = \frac{(1-\tau)(1+\mu)^2}{12\beta}\left[\frac{24\beta(2\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}\right]$

Taking natural logarithms on both sides and differentiating it with respect to τ, we get,

$$\frac{1}{\lambda_1^{\tau *}}\frac{\partial \lambda_1^{\tau *}}{\partial \tau} = -\frac{1}{(1-\tau)} - \frac{12(\bar{v}+\underline{v})\beta(s_1-s_2)(1+\mu)^4}{\{24\beta(2\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}\{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}}$$; Thus, $\frac{\partial \lambda_1^{\tau *}}{\partial \tau} < 0$

$$\lambda_2^{\tau *} = \frac{(1-\tau)(1+\mu)^2}{12\beta}\left[\frac{24\beta(\bar{v}-2\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4}\right]$$

Taking logarithms on both sides and differentiating with respect to τ,

$$\frac{1}{\lambda_2^{\tau *}}\frac{\partial \lambda_2^{\tau *}}{\partial \tau} = -\frac{2}{(1-\tau)}\frac{\{12\beta(\bar{v}-2\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}}{\{24\beta(\bar{v}-2\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}} - \frac{(1+\mu)^4}{\{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}}$$; Thus, $\frac{\partial \lambda_2^{\tau *}}{\partial \tau} < 0$

Again, $\left(\lambda_1^{\tau *} - \lambda_2^{\tau *}\right) = \frac{24\beta(\bar{v}+\underline{v})(s_1-s_2)(1-\tau)(1+\mu)^2}{12\beta\{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}} > 0$ and $\frac{\partial(\lambda_1^{\tau *}-\lambda_2^{\tau *})}{\partial \tau} < 0$

(ii) We can derive an expression for ${P_1^B}^{\tau *}$ as,

$${P_1^B}^{\tau} = \frac{(2\bar{v}-\underline{v})(s_1-s_2)}{3} + \frac{(1+\mu)\{2\lambda_1(2\mu-1)-\lambda_2(1+\mu)\}}{12}$$

Differentiating with respect to τ and a few steps of computations gives us,

$$\frac{\partial P_1^{B^\tau}}{\partial \tau} = \frac{(1+\mu)\left\{2(2\mu-1)\frac{\partial \lambda_1}{\partial \tau}-(1+\mu)\frac{\partial \lambda_2}{\partial \tau}\right\}}{12}$$

$$= -\frac{(1+\mu)}{12}\left[\frac{(1+\mu)^2\left\{24\beta(s_1-s_2)\left(\overline{v}(7\mu-5)+2\underline{v}(2-\mu)\right)+3(1-\tau)(1+\mu)^4(1-\mu)\right\}}{12\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}}+\frac{(\overline{v}+\underline{v})(s_1-s_2)(1+\mu)^6(1-\tau)(5\mu-1)}{\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}^2}\right] < 0$$

Similarly, $P_2^{B^\tau} = \frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3} + \frac{(1+\mu)\{2\lambda_2(2\mu-1)-\lambda_1(1+\mu)\}}{12}$

$$\frac{\partial P_2^{B^\tau}}{\partial \tau} = \frac{(1+\mu)\left\{2(2\mu-1)\frac{\partial \lambda_2}{\partial \tau}-(1+\mu)\frac{\partial \lambda_1}{\partial \tau}\right\}}{12}$$

$$= \frac{(1+\mu)}{12}\left[\frac{(1+\mu)^2\left\{24\beta(s_1-s_2)\left(2\overline{v}(2-\mu)+\underline{v}(7\mu-5)\right)-3(1-\tau)(1+\mu)^4(1-\mu)\right\}}{12\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}}+\frac{(\overline{v}+\underline{v})(s_1-s_2)(1+\mu)^6(1-\tau)(5\mu-1)}{\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}^2}\right] > 0$$

$\frac{\partial P_1^{B^\tau}}{\partial \tau} < 0$ & $\frac{\partial P_2^{B^\tau}}{\partial \tau} > 0$ if $\mu > 0.7143$

(iii) $\Pi_1^{P^{\tau *}} = \frac{(1-\tau)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3}+\frac{(\lambda_1^{\tau *}-\lambda_2^{\tau *})(1+\mu)^2}{12}\right]^2 - \frac{\beta\lambda_1^{\tau *2}}{2}$

$$\frac{\partial \Pi_1^{P^\tau}}{\partial \tau} = -\frac{\left\{\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3}+\frac{(\lambda_1^{\tau *}-\lambda_2^{\tau *})(1+\mu)^2}{12}\right\}\left[8\beta(2\overline{v}-\underline{v})(s_1-s_2)\left\{9(\overline{v}-\underline{v})(s_1-s_2)+\frac{3(1-\tau)^2(1+\mu)^8}{12\beta\Delta}\right\}-(1-\tau)(1+\mu)^4\left\{(5\overline{v}-7\underline{v})(s_1-s_2)+\frac{(1-\tau)^2(1+\mu)^8}{12\beta\Delta}\right\}\right]}{6(\overline{v}-\underline{v})(s_1-s_2)\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}} < 0$$

$$\Pi_2^{P^{\tau *}} = \frac{(1-\tau)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3}-\frac{(\lambda_1^{\tau *}-\lambda_2^{\tau *})(1+\mu)^2}{12}\right]^2 - \frac{\beta\lambda_2^{\tau *2}}{2}$$

$$\frac{\partial \Pi_2^{P^\tau}}{\partial \tau} = -\frac{\left\{\frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3}-\frac{(\lambda_1^{\tau *}-\lambda_2^{\tau *})(1+\mu)^2}{12}\right\}\left[8\beta(\overline{v}-2\underline{v})(s_1-s_2)\left\{9(\overline{v}-\underline{v})(s_1-s_2)+\frac{3(1-\tau)^2(1+\mu)^8}{12\beta\Delta}\right\}-(1-\tau)(1+\mu)^4\left\{(7\overline{v}-5\underline{v})(s_1-s_2)+\frac{(1-\tau)^2(1+\mu)^8}{12\beta\Delta}\right\}\right]}{6(\overline{v}-\underline{v})(s_1-s_2)\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1-\tau)(1+\mu)^4\}} < 0$$

(iv) $CS_1{}^\tau = \frac{1}{(\overline{v}-\underline{v})}\int_{v^*}^{\overline{v}}(vs_1 - P_1^B)\, dv + \frac{1}{(\overline{v}-\underline{v})}\int_{P_1^S}^{1}\mu\lambda_1 d\Pi \int_{v^*}^{\overline{v}} dv$

$$= \frac{1}{2(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3}+\frac{(\lambda_1-\lambda_2)(1+\mu)^2}{12}\right]\left[\left\{\underline{v}s_1+\frac{2s_2(2\overline{v}-\underline{v})}{3}\right\}+\frac{(1+\mu)^2}{12(s_1-s_2)}\{(3s_1-4s_2)(\lambda_1+\lambda_2)+2s_2\lambda_2\}\right]$$

Differentiating $CS_1{}^\tau$ with respect to τ, we easily get $\frac{\partial CS_1{}^\tau}{\partial \tau} < 0$

$$CS_2{}^\tau = \frac{1}{(\overline{v}-\underline{v})}\int_{\underline{v}}^{v^*}(vs_2 - P_2^B)\, dv + \frac{1}{(\overline{v}-\underline{v})}\int_{P_2^S}^{1}\mu\lambda_2 d\Pi \int_{\underline{v}}^{v^*} dv$$

$$= \frac{1}{2(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3}-\frac{(\lambda_1-\lambda_2)(1+\mu)^2}{12}\right]\left[\left\{\overline{v}s_2-\frac{2s_1(\overline{v}-2\underline{v})}{3}\right\}+\frac{(1+\mu)^2}{12(s_1-s_2)}\{(2s_1-3s_2)(\lambda_1+2\lambda_2)+3s_2\lambda_2\}\right]$$

We cannot deduce mathematically the change in consumer surplus of platform 2 with respect to the change in τ as $\frac{\partial {CS_1}^{\tau}}{\partial \tau} \lessgtr 0$. However, numerical analysis derives a negative association between ${CS_2}^{\tau}$ and τ.

2) *Proof of Proposition 2*

(i) $$\lambda_1^{t*} = \frac{(1+\frac{\mu}{1+t})^2}{12\beta}\left[\frac{24\beta(2\overline{v}-\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}\right]$$

Taking logarithms on both sides and differentiating it with respect to "t", we obtain,

$$\frac{1}{\lambda_1^{t*}}\frac{\partial \lambda_1^{t*}}{\partial t} = -\frac{2\mu}{(1+t)(1+t+\mu)} - \frac{12\beta(\overline{v}+\underline{v})(s_1-s_2)\left(1+\frac{\mu}{1+t}\right)^3\left(\frac{3\mu}{1+t}-1\right)}{\left\{24\beta(2\overline{v}-\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}\left\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}} < 0$$

Similarly, $\lambda_2^{t*} = \frac{(1+\frac{\mu}{1+t})^2}{12\beta}\left[\frac{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)(1+\frac{\mu}{1+t})^4}\right]$

Taking logarithms on both sides and differentiating it with respect to "t", we derive,

$$\frac{1}{\lambda_2^{t*}}\frac{\partial \lambda_2^{t*}}{\partial t} =$$

$$-\frac{\left[\mu\left\{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}+4\mu\left\{6\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}+(1+t)^2\left(1+\frac{\mu}{1+t}\right)^4\right]}{(1+t)^2\left(1+\frac{\mu}{1+t}\right)\left\{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}}$$

$$- \frac{\left(1+\frac{\mu}{1+t}\right)^3\left(\frac{3\mu}{1+t}-1\right)}{\left\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}} < 0$$

$$P_1^{B^t} = \frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3(1+t)} + \frac{1}{12(1+t)}\left(1+\frac{\mu}{1+t}\right)[2\lambda_1(2\mu-1-t)-\lambda_2(\mu+1+t)]$$

Differentiating $P_1^{B^t}$ with respect to "t", we get,

$$\frac{\partial P_1^{B^t}}{\partial t} = -\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3(1+t)^2} - \{2\lambda_1(2\mu-1-t)-\lambda_2(\mu+1+t)\}\left[\frac{1}{12(1+t)^2}\left(1+\frac{\mu}{1+t}\right)+\frac{\mu}{12(1+t)^3}\right]$$

$$-\frac{(2\lambda_1+\lambda_2)}{12(1+t)}\left(1+\frac{\mu}{1+t}\right)+\frac{1}{12(1+t)}\left(1+\frac{\mu}{1+t}\right)\left[2(2\mu-1-t)\frac{\partial\lambda_1}{\partial t}-\lambda_2(\mu+1+t)\frac{\partial\lambda_2}{\partial t}\right]$$

$$= -[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3(1+t)^2} + \{2\lambda_1(2\mu-1-t)-\lambda_2(\mu+1+t)\}\left\{\frac{1}{12(1+t)^2}\left(1+\frac{\mu}{1+t}\right)+\frac{\mu}{12(1+t)^3}\right\}+\frac{(2\lambda_1+\lambda_2)}{12(1+t)}\left(1+\frac{\mu}{1+t}\right)$$

$$+\frac{2\mu\left(1+\frac{\mu}{1+t}\right)^3}{144\beta\Delta(1+t)^2(1+t+\mu)}\left\{24\beta(s_1-s_2)\left(\overline{v}(7\mu-5-5t)+2\underline{v}(2+2t-\mu)\right)+3(1+t)\left(1+\frac{\mu}{1+t}\right)^4(1+t-\mu)\right\}$$

$$+\frac{(\overline{v}+\underline{v})(s_1-s_2)\left(1+\frac{\mu}{1+t}\right)^6\left(\frac{3\mu}{1+t}-1\right)(5\mu-1-t)}{12(1+t)\left\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}^2}] < 0$$

All the above results will get satisfied if $(t+1) < 1.4\mu$.

Again,

$$P_2^{B^t} = \frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3(1+t)} - \frac{1}{12(1+t)}\left(1+\frac{\mu}{1+t}\right)[\lambda_1(\mu+1+t)-2\lambda_2(2\mu-1-t)]$$

From the above equation we cannot establish the change in $P_2^{B^t}$ unambiguously since $\frac{\partial P_1^{B^t}}{\partial t} \gtrless 0$. However, numerical analysis based on certain parameter values presents a clear negative relationship between $P_2^{B^t}$ and t.

(ii) $P_1^{S^t} = \frac{1}{2}\left[1-\frac{\mu}{(1+t)}\right] = P_2^{S^t}$

Simple calculations allow us to derive, $\frac{\partial P_1^{S^t}}{\partial t} > 0$ and $\frac{\partial P_2^{S^t}}{\partial t} > 0$

(iii) $\Pi_1^{P^{t*}} = \frac{(1+t)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3(1+t)} + \frac{(\lambda_1^{\tau*}-\lambda_2^{\tau*})(1+\frac{\mu}{1+t})^2}{12}\right]^2 - \frac{\beta\lambda_1^{\tau*2}}{2}$

$$\frac{\partial\Pi_1^{P^t}}{\partial t} = -\frac{\left[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{(1+t)}+\frac{(\lambda_1-\lambda_2)\left(1+\frac{\mu}{1+t}\right)^2}{4}\right]}{9(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(2\overline{v}-\underline{v})(s_1-s_2)}{(1+t)}+\frac{(\lambda_1-\lambda_2)\left(1+\frac{\mu}{1+t}\right)\left(\frac{3\mu}{1+t}-1\right)}{4}-\frac{\lambda_2\mu\left(1+\frac{\mu}{1+t}\right)}{(1+t)}+\right.$$

$$\left.\frac{12\beta(1+t)\lambda_2(\overline{v}+\underline{v})(s_1-s_2)\left(1+\frac{\mu}{1+t}\right)^5\left(\frac{3\mu}{1+t}-1\right)}{2\Delta\left\{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}}\right] < 0$$

$$\Pi_2^{P^{t*}} = \frac{(1+t)}{(\overline{v}-\underline{v})(s_1-s_2)}\left[\frac{(\overline{v}-2\underline{v})(s_1-s_2)}{3(1+t)} - \frac{(\lambda_1-\lambda_2)(1+\frac{\mu}{1+t})^2}{12}\right]^2 - \frac{\beta\lambda_2^{\tau*2}}{2}$$

$$\frac{\partial \Pi_2^{P^t}}{\partial t} = -\frac{\left[\frac{(\bar{v}-2\underline{v})(s_1-s_2)}{(1+t)} - \frac{(\lambda_1-\lambda_2)\left(1+\frac{\mu}{1+t}\right)^2}{4}\right]}{9(\bar{v}-\underline{v})(s_1-s_2)}\left[\frac{(\bar{v}-2\underline{v})(s_1-s_2)}{(1+t)} - \frac{(\lambda_1-\lambda_2)\left(1+\frac{\mu}{1+t}\right)\left(\frac{3\mu}{1+t}-1\right)}{4} - \frac{\lambda_1\mu\left(1+\frac{\mu}{1+t}\right)}{(1+t)} - \frac{12\beta(1+t)\lambda_1(\bar{v}+\underline{v})(s_1-s_2)\left(1+\frac{\mu}{1+t}\right)^5\left(\frac{3\mu}{1+t}-1\right)}{2\Delta\left\{24\beta(2\bar{v}-\underline{v})(s_1-s_2)-(1+t)\left(1+\frac{\mu}{1+t}\right)^4\right\}}\right] < 0$$

The second order condition for profit maximization ensures the satisfaction of above results.

$$CS_1{}^t = \frac{1}{(\bar{v}-\underline{v})}\int_{v^*}^{\bar{v}}\{vs_1 - P_1^B(1+t)\}\,dv + \frac{1}{(\bar{v}-\underline{v})}\int_{P_1^S}^{1}\mu\lambda_1 d\Pi\int_{v^*}^{\bar{v}}dv$$

$$= \frac{1}{2(\bar{v}-\underline{v})}\left[\frac{(2\bar{v}-\underline{v})}{3} + \frac{(\lambda_1-\lambda_2)(1+t)\left(1+\frac{\mu}{1+t}\right)^2}{12(s_1-s_2)}\right]\left[\left\{\underline{v}s_1 + \frac{2s_2(2\bar{v}-\underline{v})}{3}\right\} + \frac{\left(1+\frac{\mu}{1+t}\right)^2(1+t)}{12(s_1-s_2)}\{(3s_1-4s_2)(\lambda_1+\lambda_2)+2s_2\lambda_2\}\right]$$

$$CS_2{}^\tau = \frac{1}{(\bar{v}-\underline{v})}\int_{\underline{v}}^{v^*}\{vs_2 - P_2^B(1+t)\}\,dv + \frac{1}{(\bar{v}-\underline{v})}\int_{P_2^S}^{1}\mu\lambda_2 d\Pi\int_{\underline{v}}^{v^*}dv$$

$$= \frac{1}{2(\bar{v}-\underline{v})}\left[\frac{(\bar{v}-2\underline{v})}{3} - \frac{(\lambda_1-\lambda_2)(1+t)\left(1+\frac{\mu}{1+t}\right)^2}{12(s_1-s_2)}\right]\left[\left\{\bar{v}s_2 - \frac{2s_1(\bar{v}-2\underline{v})}{3}\right\} + \frac{\left(1+\frac{\mu}{1+t}\right)^2(1+t)}{12(s_1-s_2)}\{(2s_1-3s_2)(\lambda_1+2\lambda_2)+3s_2\lambda_2\}\right]$$

Given the complexity of the expressions of consumer surpluses, we cannot deduce mathematically the change in consumer surpluses of both platforms with respect to the change in t. However, numerical analysis produces a negative association between consumer surplus and t for each platform.

3) *Proof of Proposition 3*

(i) $\lambda_1 = \frac{(1+\mu)^2}{12\beta}\left[\frac{24\beta(2\bar{v}-\underline{v})(s_1-s_2)-(1+\mu)^4}{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1+\mu)^4}\right]$ Say, $\tau = 0 = t$

Differentiating with respect to μ, we get,

$$\frac{\partial\lambda_1}{\partial\mu} = \frac{(1+\mu)\left[2\{24\beta(2\bar{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\} + \frac{48\beta(\bar{v}+\underline{v})(s_1-s_2)(1+\mu)^4}{\{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}}\right]}{12\beta\{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}} > 0$$

$$\lambda_2 = \frac{(1+\mu)^2}{12\beta}\left[\frac{24\beta(\bar{v}-2\underline{v})(s_1-s_2)-(1+\mu)^4}{36\beta(\bar{v}-\underline{v})(s_1-s_2)-(1+\mu)^4}\right]$$

$$\frac{\partial \lambda_2}{\partial \mu} = \frac{(1+\mu)\{8\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+\mu)^4\}}{2\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}} + \frac{(1+\mu)^2}{12\beta}\left[\frac{4(1+\mu)^3\{24\beta(\overline{v}-2\underline{v})(s_1-s_2)-(1+\mu)^4\}}{\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}^2}\right] > 0$$

(ii) $P_1^B = \frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3} + \frac{(1+\mu)\{2\lambda_1(2\mu-1)-\lambda_2(1+\mu)\}}{12}$

$= \frac{(2\overline{v}-\underline{v})(s_1-s_2)}{3} + \frac{(1+\mu)^3[\{24\beta(7\overline{v}-2\underline{v})(s_1-s_2)-3(1+\mu)^4\}\mu-24\beta(5\overline{v}-4\underline{v})(s_1-s_2)+3(1+\mu)^4]}{144\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}}$ (Putting the values of λ_1 and λ_2)

Say, $[\{24\beta(7\overline{v}-2\underline{v})(s_1-s_2)-3(1+\mu)^4\}\mu-24\beta(5\overline{v}-4\underline{v})(s_1-s_2)+3(1+\mu)^4] = m > 0$

Differentiating with respect to μ, we have,

$$\frac{\partial P_1^B}{\partial \mu} = \left[\frac{3(1+\mu)^2 m}{144\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}} + \frac{(1+\mu)^6 m}{36\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}^2} + \frac{(1+\mu)^3\{24\beta(7\overline{v}-2\underline{v})(s_1-s_2)-3(1+\mu)^4+12(1+\mu)^3(1-\mu)}{144\beta\{36\beta(\overline{v}-\underline{v})(s_1-s_2)-(1+\mu)^4\}}\right] > 0$$

The computation to derive the effect of μ on per-transaction fees paid by sellers is straightforward and thus omitted.

Appendix 4.B: Table

Table 4.1: Summary of the effects on model variables under two tax structures

Model Variables \ Tax Regimes		Tax levied on Platforms(τ)	Tax levied on consumers(t)
Platform 1	$\lambda_1{}^*$	−	−
	$P_{B1}{}^*$	−	−
	$P_{S1}{}^*$	0	+
	$\Pi_{P1}{}^*$	−	−
	$CS_1{}^*$	−	±
Platform 2	$\lambda_2{}^*$	−	−
	$P_{B2}{}^*$	+	±
	$P_{S2}{}^*$	0	+
	$\Pi_{P2}{}^*$	−	−
	$CS_2{}^*$	±	±

Chapter 5: Interaction between online platform and seller: Deriving the impact of tax and advertising

5.1 Introduction

The present era is marked by an exponential growth of e-commerce sector. The e-commerce sales reached $ 4.28 trillion in 2020 and it is expected to grow to $ 5.4 trillion in 2022. [34] E-retail sales is projected to hit 21.8% of all retail sales in 2021, up from 18% in 2020. [35] The global websites visits grew substantially from 16.07 billion in January 2020 to 22 billion in June 2020. [36] Moreover, the Covid-19 pandemic led retail e-commerce revenue to grow at a striking rate of 25%. [37] The growing platform market is subject to several disputes over sales proceeds sharing between platform providers and sellers who continue to argue over getting unfair share of revenue (Sur et al., 2019). Thus contract design between them has been one of the most important business decisions in the space of digital market (Sur et al., 2019).

There exists a gamut of literature concerning the contracting problem of retail platform and supply chain networks. Ma et al. (2013) regarded a supply chain in their study where demand is affected by retailer's marketing effort and manufacturer's quality effort. The paper discussed different kinds of contracts and concluded that the two-part tariff contract with both kinds of cost-sharing (marketing cost and quality cost) by the members of supply networks coordinates the members well and increases the total profit. Zhang et al. (2019) discussed two types of contracts, revenue-sharing and fixed fee contracts in platform-manufacturer setting and figured

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[34] Reported at https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/

[35] Reported at https://www.statista.com/statistics/534123/e-commerce-share-of-retail-sales-worldwide/

[36] Reported at https://www.statista.com/statistics/1112595/covid-19-impact-retail-e-commerce-site-traffic-global/

[37] Reported at https://www.statista.com/topics/871/online-shopping/#dossier-chapter1

that fixed fee contract leads to higher quality compared to revenue-sharing. Roger and Vasconcelos (2014) studied the moral hazard for two-sided platform in infinite horizon structure and found that registration fees along with transaction fees alleviate moral hazard. Ma et al. (2017) analyzed the optimal contract in presence of information asymmetry for supply chain where the manufacturer influences the demand by investing on corporate social responsibility. Mukhopadhyay et al. (2008) studied the contracting problem with information asymmetry for mixed networks where manufacturer not only sells through retailer but it also directly targets the consumer pool. Babich et al. (2012) explored the buyback contract problem with one supplier and one retailer who has private information about the state of demand.

Our discussion in this study emphasizes the contract design between a platform and a seller targeting the customer pool through intermediary platform where price per product that a consumer pays is influenced by seller's product quality and platform's service quality. Under complete information, a simple contract can help the platform to squeeze out all the first-best profit, giving seller only his/her reservation value. However, under information asymmetry the seller holds the private information about the cost for product quality. Optimal contract in presence of private information allows efficient seller to achieve higher profit than the reservation level at the cost of the platform. Most importantly, the one of the innovations of our study is the introduction of ad valorem tax rate in our model where the government levies per unit tax on price paid by consumer. Sensitivity analysis emphasizes the effect of tax on product quality, service quality and profit of the platform.

The contribution of our study is that we discuss a crucial topic regarding coordination problem between two agents of platform and derive the optimal choices for platform and seller for two most commonly adopted agreements, revenue-sharing and cost-sharing contracts, an issue that has not been received exhaustive and in-depth research attention in literature pertaining to online platforms. Our study contributes to the literature on contract design with the following results. The key finding obtained is that the optimal contract in presence of information asymmetry induces high type seller to supply product quality less than the first-best quality when service quality is endogenous. This result sets a major departure from the standard one-sided model which states the high type seller to provide first-best efficient quality in presence of information asymmetry. Additionally, the platform is required to supply lower level of service quality compared to first-best quality in presence of asymmetry. We find the other contract pair as well. Comparative static analysis shows the product quality, service quality and profit of the platform are negatively related to tax rate. We then compare the optimal values of contract variables for two different types of contracts and conclude that cost-sharing contract is more desirable as it induces higher level of product quality, service quality and platform's profit compared to revenue-sharing contract. A numerical analysis based on certain parameter values has been conducted to validate the analytical findings. Finally, we introduce advertising in our model and observe that platform uses more advertising signals in complete information case when it is certain about the type of the seller.

The rest of the study proceeds as follows. We establish the basic framework with two possible kinds of seller in Section 5.2. Section 5.3 explores two common forms of contract structure and examines the effect of tax on contract variables for both types of contract. Section 5.4 compares the findings obtained for two contracts. Section 5.5 introduces the effect of advertising in our analytical model. Ultimately, Section 5.6 draws the conclusion of the paper. Appendix includes proof of propositions and mathematical calculations.

5.2 The Model

Consider a digital marketplace with one intermediary platform and one seller. The seller produces a product with quality "q" at a unit cost of β and enters into a contract with the monopoly platform in order to sell the product to final consumer at a unit price P against a payment of a part of his/her revenue, α to platform. The seller gives a fraction of his/her revenue to platform to be able to trade on it. Moreover, the platform is providing services to all the buyers and the service quality of platform is represented by "s". The services offered by platform to buyers can be considered as a composite measure for daily service level settled by platform like return and refund policy, replacement policy, delivery speed etc. All these come under the category of platform's services. We assume, per unit price is a function of product quality, q and service quality, s; $P = f(q, s)$ and in particular, for simplicity of analysis, we specify the following constant elasticity functional form as:

$$P(q_i, s) = \gamma s q_i^{\lambda} \text{ where } 0 < \lambda < 1; \frac{\partial P}{\partial q_i} > 0; \frac{\partial^2 P}{\partial {q_i}^2} < 0 \tag{5.1}$$

This may be interpreted as consumers' willingness to pay per unit of product where γ signifies a parameter that relies on components not included in our framework and λ captures price elasticity measuring the responsiveness of the price of the product to its product quality. [38] In addition, we assume that government levies ad valorem tax, t on product price. Therefore, the net price per product sold that seller receives after imposition of tax is $(1 - t)P$. Studies by Kind, Koethenbuerger & Schjelderup (2008, 2009), Belleflamme & Toulemonde (2018), Bajo-Buenestado & Kinateder (2019) have dealt with the issues related to the effect of ad valorem taxes. Following these pioneering studies, we also emphasize the impact of ad valorem taxes on product quality, service quality and platform's profit.

The profit of the platform is influenced by the quality choice made by the seller. If choices are easily verifiable, the agreement between seller and platform would be pretty straightforward.

[38] In Section 5.5, the effect of advertising, "a" which influences the parameter γ, has been analysed on contract design.

However, when there is no way for platform to notice the seller's choices then a contract must be designed in a way that elicits seller to choose the right action. Depending on the unit cost for quality of product, two types of seller can exist: efficient seller and inefficient seller. An efficient seller can produce a product in a cost effective way than the inefficient seller and thus incurs lower unit cost for quality of product. Hereafter, we label the efficient seller as high (h) type and inefficient seller as low (l) type. Let, β_i be the unit cost for producing a product with quality q_i by the i^{th} type seller, $i \in (h, l)$. By our assumption, the h type seller produces the product by incurring lower unit quality cost compared to low type seller, thus $\beta_l > \beta_h$. Further we assume that, $Prob(\beta_h) = \phi \in (0,1)$. The seller aims to maximize his/her idiosyncratic expected profit and the profit per unit product sold, $\Pi^s(q, \alpha, \beta)$ depends on the realization of β which can only be verified after the contract is penned and that only seller observes. While the seller certainly knows its individual type, the platform possesses only a subjective evaluation about the occurrence of two possible states. In this form of setting, the platform whose objective is to maximize its expected profit (Π^p), proposes a menu of contract that induces the seller to truthfully declare its type through the selection of agreement from the menu. The platform proposes two sets of contract to seller, specified by (α_i, s) for each type i , $i \in (h, l)$ and optimally determines these two revenue fees together with service quality by maximizing its expected net profit. We answer this platform-seller problem as a game of principal-agent framework. The sequence of the game is as follows: First, the platform takes the lead by offering the menu of contracts to a seller of the particular type, i. Finally, seller chooses a particular contract along with the product quality and thus, type i is revealed through the selection of the contract from the menu.

Following Ma, Wang & Shang (2013), Tsao and Sheen (2012), Zhang et al. (2019), we examine two common forms of contract: Revenue-Sharing (RS) Contract and Cost-Sharing (CS)

Contract, however, with information asymmetry. We first formulate the contracting problem when β is observable and then discuss the analysis of the contract when seller only observes β for each type of contract.

5.3 Contract Design

5.3.1 Revenue Sharing (RS) Contract

We discuss the form of contract where seller shares a portion of his/her revenue with platform. Recall that the fraction of the revenue the seller pays is indexed here as α which is taken to be endogenous in our model. When the platform exerts services with "s" level of quality and seller of type i produces the product with quality q_i , profit of the seller "i" per product sold can be expressed as,

$$\Pi_i^s(q, \alpha, \beta) = (1 - \alpha_i)(1 - t)\gamma s q_i^\lambda - \frac{\beta_i q_i^2}{2}$$

The above expression indicates the net profit of the seller per product sold where seller of type i obtains $(1 - \alpha_i)$ fraction of his/her revenue after paying α_i to platform and $\frac{\beta_i q_i^2}{2}$ is the lump sum quadratic cost for producing a product with quality, q_i. [39]

5.3.1.1 When β is observable (First-best case)

5.3.1.1.1 Optimal Contracting Problem

A contract between platform and seller where both possess the complete knowledge of type of the seller can directly state revenue-sharing rate conditional on β. The expected profit of the platform can be described as,

$$\Pi^p = \phi \Pi_h^P(\alpha_h, q_h(\alpha_h, s), s) + (1 - \phi)\Pi_l^p(\alpha_l, q_l(\alpha_l, s), s)$$

[39] The assumption of quadratic cost function is in line with existing literature (Ma et al., 2013, 2017).

$$= \phi\left[\alpha_h(1-t)\gamma s(q_h(\alpha_h, s))^{\lambda} - \frac{s^2}{2}\right] + (1-\phi)\left[\alpha_l(1-t)\gamma s(q_l(\alpha_l, s))^{\lambda} - \frac{\eta s^2}{2}\right] \tag{5.2}$$

$$\text{where } \eta > 1$$

where the share of the revenue per product sold that platform receives from seller of type i is amounted to $[\alpha_i(1-t)\gamma s(q_i(.,.))^{\lambda}]$. Here, $q_i(\alpha_i, s)$ is decided by the i[th] seller. The platform incurs a lump sum quadratic cost for providing service quality. When inefficient seller supplies a product there remains a high possibility of return or replacement of the product. In which case the platform has to incur a higher service quality cost. So, we assume $\eta > 1$. The optimal problem of platform becomes,

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s} \qquad \Pi^p(\alpha_h, \alpha_l, s)$$

$$\text{Subject to} \quad IR_h: \quad \Pi_h^s = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} \geq 0 \tag{5.3a}$$

$$IR_l: \quad \Pi_l^s = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} \geq 0 \tag{5.3b}$$

Given the optimal quality chosen by the sellers (q_h^*, q_l^*), for any answer $(\alpha_h^*, \alpha_l^*, s^*)$ to the above optimization problem, reservation utility or individual rationality constraints must bind; or else the platform could higher its share of the revenue fee (α_i) and still compel the seller to accept the agreement. Thus, IR conditions imply that seller's profit is equalized across types and the profit is equal to the reservation profit in each state. Therefore, the platform's profit is maximized with respect to (α_h, α_l, s) given that the individual rationality constraint for each type is satisfied, and we obtain,

$$s_R^* = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}} + (1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}, \quad \alpha_{h_R}^* = \left(1-\frac{\lambda}{2}\right), \quad \alpha_{l_R}^* = \left(1-\frac{\lambda}{2}\right)$$

Hence, optimal quality levels chosen by sellers are,

$$q_{h_R}^* = \left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}} \quad \&$$

$$q_{l_R}^* = \left(\frac{(1-t)\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}$$

Thus we derive the profit maximizing level of service quality, s_R^*, revenue-sharing fees, $\alpha_{h_R}^*, \alpha_{l_R}^*$ and product quality choices for two types of seller when the platform has full information regarding the type of seller.

In the optimum $q_{h_R}^* > q_{l_R}^*$ must satisfy which gives us the result similar to the contract problem in one-sided market. [40] The type specific equilibrium requires for cost-efficient h-type seller to exert higher product quality than the l-type as unit cost for effort is lower for type h than l-type. Both types of sellers share same amount of revenue with platform. The first-best results can be taken as benchmark since this serves as ideal scenario with full observable situation.

40 $$\frac{q_{h_R}^*}{q_{l_R}^*} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}}{\left(\frac{(1-t)\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}} = \frac{\left(\frac{1}{\beta_h}\right)^{\frac{1}{2-\lambda}}}{\left(\frac{1}{\beta_l}\right)^{\frac{1}{2-\lambda}}} > 1$$

5.3.1.2 When β is not observable by platform (Second-best case)

5.3.1.2.1 Optimal Contracting Problem

In this subsection, we consider the case where platform cannot differentiate the type of seller. If platform proposes an agreement similar to the first-best case in presence of information asymmetries and believes that a seller will truly reveal its type, then the platform will face misfortune (Mas-Colell et al., 1995). Since the seller of type h will end up choosing the contract intended for cost-inefficient seller.[41] So seller of type h does not reveal his/her true type and prefers the contract assigned to l type seller when information asymmetry is present. In that case the platform must form a contract in a way that elicit seller to reveal his/her true type voluntarily. For this purpose, the platform trusts on the revelation principle (Myerson, 1979), which ensures that the seller reveals his/her true type "i" by choosing the contract designed for his/her type since by doing so, he/she will earn higher profit. Therefore, the revelation principle guarantees that the announced type of the seller is his/her true type. The essence of revelation principle with its truthful revelation property is captured by introducing the Incentive Compatibility Constraint (IC) in our model which assures a seller chooses the particular contract assigned to his/her true type. Hence an additional constraint, IC for each type of seller along with IR constraint has been introduced for the model with information asymmetries. We now formulate the platform's problem. The characterization of platform's problem which is to maximize its expected profit subject to IR and IC constraints is outlined as,

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s} \quad \Pi^p = \phi\left[\alpha_h(1-t)\gamma s q_h^{\lambda} - \frac{s^2}{2}\right] + (1-\phi)\left[\alpha_l(1-t)\gamma s q_l^{\lambda} - \frac{\eta s^2}{2}\right] \tag{5.4}$$

Subject to $\quad IR_h: \quad \Pi_h^s = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} \geq 0 \qquad$ (5.5a)

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[41] $\Pi_h^s = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2} = \frac{\beta_l q_l^2}{2} - \frac{\beta_h q_l^2}{2} = \frac{q_l^2}{2}(\beta_l - \beta_h) > 0$

$$\mathrm{IR_l}: \quad \Pi_l^s = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} \geq 0 \tag{5.5b}$$

$$\mathrm{IC_h}: \quad (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} \geq (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2} \tag{5.5c}$$

$$\mathrm{IC_l}: \quad (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} \geq (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_l q_h^2}{2} \tag{5.5d}$$

Constraints (5.5a) and (5.5b) that represent the individual rationality or participation constraints for the seller of type h and l respectively indicate a seller of type i must receive his/her reservation profit if he accepts the contract. Constraints (5.5c) and (5.5d) which constitute the incentive compatibility (IC) or truth-telling constraints for type h and l seller respectively induce the seller to select that particular contract menu entitled to his/her true state. Let us consider constraint $\mathrm{IC_h}$ in (5.5c). Seller of type h will obtain a profit of $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2}$ if he reveals his true type, but it is $(1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2}$ if he instead declares his type to be “l”. Thus he reveals his true type if $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} \geq (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2}$. Constraint represented by (5.5d) follows the similar ground. Note that full information contract is not incentive compatible as it does not satisfy the constraint (5.5c). We begin to solve the platform’s optimization problem by identifying the above four constraints in its contract problem. In the process of identification of constraints, we lay down two claims which will be crucial for solving the optimization problem. First, the following claim shows that constraints $\mathrm{IR_l}$ and $\mathrm{IC_h}$ indicate the constraint $\mathrm{IR_h}$, hence the optimal problem of platform can be answered by dropping the constraint (5.5a).

Claim 1: If $\mathrm{IR_l}$ and $\mathrm{IC_h}$ are binding then $\mathrm{IR_h}$ is satisfied and non-binding. Thus the constraint $\mathrm{IR_h}$ can be ignored while solving the optimization problem.

Therefore the set of optimal contracts obtained by ignoring the constraint IR_h in the optimization problem will yield identical menu of contracts derived by taking into account all the constraints. The next claim indicates that the constraint IC_l is redundant as well in interpreting the optimal contracting problem (specified in (5.4)).

Claim 2: If IC_h is binding then IC_l is satisfied and non-binding. [42]

Thus we proceed to answer the optimization problem by ignoring the two constraints IR_h and IC_l as indicated by the above two claims. The reduced optimization problem of the platform which becomes maximization of expected profit subject to the constraints IR_l and IC_h is described as follows,

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s} \quad \Pi^p = \phi\left[\alpha_h(1-t)\gamma s(q_h(\alpha_h,s))^{\lambda} - \frac{s^2}{2}\right] + (1-\phi)\left[\alpha_l(1-t)\gamma s(q_l(\alpha_l,s))^{\lambda} - \frac{\eta s^2}{2}\right] \quad (5.4)$$

Subject to $\quad IR_l: \quad \Pi_l^s = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} = 0 \quad (5.5b)$

$$IC_h: \quad (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2} \quad (5.5c)$$

where $q_i(\alpha_i, s)$ is determined by the seller through the truthful revelation of his/her type captured through its IC. The optimal decision of the above optimization problem is,

$$s_R' = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}} + (1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$$

[42] The mathematical proofs of two claims are in the Appendix 5.A.

$$q_{h}{}'_{R} = \left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}$$

$$q_{l}{}'_{R} = \left(\frac{(1-\phi)(1-t)\gamma\lambda}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}$$

$$\alpha_{h}{}'_{R} = 1-\frac{\lambda}{2}-\frac{\lambda(\beta_l-\beta_h)(\beta_h)^{\frac{\lambda}{2-\lambda}}}{2}\left(\frac{1-\phi}{(\beta_l-\phi\beta_h)}\right)^{\frac{2}{2-\lambda}} \quad ; \quad \alpha_{l}{}'_{R} = 1-\frac{\beta_l\lambda(1-\phi)}{2(\beta_l-\phi\beta_h)}$$

The equilibrium contract dependent on type still induces h-type seller to exert higher product quality than the l-type as unit cost for quality is lower for type h than l-type. Thus the equilibrium quality-fee bundle for high type comprises of higher product quality and lower revenue-sharing fee relative to the bundle for low type.[43] The intuition is that a cost-effective seller (here, h type) will give a lower proportion of its revenue to platform and exert higher product quality and therefore, can expect a higher price per product sold. All these forces in turn contribute to earn higher profits by both the platform and the seller. This is a crucial insight

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[43] $$\frac{q_{h}{}'_{R}}{q_{l}{}'_{R}} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}}{\left(\frac{(1-\phi)(1-t)\gamma\lambda}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}} \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}} = \frac{\left(\frac{1}{\beta_h}\right)^{\frac{1}{2-\lambda}}}{\left(\frac{(1-\phi)}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}}} > 1 \quad \text{when } \frac{\beta_l}{\beta_h} > 1$$

Moreover, $(\alpha_{l}{}'_{R} - \alpha_{h}{}'_{R}) = 1-\frac{\beta_l\lambda(1-\phi)}{2(\beta_l-\phi\beta_h)} - 1 + \frac{\lambda}{2} + \frac{(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^{\lambda}} = \frac{\lambda}{2}\left(1-\frac{\beta_l(1-\phi)}{(\beta_l-\phi\beta_h)}\right) + \frac{(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^{\lambda}} > 0$

of our study. To complete our investigation on two state framework under RS contract, we examine that both the constraints IR_h and IC_l which are dropped in analyzing the optimal contract pairs, are satisfied by the optimal values of contract variables. [44]

5.3.1.3 Comparing two regimes under revenue-sharing model

In this subsection, we compare the results obtained under two regimes of RS contract. We validate the theoretical findings by employing a numerical study. To conduct the numerical analysis, we assume the parameter values as: $\beta_l = 2$, $\beta_h = 1$, $\phi = 0.5$, $\lambda = 0.3$, $\gamma = 1$, $\eta = 2$, $\theta = 0.6$. We employ these values to study the comparative findings of two cases.

In the presence of complete information, the platform can exactly know the type of the seller and it can offer the exact contract (α_i, s) if it believes the seller to be of type "i". In that case the platform can extract all its first-best profit for itself using a simple contract, leaving the seller to have the reservation profit. In case of hidden information two state structure, binding IR_l constraint indicates the l type seller will earn no additional profit over his reservation profit (that is, $\Pi_l^s = 0$). However, the fact that IR_h is satisfied and non-binding, signifies that the h type seller will realize additional profit greater than his reservation profit (that is, $\Pi_h^s > 0$). The expected profit earned by h type seller, defined as $\phi\Pi_h^s$, which is also known as information rent, is strictly greater than his reservation profit and the platform requires to pay this expected rent to h type seller to obtain the hidden information regarding the type. The information rent, in our model, is precisely obtained as $\phi\frac{(\beta_l-\beta_h)q_l^2}{2}$. Thus, with asymmetric information, the platform fails to derive all the first-best profit (that is $\Pi_{PR}^* > \Pi_{PR}'$) because of the information rent which helps the high type seller to achieve higher surplus more than the reservation profit. Figure 5.1 presents the graphical illustration of the relationship between tax and profit level of

[44] See Appendix 5.B.

the platform under two regimes of RS contract obtained by conducting a numerical analysis with the parameter values: $\beta_l = 2$, $\beta_h = 1$, $\phi = 0.5$, $\lambda = 0.3$, $\gamma = 1$, $\eta = 2$, $\theta = 0.6$. The straight lines AB and CD represent the profit level of the platform for first-best and second-best model respectively. We observe the line AB lies above the line CD for any particular value of tax. Thus the profit level achieved by platform with full information, Π^*_{PR} is higher than the profit attained with information asymmetry,Π'_{PR} for the same level of tax rate.

Figure 5.1: Comparing profit of platform between two regimes under RS contract

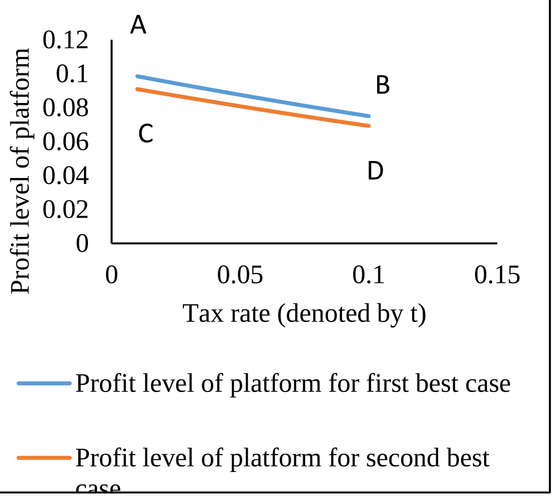


Figure 5.2: Comparing service quality under two regimes of RS contract

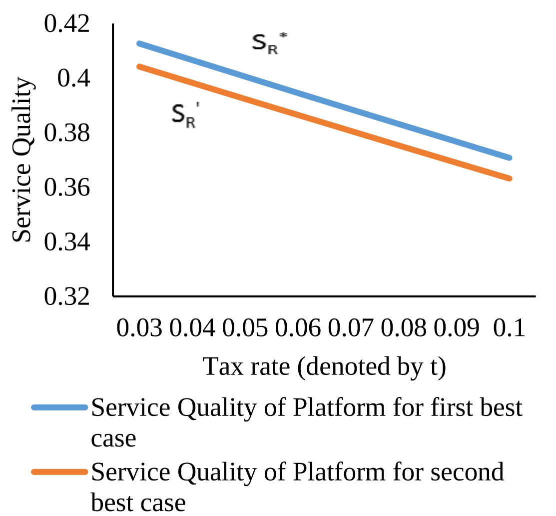


Figure 5.3: Comparing product quality of high type seller under RS contract

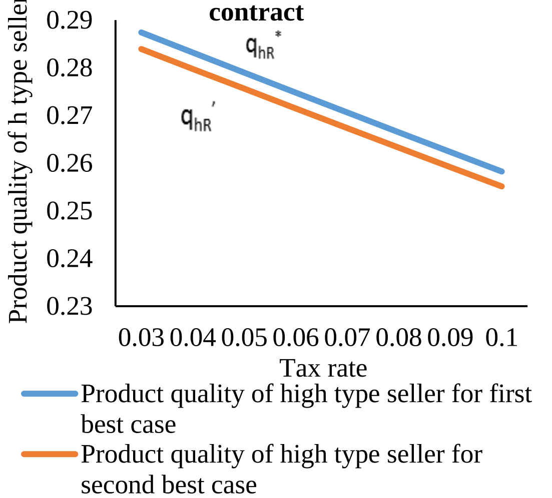
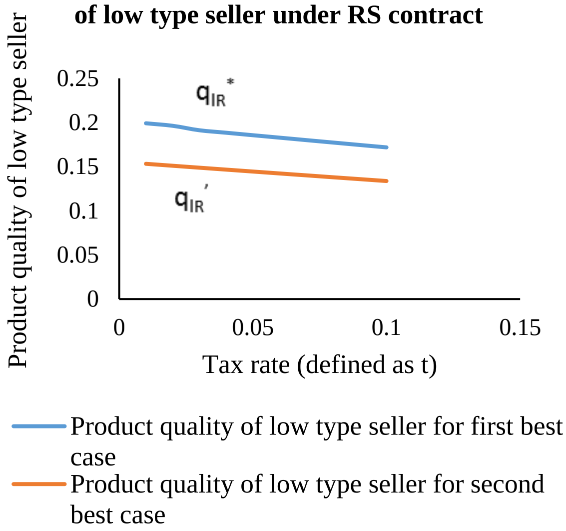


Figure 5.4: Comparing product quality of low type seller under RS contract



Source: Authors' own calculations

With platform has to spend the information rent in presence of information asymmetry, it invests less on service quality than in the first-best regime. Thus, we obtain a strictly lower level of service quality when platform is uncertain about the type of seller. Therefore, $s_R^* > s_R'$. Figure 5.2 displays the negative relationship between tax rate and service quality of platform. The curve, S_R^* depicting the service quality level with full information case lies above the service quality curve, S_R' under incomplete information case. Therefore, platform shows better service performance under complete information regime than under the information asymmetry case.

We find an interesting observation regarding the quality of the product sold. If service quality is exogenously given, then the high type seller is provided with the efficient first-best product quality and the optimum bundle for low type seller contains less quality in presence of information asymmetry than under complete information. Thus the results derived with exogenous service quality are similar to the one-sided market outcomes. However, when we make the service quality endogenous to the system, the findings get altered. With endogenous service quality, the profit maximizing level of product quality for h type seller is strictly smaller under incomplete information case than in first-best regime, i.e., $q_{h_R}^* > q_{h_R}'$. So, we observe a major deviation in incomplete information model with endogenous service quality from the results obtained under standard one-sided model. The interpretation of this result is simple. We notice the product quality of each type of seller is an increasing function of service quality. Since when platform improves the service performance, the price per unit of product increases, thereby increasing the revenue of the seller. This will act as an incentive for seller for upgrading the product quality. Thus when platform sets service quality lower under incomplete information model, it will motivate high type seller to downgrade the product quality compared to full information case. The optimum bundle for h type seller comprises less quality and less revenue fee paid to platform and for low type seller, the equilibrium bundle consists of less quality and more revenue payment than first-best bundle. To mitigate the cost of asymmetric information and to obtain the hidden information, the contract requires the h type seller to pay lower revenue share to platform and supply lower quality. By employing the identical parameter values: $\beta_l = 2$, $\beta_h = 1$, $\phi = 0.5$, $\lambda = 0.3$, $\gamma = 1$, $\eta = 2$, $\theta = 0.6$, we compare the product quality levels supplied by high type and low type seller under two regimes respectively in Figures 5.3 and 5.4. It is evident that both types of seller provide superior quality products when there is no hidden information. The next proposition outlines the results obtained by comparing the two regimes under RS agreement. The calculations are provided in Appendix 5.C.

Proposition 1 *In information asymmetric (i.e., when the platform fails to identify a seller of type "i") two state framework with one intermediary platform, the optimal type contingent equilibrium sets the product qualities for both type of sellers below the first-best amount (i.e.,* ${q_h}^*_R > {q_h}'_R$ *&* ${q_l}^*_R > {q_l}'_R$ *) and service quality is settled lower than the first-best service quality level as well. Additionally, the seller gains a surplus in excess of the reservation profit if* $\beta = \beta_h$ *and no additional surplus if* $\beta = \beta_l$*. Since the platform bears the cost of hidden information in the form of information rent, the expected second-best platform's profit is strictly lesser than the first-best profit achieved when type being full observable.*

A fundamental and most important point that arises from our study is that the optimal product quality for each type of seller and service quality of platform in the second-best framework are necessarily distorted from the full observable level.

5.3.2 Cost Sharing (CS) Contract

We analyze a CS model where seller not only offers a portion of his revenue to platform but platform also shares a fraction of product quality cost of seller. [45] The fraction of product quality cost that the seller bears is indexed as θ while the platform shares the remaining fraction, $(1-\theta)$ of the cost. Following Ma, Wang & Shang (2013), Tsao and Sheen (2012) we also assume that θ is exogenously given. The profit of the seller of type "i" is expressed as,

$$\Pi_i^s(q,\alpha,\beta) = (1-\alpha_i)(1-t)\gamma s q_i^{\lambda} - \frac{\theta\beta_i q_i^2}{2}$$

The seller retains $(1-\alpha_i)$ proportion of the revenue and bears θ fraction of lump sum cost for producing the product with quality "q".

5.3.2.1 When β is observable (First-Best Case)

5.3.2.1.1 Optimal Contracting Problem

Under full information, the platform knows the specific type of seller and thus it proposes the definite contract allotted to the specific type. The platform's optimal contract problem is illustrated as,

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s} \quad \Pi^p = \phi\Pi_h^p(\alpha_h, q_h, s) + (1-\phi)\Pi_l^p(\alpha_l, q_l, s)$$

$$= \phi\left[\alpha_h(1-t)\gamma s q_h^{\lambda} - \frac{s^2}{2} - \frac{(1-\theta)\beta_h q_h^2}{2}\right] + (1-\phi)\left[\alpha_l(1-t)\gamma s q_l^{\lambda} - \frac{\eta s^2}{2} - \frac{(1-\theta)\beta_l q_l^2}{2}\right]$$

(5.6)

Subject to IR_h: $\quad \Pi_h^s = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\theta\beta_h q_h^2}{2} \geq 0 \qquad (5.7a)$

[45] Cost-sharing contract is very much popular in reality when an intermediary is more inclined to trade eco-friendly products through its platform and thus by sharing product quality cost, it actually offers incentive to sales-agent to sell environmentally-safe products.

$$\text{IR}_l: \quad \Pi_l^s = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\theta\beta_l q_l^2}{2} \geq 0 \tag{5.7b}$$

The equation (5.6) describes the expected profit of the platform under complete information model of CS contract. As discussed earlier, the platform in this case not only receives α portion of revenue from seller but incurs $(1-\theta)$ fraction of product quality cost as well. Additionally we assume $\eta > 1$ as platform needs to bear higher cost for providing services when low type seller supplies a product to consumer. We already know for any result $(\alpha_h^*, q_h^*, \alpha_l^*, q_l^*, s^*)$ to the above contracting problem, IR constraints must bind. Thus from the conditions that both IR_h and IR_l are equal to reservation profit (we normalize the reservation profit for each type to be zero), the optimal platform problem becomes,

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s} \qquad \Pi^p = \phi\Pi_h^P(\alpha_h, q_h(\alpha_h, s), s) + (1-\phi)\Pi_l^p(\alpha_l, q_l(\alpha_l, s), s)$$

We obtain profit maximizing level of service quality, s_C^* and product quality choices of both types of seller under information symmetry model as,

$$s_C^* = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}} + (1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}, \quad {\alpha_h}_C^* = \left(1-\frac{\theta\lambda}{2}\right), \quad {\alpha_l}_C^* = \left(1-\frac{\theta\lambda}{2}\right)$$

$${q_h}_C^* = \left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}} + (1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}} \quad \&$$

$${q_l}_C^* = \left(\frac{(1-t)\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}} + (1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}$$

The equilibrium bundle for high type seller under full information symmetry case of CS agreement comprises higher product quality and same amount of revenue-sharing rate compared to the bundle for low type.

5.3.2.2 When β is not observable by platform (Second-best case)

5.3.2.2.1 Optimal Contracting Problem

In this subsection, we interpret the optimal contract for the case where the platform cannot exactly know the type of the seller. As explained earlier for the case of RS contract, the high type seller may imitate the low type as he has an incentive to choose the contract pair designated to the low type seller. Thus a contract should be designed in a way that compel seller to truthfully reveal his true type when information asymmetry is present. We now formalize the platform's problem which is to maximize its own profit subject to the IR and IC constraints.

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s} \quad \Pi^p = \phi\left[\alpha_h(1-t)\gamma s q_h^\lambda - \frac{s^2}{2} - \frac{(1-\theta)\beta_h q_h^2}{2}\right] + (1-\phi)\left[\alpha_l(1-t)\gamma s q_l^\lambda - \frac{\eta s^2}{2} - \frac{(1-\theta)\beta_l q_l^2}{2}\right] \tag{5.8}$$

Subject to

$$IR_h: \quad \Pi_h^s = (1-\alpha_h)(1-t)\gamma s q_h^\lambda - \frac{\theta\beta_h q_h^2}{2} \geq 0 \tag{5.9a}$$

$$IR_l: \quad \Pi_l^s = (1-\alpha_l)(1-t)\gamma s q_l^\lambda - \frac{\theta\beta_l q_l^2}{2} \geq 0 \tag{5.9b}$$

$$IC_h: \quad (1-\alpha_h)(1-t)\gamma s q_h^\lambda - \frac{\theta\beta_h q_h^2}{2} \geq (1-\alpha_l)(1-t)\gamma s q_l^\lambda - \frac{\theta\beta_h q_l^2}{2} \tag{5.9c}$$

$$IC_l: \quad (1-\alpha_l)(1-t)\gamma s q_l^\lambda - \frac{\theta\beta_l q_l^2}{2} \geq (1-\alpha_h)(1-t)\gamma s q_h^\lambda - \frac{\theta\beta_l q_h^2}{2} \tag{5.9d}$$

The equations (5.9a) & (5.9b) represent the individual rationality constraints and (5.9c) & (5.9d) indicate the incentive compatibility constraints for high and low type seller respectively. We already observe the constraints IR_h and IC_l are not essential to find the optimal contract. Thus we begin our analysis by only considering constraints IR_l and IC_h and abandoning constraints IR_h and IC_l. The satisfaction of the constraints IR_h and IC_l will be verified in the end after obtaining the values of contract variables. Hence the modified platform's problem can be expressed as,

$$\underbrace{\text{Max}}_{\alpha_h,\alpha_l,s}\ \Pi^p = \phi\left[\alpha_h(1-t)\gamma s(q_h(\alpha_h,s))^{\lambda} - \frac{s^2}{2} - \frac{(1-\theta)\beta_h(q_h(\alpha_h,s))^2}{2}\right] + (1-\phi)\left[\alpha_l(1-t)\gamma s(q_l(\alpha_l,s))^{\lambda} - \frac{\eta s^2}{2} - \frac{(1-\theta)\beta_l(q_l(\alpha_l,s))^2}{2}\right] \quad (5.10)$$

Subject to IR_l: $\Pi_l^s = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\theta\beta_l q_l^2}{2} \geq 0$ (5.11a)

IC_h: $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\theta\beta_h q_h^2}{2} \geq (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\theta\beta_h q_l^2}{2}$ (5.11b)

The optimal solution of the above optimization problem can be expressed as $(s'_C, {\alpha_h}'_C, {\alpha_l}'_C, {q_h}'_c, {q_l}'_c)$, where

$$s'_C = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$$

$${q_h}'_c = \left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}$$

$${q_l}'_c = \left(\frac{(1-\phi)(1-t)\gamma\lambda}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{1}{2-\lambda}}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}$$

$${\alpha_h}'_C = 1 - \frac{\theta\lambda}{2} - \frac{\theta\lambda(\beta_l-\beta_h)\beta_h^{\frac{\lambda}{2-\lambda}}}{2}\left(\frac{1-\phi}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{2}{2-\lambda}} \;;\; {\alpha_l}'_C = 1 - \frac{\beta_l\lambda\theta(1-\phi)}{2(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}$$

The equilibrium bundle for high type comprises higher product quality and lower revenue-sharing fee relative to the bundle for low type.[46] We then verify that both the constraints $\mathrm{IR_h}$ and $\mathrm{IC_l}$ which are not considered in analyzing the optimal contract, are fulfilled by the optimal values of contract variables. [47]

We examine the contract values (α_i, s) under cost-sharing contract and produce the effect of change of the cost-sharing parameter, θ on contract variables. Platform's service quality and product quality of each seller fall unambiguously with the cost-sharing fraction of seller, θ $\left(\frac{\partial s_C'}{\partial \theta} < 0, \frac{\partial q_{h_C}'}{\partial \theta} < 0, \frac{\partial q_{l_C}'}{\partial \theta} < 0\right)$. When the seller bears a greater share of cost of product quality (as θ rises), his/her level of product quality provision becomes lower and this in turn reduces the price per product and thus the revenue of the seller. Lower revenue of seller generating through the higher θ adversely affects the platform's level of service quality as well. The numerical analysis with $\beta_l = 2,\ \beta_h = 1,\ \phi = 0.5,\ \lambda = 0.3,\ \gamma = 1,\ \eta = 2,\ t = 0.1,\ \theta \in [0.01, 0.95]$ validates the findings of falling level of service quality and product quality with θ under cost-sharing asymmetric contract design.

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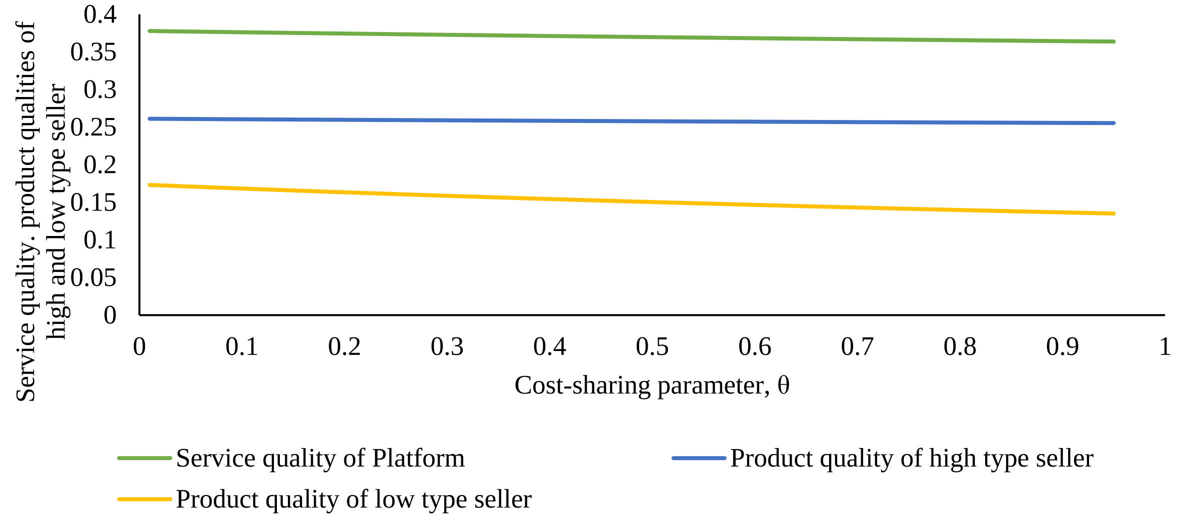
46 $$\frac{q_{h_C}'}{q_{l_C}'} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}}{\left(\frac{(1-\phi)(1-t)\gamma\lambda}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{1}{2-\lambda}}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{2(1-\lambda)}}} = \frac{\left(\frac{1}{\beta_h}\right)^{\frac{1}{2-\lambda}}}{\left(\frac{(1-\phi)}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{1}{2-\lambda}}} > 1$$

Moreover, $(\alpha_{l_C}' - \alpha_{h_C}') = \frac{\lambda\theta}{2}\left(1 - \frac{\beta_l(1-\phi)}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right) + \frac{\theta(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^{\lambda}} > 0$

47 See Appendix 5.D.

Figure 5.5: The effect of cost-sharing parameter on model variables under CS contract with asymmetry



Source: Authors' own calculation

5.3.2.3 Comparing two regimes under cost-sharing contract

In this subsection, we present the comparison between the two regimes under CS contract by performing a numerical analysis with parameter values $\beta_l = 2, \beta_h = 1, \phi = 0.5, \lambda = 0.3, \gamma = 1, \eta = 2, \theta = 0.6$. In the case of incomplete information, platform carries the cost of hidden information in the form of information rent which has to be paid to high type seller in order to reveal his/her true type. Thus platform fails to achieve the first-best profit in presence of information asymmetry and second-best profit is strictly lower than the profit obtained with complete information. Figure 5.6 depicts the profit of the platform under two regimes. The straight lines A'B' and C'D' represent the profit line of platform for full information and incomplete information respectively. We find, $\frac{d\Pi^*_{PC}}{dt} < 0$, $\frac{d\Pi'_{PC}}{dt} < 0$. It is evident from the diagram that the platform obtains lower level of profit under incomplete information case, Π'_{PC} than under first-best case, Π^*_{PC}.

Figure 5.6: Comparing profit of the platform under CS contract

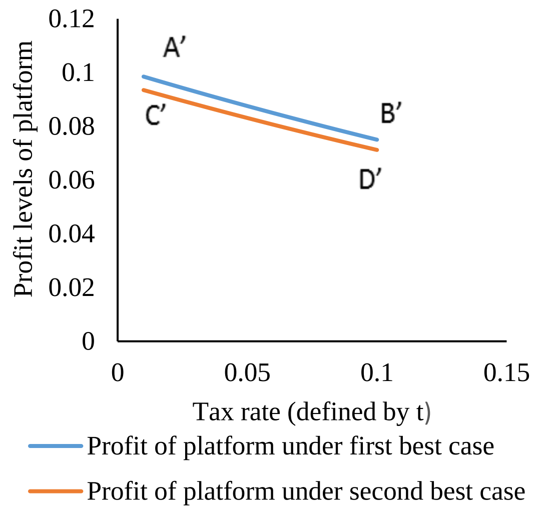


Figure 5.7: Comparing service quality under CS contract

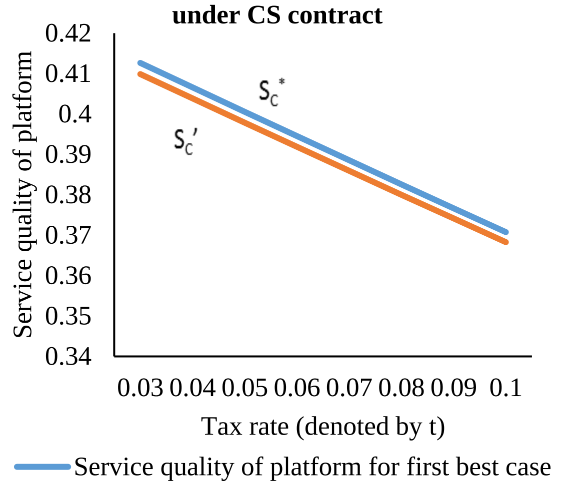


Figure 5.8: Comparing product quality of high type seller under CS contract

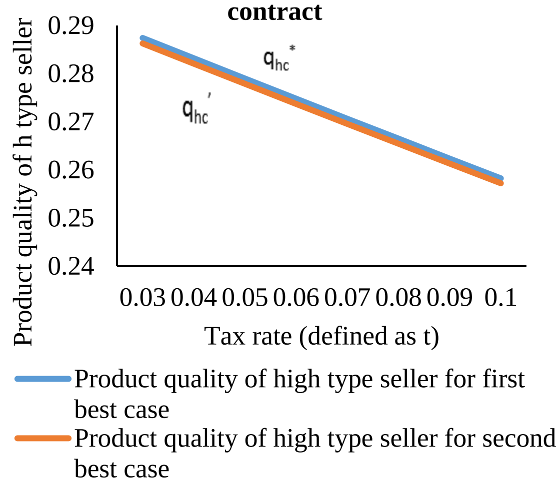
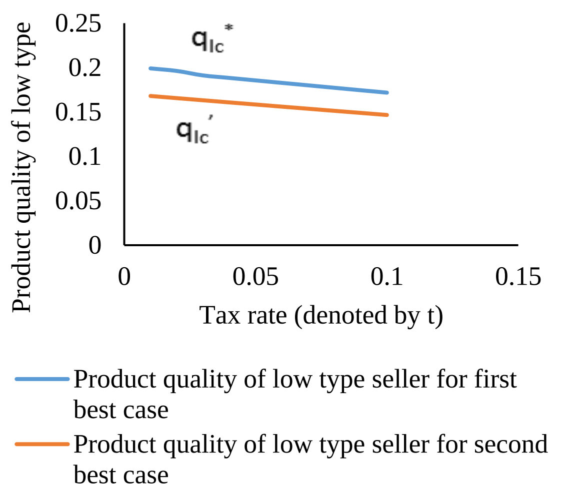


Figure 5.9: Comparing product quality of low type seller under CS contract



Source: Authors' own calculations

Since the platform has to forgo a part of its profit to acquire the hidden information regarding the true type of the seller under incomplete information case, it chooses to invest less on service quality and that's why service quality with asymmetric information (s_C') is lower than the first-best quality (s_C^*). Thus, $s_C^* > s_C'$. Figure 5.7 displays two curves, S_C^* and S_C' indicating the level of service quality under complete & incomplete information respectively. It shows that platform provides higher level of service quality with no hidden information than in the case of incomplete information.

A result identical with one-sided market has been derived in incomplete information model of online platform when service quality is exogenously specified (say, $s = \bar{s}$) . In which case, the optimal level of product quality for each type of seller under second-best contract is set at, ${q_h}'_{C|s=\bar{s}} = \left(\frac{(1-t)\gamma\lambda\bar{s}}{\beta_h}\right)^{\frac{1}{2-\lambda}}$ & ${q_l}'_{C|s=\bar{s}} = \left(\frac{(1-\phi)(1-t)\gamma\lambda\bar{s}}{[\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l]}\right)^{\frac{1}{2-\lambda}}$. Evidently, ${q_h}'_{C|s=\bar{s}} = \left(\frac{(1-t)\gamma\lambda\bar{s}}{\beta_h}\right)^{\frac{1}{2-\lambda}} = {q_h}^*_{C|s=\bar{s}}$; ${q_l}'_{C|s=\bar{s}} = \left(\frac{(1-\phi)(1-t)\gamma\lambda\bar{s}}{[\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l]}\right)^{\frac{1}{2-\lambda}} < \left(\frac{(1-t)\gamma\lambda\bar{s}}{\beta_l}\right)^{\frac{1}{2-\lambda}} = {q_l}^*_{C_{|s=\bar{s}}}$. Thus, the high type seller is required to supply the optimum first-best level and low type seller supplies lower level of product quality with incomplete information compared to the first-best regime when service quality is exogenously given. However, the outcomes modify when we allow quality of service to vary in our model. With endogenous level of service quality, optimum level of product quality for h type seller under information asymmetry is significantly lower than the first-best quality. So, we notice a significant departure under information asymmetry regime from one sided market outcome. The equilibrium contract-pair for h type seller contains lower product quality and lower revenue payment to platform than the first-best outcome and l type seller is required to provide smaller level of product quality and higher amount of revenue to platform in case of incomplete information. We present the graphical illustration of comparative results in figures 5.8 and 5.9.

We see from the figures that product quality for each type of seller diminishes with tax rate. Both the figures show that each type of seller provides higher level of product quality in full information regime than the information asymmetry case. Thus, ${q_h}^*_C > {q_h}'_C$ & ${q_l}^*_C > {q_l}'_C$. All the comparative results described above have been summarized in the next proposition and all the relevant calculations are given in the Appendix 5.E.

Proposition 2 *In case of cost-sharing agreement, optimal contract equilibrium in presence of information asymmetry requires each type of seller to provide lower level of product quality* *than the full observable level (i.e., ${q_h}_C^* > {q_h}_C'$ & ${q_l}_C^* > {q_l}_C'$) and the service quality of platform is also set below the first-best quality ($s_C^* > s_C'$). Both the product quality of each type of seller and service quality of platform in presence of incomplete information downgrade from the first-best level. Platform realizes lower level of profit in presence of the hidden information than with full information ($\Pi_{PC}^* > \Pi_{PC}'$).*

5.3.3 Sensitivity Analysis: Revenue-sharing and Cost-sharing Contracts

Let us now find the effect of tax on service quality, product quality and profit of platform for both the revenue-sharing and cost-sharing contracts. Proposition 3 outlines the results obtained using comparative static exercise. Proofs are given in Appendix 5.F.

Proposition 3

(i) *The product quality supplied by each type of seller deteriorates as ad valorem tax on product price rises under each information regime of both contracts.*

(ii) *The optimum service quality falls unambiguously as tax on product price increases.*

(iii) *The equilibrium level of profit of the platform decreases with tax imposed on product price.*

The intuition behind Proposition 3 is pretty straightforward. As ad valorem tax increases, the seller who receives $(1 - \mathrm{t})\mathrm{P}$ per product sold after imposition of tax, obtains lower level of revenue per product. Fall in revenue works as disincentive for upgrading product quality for either type of seller and thus he invests less on improving product quality.

With revenue reduces with tax rate, seller now transfers lower level of his/her revenue to platform. Thus platform spends less on improving its service performance in each regime. Moreover, lower revenue earned per product by seller with rise in tax leads to lower payment of revenue to platform which in turn reduces the profit of the platform. The result for each information regime for either form of contract is summarized in Table 5.1.

Figure 5.1 and 5.6 present the graphical illustration of the relationship between tax and profit level of platform under two regimes of RS and CS contracts respectively. Both figures support the theoretical finding of negative association between tax and profit of platform as profit lines fall with tax rate. Figure 5.2 and 5.7 display the negative relationship between tax rate and service quality of platform under two contract regimes. Both the figures 5.3 and 5.4 validate the negative association between tax and product quality of each seller type diagrammatically and figures 5.8, 5.9 establish that product qualities vary adversely with tax rate.

Table 5.1: Summary of Results under Sensitivity Analysis

Information Regime \ Contract Type		Revenue Sharing Contract	Cost Sharing Contract
Information symmetry	$\frac{\partial s^*}{\partial t}$	$-\frac{(1-t)^{\frac{\lambda}{1-\lambda}}}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$	$-\frac{(1-t)^{\frac{\lambda}{1-\lambda}}}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$
	$\frac{\partial q_h}{\partial t}$	$-\frac{s^{*\frac{1}{2-\lambda}}}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}-(1-t)^{\frac{1}{2-\lambda}}s^{*-1}\frac{ds^*}{dt}\right]$	$-\frac{s^{*\frac{1}{2-\lambda}}}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}-(1-t)^{\frac{1}{2-\lambda}}s^{*-1}\frac{ds^*}{dt}\right]$
	$\frac{\partial q_l}{\partial t}$	$-\frac{s^{*\frac{1}{2-\lambda}}}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}\left[(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}-(1-t)^{\frac{1}{2-\lambda}}s^{*-1}\frac{ds^*}{dt}\right]$	$-\frac{s^{*\frac{1}{2-\lambda}}}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}\left[(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}-(1-t)^{\frac{1}{2-\lambda}}s^{*-1}\frac{ds^*}{dt}\right]$
	$\frac{\partial \pi_p}{\partial t}$	$-\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}}$	$-\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}}$
Information asymmetry	$\frac{\partial s'}{\partial t}$	$-\frac{(1-t)^{\frac{\lambda}{1-\lambda}}}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$	$-\frac{(1-t)^{\frac{\lambda}{1-\lambda}}}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$
	$\frac{\partial q_h}{\partial t}$	$-\frac{s'^{\frac{1}{2-\lambda}}}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}-(1-t)^{\frac{1}{2-\lambda}}s'^{-1}\frac{ds'}{dt}\right]$	$-\frac{s'^{\frac{1}{2-\lambda}}}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}-(1-t)^{\frac{1}{2-\lambda}}s'^{-1}\frac{ds'}{dt}\right]$
	$\frac{\partial q_l}{\partial t}$	$-\frac{\left(\frac{(1-\phi)\gamma\lambda s'(1-t)}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}}}{2-\lambda}\left[(1-t)^{-1}-s'^{-1}\frac{ds'}{dt}\right]$	$-\frac{\left(\frac{(1-\phi)\gamma\lambda(1-t)s'}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{1}{2-\lambda}}}{2-\lambda}\left[(1-t)^{-1}-s'^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds'}{dt}\right]$
	$\frac{\partial \pi_p}{\partial t}$	$-\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}}$	$-\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}}$

Source: Authors' own calculations

5.4 Comparison between revenue-sharing and cost-sharing contracts

We note that optimal product quality provided by each type of seller and service quality of platform are greater for CS contract compared to the RS agreement in presence of information asymmetry. Thus, ${q_h}'_C > {q_h}'_R$, ${q_l}'_C > {q_l}'_R$ & $s'_C > s'_R$. Moreover, the platform attains higher profit in cost-sharing contract compared to revenue-sharing under incomplete information model, $\Pi'_{PC} > \Pi'_{PR}$. Here we formulate our Proposition 4. Proofs are simply derived using the earlier findings, thus omitted.

Proposition 4: *Cost-sharing contract pronounces each type of seller to provide higher product quality and platform to offer better services than revenue-sharing agreement in presence of incomplete information.*

A remarkable result observed in Proposition 4 reveals that platform and each type of seller under RS contract actually underinvests on quality relative to CS contract in presence of information asymmetry. Moreover, by persuading the seller to accept CS contract, platform earns higher profit compared to RS contract. It may be possible that information asymmetry is mitigated to some extent in CS contract when platform not only shares revenue of seller but bears a part of product quality cost of seller as well. Platform can have a better grasp about the type of seller under CS model as sharing the cost burden helps platform to realize the cost structure of each type of seller. The CS contract is more preferable as it induces the members of online platform to exert better performance. Due to the presence of cost-sharing element, seller enables to uplift its product quality provision. Better provision of product quality raises the price per product which in turn increases the profit earned by both the platform and the seller. Intermediary provides improved services to its users as well under CS contract. Our model derives a crucial facet of contract design by comparing these two forms of contract.

5.5 Extension: Introduction of advertising in the model

Suppose the platform introduces advertising (defined as "a") to expand the audience base and boost the sales volume. Advertisement helps platform to drive up sales in many ways by generating brand and product awareness among customers, informing them about promotional offers, daily offers etc. We let, $\gamma = \gamma(a)$ where $\gamma'(a) > 0$. For sending advertising signal, platform incurs a cost and let that be equal to "a" under both contracts. When the platform sends "a" level of advertising signal to its users, the final form of platform's profit is written under first-best case of RS structure as,

$$\Pi^*_{PR} = \frac{(1-\lambda)\{(1-t)\gamma(a)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}} - a$$

Differentiating the above profit equation with respect to advertising level, a and making that equal to zero, we attain,

$$\frac{d\Pi^*_{PR}}{da} = \frac{(1-\lambda)\{(1-t)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}} \frac{2}{1-\lambda}\gamma(a)^{\frac{1+\lambda}{1-\lambda}}\gamma'(a) - 1 = 0$$

$$\text{Or, } \frac{\{(1-t)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}} \gamma(a)^{\frac{1+\lambda}{1-\lambda}}\gamma'(a) = 1 \qquad (5.12)$$

By solving the above first order condition, we get the advertising level under no information asymmetry case (a^*_R). The profit of platform under second-best case is as follows,

$$\Pi'_{PR} = \frac{(1-\lambda)\{(1-t)\gamma(a)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}} - a$$

From the FOC for profit maximization with respect to advertisement, a, we have,

$$\frac{d\Pi'_{PR}}{da} = \frac{(1-\lambda)\{(1-t)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}} \frac{2}{1-\lambda}\gamma(a)^{\frac{1+\lambda}{1-\lambda}}\gamma'(a) - 1 = 0$$

$$\text{Or, } \frac{\{(1-t)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}} \gamma(a)^{\frac{1+\lambda}{1-\lambda}}\gamma'(a) = 1 \qquad (5.13)$$

By solving (5.13), we get the advertising level under information asymmetry case (a'_R).

Comparing the first order conditions for profit maximization of platform under first-best case (equation (5.12)) and second-best case (equation (5.13)) under RS model, we conclude that the advertising level under first-best case, a^*_R is higher than the level obtained under second-best case, a'_R. The intuition is straightforward. When platform is absolutely sure about the seller's type, it will send more advertising signal compared to when it is uncertain about the nature of the seller.

Similarly, first order conditions for both symmetry and asymmetry cases under CS model are as follows:

$$\frac{\{(1-t)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\gamma(a)^{\frac{1+\lambda}{1-\lambda}}\gamma'(a)=1 \tag{5.14}$$

$$\frac{\{(1-t)\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\gamma(a)^{\frac{1+\lambda}{1-\lambda}}\gamma'(a)=1 \tag{5.15}$$

By comparing these two conditions (equations (5.14) & (5.15)), we infer that platform will deliver higher amount of advertising under information symmetry regime (since $a^*_C > a'_C$) for CS contract. Moreover, the platform will provide higher level of advertising under cost-sharing contract compared to revenue-sharing regime for incomplete information case as $a'_C > a'_R$.

5.6 Conclusion

Contract design establishes coordination among two parties and is prevalent across all sectors of an economy. However, in the existing literature, little attention has been offered on contracting relationship concerning the members of platform and impact of taxation under information asymmetry. The present study discusses the issue of contract design between an online platform and a seller when the willingness to pay per product is influenced by the platform's service quality and quality of product supplied by seller. The model discusses the contracting problem for the case when the platform is not informed about the type of seller which can be of either high type or low type based on unit cost of product quality. To analyze this issue of contracting, we explore two common forms of agreements: Revenue Sharing and Cost Sharing. An interesting observation shows that at optimum, high type seller is required to provide less product quality under incomplete information compared to full information for both contracts when service quality is endogenously determined. Most importantly, with hidden information, platform achieves lower profit compared to the first-best profit as the platform gives up a portion of its profit in order to extract the hidden information about the type from the seller. The comparison between two contracts yields that CS contract secures more profit for platform by inducing every member of platform to supply greater quality relative to RS contract.

The study subsequently examines the effect of change in tax rate on service quality, product quality and profit of the platform. The analytical findings exhibit that tax places negative impact on all the model variables. We then introduce advertising in our model and find that the platform will invest more on advertising when it is fully informed about the type of the seller rather when it does not know the type. For the future analysis, we will examine the contract design for competitive platform setting and find how competitive setting changes the results found for monopoly platform.

Appendices to Chapter 5

5. A. Proofs of Claim 1 and Claim 2

Proof of Claim 1: When the condition IC_h binds then,

$$(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2} \tag{5.i}$$

$$(1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2} > (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} \quad \text{Since } \beta_l > \beta_h \tag{5.ii}$$

From (5.i) and (5.ii), we have, $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} > (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2}$

Thus $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} > 0$ (Since if IR_l binds: $(1-\alpha_l)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} = 0$)

Proof of Claim 2: When the condition IC_h binds then,

$$(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} = (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_h q_l^2}{2}$$

Or, $\frac{\beta_h (q_h^2 - q_l^2)}{2} = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - (1-\alpha_l)(1-t)\gamma s q_l^{\lambda}$ (5.iii)

We know, $\frac{\beta_l (q_h^2 - q_l^2)}{2} > \frac{\beta_h (q_h^2 - q_l^2)}{2} = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - (1-\alpha_l)(1-t)\gamma s q_l^{\lambda}$ (using (5.iii))

Or, $(1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2} > (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_l q_h^2}{2}$ ■

5. B. Consistency Check for RS Contract

- IR_h: $\Pi_h^s = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h q_h^2}{2} = \frac{\beta_h q_h^2}{2} + \frac{\beta_l q_l^2}{2} - \frac{\beta_h q_l^2}{2} - \frac{\beta_h q_h^2}{2} = \frac{(\beta_l - \beta_h) q_l^2}{2} > 0$
- IC_l: $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\beta_l q_h^2}{2} = \frac{\beta_h q_h^2}{2} + \frac{\beta_l q_l^2}{2} - \frac{\beta_h q_l^2}{2} - \frac{\beta_l q_h^2}{2} = -\frac{1}{2}(\beta_l - \beta_h)(q_h^2 - q_l^2) < 0 \underbrace{=}_{IR_l} (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l q_l^2}{2}$

Thus, we justify IR_h and IC_l constraints.

5. C. Proof of Proposition 1

- $$\frac{s_R^*}{s_R'} = \frac{\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}}{\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}} = \left[\frac{\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)^{\frac{2}{2-\lambda}}\left(\frac{1}{(\beta_l-\phi\beta_h)}\right)^{\frac{\lambda}{2-\lambda}}\right\}}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$$

Since, $\beta_l > \beta_h$; Therefore $s_R^* > s_R'$

- $\frac{q_{h_R}^*}{q_{h_R}'} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(s_R^*)^{\frac{1}{2-\lambda}}}{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(s_R')^{\frac{1}{2-\lambda}}} > 1$ & $\frac{q_{l_R}^*}{q_{l_R}'} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}(s_R^*)^{\frac{1}{2-\lambda}}}{\left(\frac{(1-\phi)(1-t)\gamma\lambda}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}}(s_R')^{\frac{1}{2-\lambda}}} > 1$

Therefore, $q_{h_R}^* > q_{h_R}'$ & $q_{l_R}^* > q_{l_R}'$.

- $\alpha_{l_R}^* = (1 - \frac{\lambda}{2})$ & $\alpha_{l_R}' = 1 - \frac{\beta_l\lambda(1-\phi)}{2(\beta_l-\phi\beta_h)}$

$(\alpha_{l_R}' - \alpha_{l_R}^*) = \frac{\lambda}{2}(1 - \frac{\beta_l(1-\phi)}{(\beta_l-\phi\beta_h)}) = \frac{\lambda\phi}{2}\frac{(\beta_l-\beta_h)}{(\beta_l-\phi\beta_h)} > 0$; Therefore, $\alpha_{l_R}' > \alpha_{l_R}^*$

- $\alpha_{h_R}^* = (1 - \frac{\lambda}{2})$ & $\alpha_{h_R}' = 1 - \frac{\lambda}{2} - \frac{(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^\lambda}$

Now, $\left(\alpha_{h_R}^* - \alpha_{h_R}'\right) = \frac{(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^\lambda} > 0$; Therefore, $\alpha_{h_R}^* > \alpha_{h_R}'$

- $\Pi_{PR}^* = \phi\left[(1-t)\gamma s q_h^\lambda - \frac{\beta_h}{2}q_h^2 - \frac{s^2}{2}\right] + (1-\phi)\left[(1-t)\,\gamma s q_l^\lambda - \frac{\beta_l}{2}q_l^2 - \frac{\eta s^2}{2}\right]$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s_R^*)^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right) - \frac{(s_R^*)^2}{2}[\phi + (1-\phi)\eta]$$

$$\Pi_{PR}' = \phi\left[(1-t)\gamma s q_h^\lambda - \frac{\beta_h}{2}q_h^2 - \frac{(\beta_l-\beta_h)q_l^2}{2} - \frac{s^2}{2}\right] + (1-\phi)\left[(1-t)\,\gamma s q_l^\lambda - \frac{\beta_l}{2}q_l^2 - \frac{\eta s^2}{2}\right]$$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s_R')^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right) - \frac{(s_R')^2}{2}[\phi + (1-\phi)\eta]$$

Therefore,

$$(\Pi_{PR}^* - \Pi_{PR}') = \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left[(s_R^*)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\} - (s_R')^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}\right] - \frac{[\phi+(1-\phi)\eta]}{2}[(s_R^*)^2 - (s_R')^2]$$

$$= \frac{\{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left(\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\right)^{\frac{1}{(1-\lambda)}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left[\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}-\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\right]-\frac{\lambda^{\frac{\lambda}{1-\lambda}}((1-t)\gamma)^{\frac{2}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left[\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}-\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\right]$$

(After putting the value of s)

$$= \frac{(1-\lambda)\{(1-t)\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}\left[\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}-\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\right]}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}} > 0; \text{ As, } \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}} > \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}} \blacksquare$$

5. D. Consistency Check for CS Contract

- IR_h: $\Pi_h^s = (1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\theta\beta_h q_h^2}{2} = \frac{\theta\beta_h q_h^2}{2} + \frac{\theta\beta_l q_l^2}{2} - \frac{\theta\beta_h q_l^2}{2} - \frac{\theta\beta_h q_h^2}{2} = \frac{\theta(\beta_l-\beta_h)q_l^2}{2} > 0$

- IC_l: $(1-\alpha_h)(1-t)\gamma s q_h^{\lambda} - \frac{\theta\beta_l q_h^2}{2} = -\frac{\theta}{2}\left(\beta_l-\beta_h\right)\left(q_h^2-q_l^2\right) < 0 \underbrace{=}_{IR_l} (1-\alpha_l)(1-t)\gamma s q_l^{\lambda} - \frac{\theta\beta_l q_l^2}{2}$

Thus, we justify IR_h and IC_l constraints.

5. E. Proof of Proposition 2

- $$\frac{s_C^*}{s_C'} = \left[\frac{\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}$$

Since, $\beta_l > \beta_h$; Therefore $s_C^* > s_C'$

- $\frac{q_{h_C}^*}{q_{h_C}'} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(s_C^{FB})^{\frac{1}{2-\lambda}}}{\left(\frac{(1-t)\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(s_C^{SB})^{\frac{1}{2-\lambda}}} > 1$ and $\frac{q_{l_C}^*}{q_{l_C}'} = \frac{\left(\frac{(1-t)\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}(s_C^*)^{\frac{1}{2-\lambda}}}{\left(\frac{(1-\phi)(1-t)\gamma\lambda}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{1}{2-\lambda}}(s_C')^{\frac{1}{2-\lambda}}} > 1$

Therefore, $q_{h_C}^* > q_{h_C}'$ and $q_{l_C}^* > q_{l_C}'$.

- $\alpha_{l_C}^* = (1-\frac{\theta\lambda}{2})$ & $\alpha_{l_C}' = 1 - \frac{\theta\beta_l}{2(1-t)\gamma s} q_l^{2-\lambda} = 1 - \frac{\theta\beta_l\lambda(1-\phi)}{2(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}$

$(\alpha_{l_C}' - \alpha_{l_C}^*) = 1 - \frac{\theta\beta_l\lambda(1-\phi)}{2(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)} - 1 + \frac{\theta\lambda}{2} = \frac{\lambda\phi}{2}\frac{\theta^2(\beta_l-\beta_h)}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)} > 0$; Therefore, $\alpha_{l_C}' > \alpha_{l_C}^*$

- $\alpha_{h_C}^* = (1-\frac{\theta\lambda}{2})$ & $\alpha_{h_C}' = 1 - \frac{\theta\lambda}{2} - \frac{\theta(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^{\lambda}}$

Now, $\left(\alpha_{h_C}^* - \alpha_{h_C}'\right) = \frac{\theta(\beta_l-\beta_h)q_l^2}{2(1-t)\gamma s q_h^{\lambda}} > 0$; Therefore, $\alpha_{h_C}^* > \alpha_{h_C}'$

- $\Pi_{PC}^* = \phi\left[(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h}{2}q_h^2 - \frac{s^2}{2}\right] + (1-\phi)\left[(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l}{2}q_l^2 - \frac{\eta s^2}{2}\right]$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s_C^*)^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right) - \frac{(s_C^*)^2}{2}[\phi + (1-\phi)\eta]$$

$$\Pi_{PC}' = \phi\left[(1-t)\gamma s q_h^{\lambda} - \frac{\beta_h}{2}q_h^2 - \frac{\theta(\beta_l-\beta_h)q_l^2}{2} - \frac{s^2}{2}\right] + (1-\phi)\left[(1-t)\gamma s q_l^{\lambda} - \frac{\beta_l}{2}q_l^2 - \frac{\eta s^2}{2}\right]$$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s_C')^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right) - \frac{(s_C')^2}{2}[\phi + (1-\phi)\eta]$$

Therefore,

$$(\Pi_{PC}^* - \Pi_{PC}') = \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left[(s_C^*)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\} - (s_C')^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}\right] - \frac{[\phi+(1-\phi)\eta]}{2}\left[(s_C^*)^2 - (s_C')^2\right]$$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left[\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{(1-\lambda)}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}-\right.$$

$$\left.\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{(1-\lambda)}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}\right]-$$

$$\frac{[\phi+(1-\phi)\eta]}{2}\left[\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\phi\left(\frac{1}{\beta_h}\right)^{\frac{\lambda}{2-\lambda}}+(1-\phi)\left(\frac{1}{\beta_l}\right)^{\frac{\lambda}{2-\lambda}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{2-\lambda}{(1-\lambda)}}-\right.$$

$$\left.\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{2-\lambda}{(1-\lambda)}}\right] \qquad \text{(Putting the values of s)}$$

$$=\frac{\{(1-t)\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}\left[\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}-\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\right]}{\mathbf{2}(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}(1-\lambda) > 0$$

Therefore, $\Pi_{PC}^{*} > \Pi_{PC}'$ ■

5. F. Proof of Proposition 3: Results of Sensitivity Analysis

- $s_R^* = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}} = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}} (1-t)^{\frac{1}{1-\lambda}}$

$$\frac{ds_R^*}{dt} = -\frac{1}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta\,)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}} (1-t)^{\frac{\lambda}{1-\lambda}} < 0 \blacksquare$$

- $q_{h_R}^* = \left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(1-t)^{\frac{1}{2-\lambda}}(s_R^*)^{\frac{1}{2-\lambda}}$

Taking the total derivative of the above expression,

$$\underbrace{\frac{dq_{h_R}^*}{dt}}_{\substack{\text{Total effect of tax}\\ \text{on product quality}}} = \underbrace{\frac{\partial q_{h_R}^*}{\partial t}}_{\substack{\text{Direct effect of tax}\\ \text{on product quality}}} + \underbrace{\frac{\partial q_{h_R}^*}{\partial s_R^*}\frac{ds_R^*}{dt}}_{\substack{\text{Indirect effect of tax}\\ \text{on product quality}}}$$

$$\frac{dq_{h_R}^*}{dt} = \frac{1}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[-(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}(s_R^*)^{\frac{1}{2-\lambda}} + (1-t)^{\frac{1}{2-\lambda}}(s_R^*)^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds_R^*}{dt}\right] < 0 \ \text{ Since } \frac{ds_R^*}{dt} < 0$$

$$q_{l_R}^* = \left(\frac{\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}(1-t)^{\frac{1}{2-\lambda}}(s_R^*)^{\frac{1}{2-\lambda}}$$

$$\frac{dq_{l_R}^*}{dt} = \frac{1}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_l}\right)^{\frac{1}{2-\lambda}}\left[-(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}(s_R^*)^{\frac{1}{2-\lambda}} + (1-t)^{\frac{1}{2-\lambda}}(s_R^*)^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds_R^*}{dt}\right] < 0 \ \text{ Since } \frac{ds_R^*}{dt} < 0$$

■

- $\Pi_{PR}^* = \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s_R^*)^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right) - \frac{(s_R^*)^2}{2}[\phi + (1-\phi)\eta]$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta\,)}\right]^{\frac{1}{(1-\lambda)}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\} -$$

$$\frac{[\phi+(1-\phi)\eta]}{2}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta\,)}\right]^{\frac{2-\lambda}{(1-\lambda)}} \quad \text{(Putting the value of s)}$$

$$= \frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}(1-\lambda)\{(1-t)\}^{\frac{2}{1-\lambda}}$$

Therefore, $\frac{d\Pi^*_{PR}}{dt} = -\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)}{\beta_l^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}} < 0$ ■

- $$s'_R = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}(\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}(1-t)^{\frac{1}{(1-\lambda)}}$$

$$\frac{ds'_R}{dt} = -\frac{1}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}(1-t)^{\frac{\lambda}{1-\lambda}} < 0 \quad ■$$

- $${q_h}'_R = \left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(1-t)^{\frac{1}{2-\lambda}}(s'_R)^{\frac{1}{2-\lambda}}$$

Taking the total derivate with respect to tax rate,

$$\underbrace{\frac{d{q_h}'_R}{dt}}_{\substack{\text{Total effect of tax}\\ \text{on product quality}}} = \underbrace{\frac{\partial {q_h}'_R}{\partial t}}_{\substack{\text{Direct effect of tax}\\ \text{on product quality}}} + \underbrace{\frac{\partial {q_h}'_R}{\partial s'_R}\frac{ds'_R}{dt}}_{\substack{\text{Indirect effect of tax}\\ \text{on product quality}}}$$

$$\frac{d{q_h}'_R}{dt} = \frac{1}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[-(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}(s'_R)^{\frac{1}{2-\lambda}}+(1-t)^{\frac{1}{2-\lambda}}(s'_R)^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds'_R}{dt}\right] < 0 \text{ Since } \frac{ds'_R}{dt} < 0$$

$${q_l}'_R = \left(\frac{(1-\phi)\gamma\lambda}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}}(1-t)^{\frac{1}{2-\lambda}}(s'_R)^{\frac{1}{2-\lambda}}$$

$$\frac{d{q_l}'_R}{dt} = \frac{1}{2-\lambda}\left(\frac{(1-\phi)\gamma\lambda}{(\beta_l-\phi\beta_h)}\right)^{\frac{1}{2-\lambda}}\left[-(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}(s'_R)^{\frac{1}{2-\lambda}}+(1-t)^{\frac{1}{2-\lambda}}(s'_R)^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds'_R}{dt}\right] < 0 \quad ■$$

- $$\Pi'_{PR} = \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s'_R)^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right)-\frac{(s'_R)^2}{2}[\phi+(1-\phi)\eta]$$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{(1-\lambda)}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\right.$$

$$\left.\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}-\frac{[\phi+(1-\phi)\eta]}{2}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{2-\lambda}{(1-\lambda)}}$$

(Putting the value of s)

$$= \frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}(1-\lambda)\{(1-t)\}^{\frac{2}{1-\lambda}}$$

$$\frac{d\Pi'_{PR}}{dt} = -\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\beta_l-\phi\beta_h)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}} < 0 \quad \blacksquare$$

The impact of ad valorem tax on model variables for CS contract with information symmetry is similar with full information model under RS contract, thus omitted.

- $$s'_C = \left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}(\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}(1-t)^{\frac{1}{1-\lambda}}$$

Differentiating with respect to t,

$$\frac{ds'_C}{dt} = -\frac{1}{1-\lambda}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}\gamma^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{(2-\lambda)}{2(1-\lambda)}}(1-t)^{\frac{\lambda}{1-\lambda}} < 0$$

- $${q_h}'_C = \left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}(1-t)^{\frac{1}{2-\lambda}}(s'_C)^{\frac{1}{2-\lambda}}$$

Taking the total derivate with respect to tax rate,

$$\underbrace{\frac{dq_{h_C}'}{dt}}_{\substack{\text{Total effect of tax}\\ \text{on product quality}}} = \underbrace{\frac{\partial q_{h_C}'}{\partial t}}_{\substack{\text{Direct effect of tax}\\ \text{on product quality}}} + \underbrace{\frac{\partial q_{h_C}'}{\partial s_C'}\frac{ds_C'}{dt}}_{\substack{\text{Indirect effect of tax}\\ \text{on product quality}}}$$

$$\frac{dq_{h_C}'}{dt} = \frac{1}{2-\lambda}\left(\frac{\gamma\lambda}{\beta_h}\right)^{\frac{1}{2-\lambda}}\left[-(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}(s_C')^{\frac{1}{2-\lambda}} + (1-t)^{\frac{1}{2-\lambda}}(s_C')^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds_C'}{dt}\right] < 0 \text{ Since } \frac{ds_C'}{dt} < 0$$

$$\frac{dql_C'}{dt} = \frac{1}{2-\lambda}\left(\frac{(1-\phi)\gamma\lambda}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)}\right)^{\frac{1}{2-\lambda}}\left[-(1-t)^{\frac{-(1-\lambda)}{2-\lambda}}(s_C')^{\frac{1}{2-\lambda}} + (1-t)^{\frac{1}{2-\lambda}}(s_C')^{\frac{-(1-\lambda)}{2-\lambda}}\frac{ds_C'}{dt}\right] < 0 \quad \text{Since } \frac{ds_C'}{dt} < 0$$

- $$\Pi_{PC}' = \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}(s_C')^{\frac{2}{2-\lambda}}\left[\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right]\left(1-\frac{\lambda}{2}\right) - \frac{(s_C')^2}{2}[\phi+(1-\phi)\eta]$$

$$= \{(1-t)\gamma\}^{\frac{2}{2-\lambda}}\lambda^{\frac{\lambda}{2-\lambda}}\left(1-\frac{\lambda}{2}\right)\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{1}{(1-\lambda)}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\} - \frac{[\phi+(1-\phi)\eta]}{2}\left[\frac{\lambda^{\frac{\lambda}{2-\lambda}}((1-t)\gamma)^{\frac{2}{2-\lambda}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}}+\frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}}{(\phi+(1-\phi)\eta)}\right]^{\frac{2-\lambda}{(1-\lambda)}}$$

(Putting the value of s)

$$= \frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{2(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}(1-\lambda)\{(1-t)\}^{\frac{2}{1-\lambda}}$$

Differentiating with respect to t,

$$\frac{d\Pi_{PC}'}{dt} = -\frac{\{\gamma\}^{\frac{2}{1-\lambda}}\lambda^{\frac{\lambda}{1-\lambda}}}{(\phi+(1-\phi)\eta)^{\frac{1}{(1-\lambda)}}}\left\{\frac{\phi}{\beta_h^{\frac{\lambda}{2-\lambda}}} + \frac{(1-\phi)^{\frac{2}{2-\lambda}}}{(\theta\phi(\beta_l-\beta_h)+(1-\phi)\beta_l)^{\frac{\lambda}{2-\lambda}}}\right\}^{\frac{2-\lambda}{(1-\lambda)}}\{(1-t)\}^{\frac{1+\lambda}{1-\lambda}} < 0 \quad \blacksquare$$

Chapter 6: Summary and Conclusion

6.1 Summary

Platform markets have become a center point of discussion for its rapidly growing industry and huge contribution on retail growth. Many factors such as lower transaction costs, easy connectivity between members sitting on different continents, introduction of internet, have contributed to offer platform industry a prime place among all market structures. The presence of two distinct sides on board leading to indirect network effects has instituted two-sided platform economics to a separate branch from array of markets. Many significant issues concerning platforms recently emerged that have motivated us to present in-depth analysis of different facets of platform markets.

The first chapter of the thesis offers non-technical introduction explaining the background and experiences of two-sided platforms with a major focus on e-commerce markets. The motivation and objective of the study are also discussed briefly. The second chapter surveys the existing literature concerning platform economics on those particular issues which have been thoroughly described in this study. Chapter 2 concludes by discovering research gap in existing literature which are analyzed in chapters 3-5.

The third chapter models the optimal business strategies of a two-sided monopoly platform where the monopoly platform provides product discount to buyers. In this model, advertising tool plays a pivotal role in channeling information about discount to consumers. Platform also provides different services to buyers such as return and replacement services, exchange services, delivery services. The potential utility from transaction is attained through the successful interaction between two sides, buyers and sellers. The chapter considers the effects of indirect network externality originating through the participation of opposite group members. One of the identifying features of this chapter is that discount provides utility to buyers in two forms---monetary gain from paying less for purchasing a product and psychological benefit for obtaining the product at a reduced price. We derive the optimal value of service quality and advertisement under monopoly platform equilibrium and then obtain the effect of discount variation on model variables through comparative static exercise. We observe that price paid by sellers to platform is affected by discount because of the presence of cross-group network externality. The one of the important innovations in result suggests that service quality strongly falls with increase in discount, a finding that is particularly pertinent in reality. Many consumers complains about the degraded services of platforms in period of discounts. The intuition derived from the previous result proposes that quality-conscious buyers may devalue platform's quality in the period of high discounts and as a result, platform may lose buyer base significantly. Thus we notice "boomerang effect" as platform's strategy of giving high discounts to attract buyer base can actually work against platform's interest and eventually reduce sales volume in platform. Platform needs to be careful enough before devising such business strategy as the long term effect can be detrimental. Analytical finding observes that rise in the level of discount reduces the level of advertising at equilibrium. Welfare analysis has been conducted to compare the market equilibrium with the social optimum case.

Unlike the considerable amount of literature focusing on the importance of taxes and two-sidedness of platform economies separately, the fourth chapter of the thesis considers these two issues, which has not been investigated comprehensively. It devises the role of imposition of two forms of taxes--- a tax levied on platforms' revenues and an ad valorem tax on consumers' access fees, on platforms' businesses characterized with cross-side effects. We develop and incorporate another element, informative advertising in our two-sided duopoly platforms model which aims to increase the probability of matching between the registered economic agents of two distinct sides. Differing from chapter 3, here the competition between duopoly platforms has been analyzed. Each platform employs an advertising technology to transmit sellers' information to buyers and therefore, drives each buyer to purchase from those sellers whose information has been sent by them. To reflect reality, we here assume multi-homing by sellers whereas buyers participate and purchase products only from one platform. Platforms charge fixed membership or participation fees to its buyers and per-transaction fees to sellers. The stage game is answered using the backward induction and the stages of the game are---platforms determine the level of informative advertising simultaneously in the first stage; each platform simultaneously chooses the fees to be imposed on consumers and sellers; lastly consumers and sellers form their participation decisions. We derive the optimal values of fees and the level of informative advertising by using a simple theoretical model for both tax regimes. Sensitivity analysis has been conducted for each tax regime. One of the key findings of the chapter indicates that each platform reduces its investment on the informative advertising in response to increase in tax rate. Tax levied on consumers is partially shifted to opposite side, sellers. The chapter also brings forth the relationship of fees and consumer surplus with both tax rates. Both kinds of taxes generate adverse impacts on profits of platforms and consumers surpluses for both platforms. Both taxes impact negatively the welfare of the society as well. A numerical comparison between two tax regimes based on certain parameter values indicates that tax on platforms should always be preferred compared to tax on consumers as a tax on consumers produces unfavourable impact for the society as a whole by a larger amount. The effect of strength of the cross-group externality has been derived on model variables and it shows that both platforms increase the level of informative advertising in response to increase in the degree of cross-side effects.

After bringing forth some of the relevant issues revolving around the digital economics in the last two chapters, the fifth chapter of the dissertation spells out the channel coordination problem that has been solved with the help of contract theory. Unlike the plethora of articles focusing on coordination problem in supply chain economics, this chapter elaborates and analyses the situation of two-sided platform when it suffers from the hidden information about the quality cost incurred by the seller. To ensure that the seller truthfully disclose his/her nature of quality cost, the platform enters into a contract with seller. We assume per unit price charged is influenced by the seller's product quality and platform's service quality. The contracts we consider in our model are---revenue-sharing and cost-sharing contracts. The chapter observes that platform offers better service quality when it is certain about the type of the seller than the hidden information case for both type of contracts. One of the impressive results that set apart our model from the conventional one-sided market is that with endogenously determined service quality, optimal product quality for high type seller is significantly lower in presence of asymmetric information than the first-best product quality. Moreover, second-best profit is lower for platform than the first best level to extract the hidden information about the type of seller. Comparison between two forms of contract reveals that cost-sharing contract is preferable as it motivates the each agent of online platform to exert better quality performance. Then the model has been extended to take into account the possibility of advertising and it states that the platform sends higher level of advertising when it is certain about the seller' type than when it is not sure about the true nature of seller.

Thus, this chapter of dissertation offers a brief and succinct summary of model findings on two sided markets based on some emerging and exceptional issues that either went completely unnoticed in the existing literature or gained minimum focus. After building the research gap, we intend to bridge the gap with our model findings and derived intuitions. The innovative results will make significant contributions in the existing literature.

The present dissertation studies in-depth analysis of business strategies concerning the agents of two-sided platform eco-system. The study also specifies the policy prescription to maintain the well-being of different agents relating to platforms. It can be concluded that offering umpteen discount is not always desirable policy as it may adversely affect the service performance of platform and that will lead to fall in volume of purchase particularly for the quality conscious buyers. Executives of two-sided businesses should keep all these effects in mind before devising any discount strategy. Moreover, the dissertation analyses the aspect of taxation on different agents on platform and derives the welfare impacts of two important forms of taxation --- tax on platforms and tax on consumers. For evaluating the impact of taxation, it particularly focuses on duopoly platforms with its agents connected through indirect network effects. Comparison between these two forms of taxes concludes that both the taxes are welfare-reducing, however, tax on platform should always be favoured to tax on consumers as taxing platforms produces less welfare loss. The dissertation further contributes to the existing literature by solving the channel coordination problem between platform and its sellers and analyses two forms of contracts--- revenue-sharing and cost-sharing contracts. Platforms should use cost-sharing contract as it induces the members of online platform to exert better performances. Through the sharing of product-quality cost, platform provides incentive to sellers to uplift its product-quality provision. Better product quality raises the price per product which in turn increases the profitability of both the platform and the seller. Our study derives crucial facets of platform business by analyzing different strategies of platforms.

6.2 Scope for future work

While our study has some important merits to analyze, we keep some issues beyond the realm of the thesis which can add possible new dimensions for future work. In Chapter 5, the competition between platforms can be a potential extension for better understanding of channel coordination problem. Also, we retain intermediary innovation and design beyond the sphere of our framework which can be another possible avenue for future research. Another direction of future work may include the preferential treatment exercised by platforms towards its sellers through the preferential-listing of platforms' own brands. Therefore, our study formulate the technical foundation of two-sided online platform for executing new facets for future research.

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