App platforms as two-sided markets: Analysis and modeling of application distribution platforms for mobile devices

Von der Fakultät für Wirtschaftswissenschaften der Rheinisch-Westfälischen Technischen Hochschule Aachen zur Erlangung des akademischen Grades einer Doktorin der Wirtschafts- und Sozialwissenschaften genehmigte Dissertation

vorgelegt von

Dipl.-Math. Univ. Iana Kouris, B.A.

Berichter: Univ.-Prof. Dr.rer.pol. Frank Thomas Piller
Univ.-Prof. Dr.sc.pol. Oliver Lorz

Tag der mündlichen Prüfung: 28.11.2013

Diese Dissertation ist auf den Internetseiten der Hochschulbibliothek online verfügbar.
Für Rudolf, Irene, Dimitri und Evgeni
Acknowledgments

I am indebted to many people who supported me in different ways while I was working on this doctoral thesis. It is my great pleasure to take this opportunity to thank them.

First of all, I would like to thank my doctoral adviser Univ.-Prof. Dr. Frank Piller for showing a lot of openness and supervising my thesis. I am very grateful for his constant support and helpful feedback throughout the course of my research.

Also, I would like to thank Frank for giving me the opportunity to work together with Dr. Robin Kleer and to be part of TIM (Technology and Innovation Management Group) at RWTH Aachen University. I am indebted to Robin for his dedicated mentoring, deep discussions and honest advice. Being part of the TIM group, even only on a visiting bases, was very valuable to me. I was enjoying the exchange with other participants of the TIM group, the team events and the workshops. Thank you TIM group – it was a great pleasure!

I would also like to thank my second examiner Univ.-Prof. Dr. Oliver Lorz for his readiness to supervise my doctoral studies and his interest in my work.

I am grateful to the colleagues at McKinsey and Company, Inc. for making my educational leave possible. German Office, and Frankfurt Office in particular, was and remains a great place with inspiring colleagues and amazing events.

Many friends provided support and encouragement throughout my studies: Nina, Karo, Michael, Karl, Anke, Carola, Jasmin and Silvia. Thank you! To all my friends, not mentioned by name but knowing that they are meant, I am deeply thankful for having an open ear and having motivated me during this study.

With all my heart, I thank my family, in particular, my partner Rudolf, my parents Irene, Dimitri and my brother Evgeni. Without their patience and continuous support of all kinds, this work would not have been possible. Thank you so much! Rudolf, you are a great source of inspiration and happiness for me. Thank you for sharing, challenging, encouraging and just being there for me at all times.
The Big Shift is a fundamental reordering of the way we live, learn, play, and work. A new technology infrastructure is a big part of this transformation. Consider technology platforms such as Amazon Web Services, Google Apps, Android, Facebook, Twitter, the iPhone App Store, and now the iPad... Just as the telephone, automobile, and aeroplane reshaped society in the first half of the 20th century, the digital infrastructure is reshaping life in the 21st.

Financial Times, 22 September 2010

The App Store is like nothing the industry has ever seen before in both scale and quality.

Steve Jobs, Apple’s CEO, 2009
Summary

“App platforms” are electronic software distribution platforms for mobile devices like smartphones or tablets. They have gained popularity after Apple launched its App Store in July 2008. Since then, app platforms have transformed the entire mobile communication industry. Although the App Store’s advantage seemed to be incontestable, other app platforms like Google Play managed to enter the market and achieve high popularity. More platforms followed Apple and Google, trying to create niche markets. This makes the app platform market very dynamic and disruptive.

App platforms are not a single example but a part of a large-scale change. Over the last decade, platforms became the “invisible engines” of our economies (Evans et al., 2006). Amazon, eBay, and Google have advanced to top brands worldwide. Following Gawer and Cusumano (2007), we define platforms as “systems of technologies that combine core components with complementary products and services usually made by a variety of firms.” Platforms have spread across many industries, leading to creation of new business areas and products. Moreover, they change the whole economic structure and influence business strategies in fundamental ways.

Platforms that enable interactions between two groups of customers, which value each other’s presence, are called two-sided markets. Over the last decade, a large body of literature on two-sided markets has emerged, for example, Rochet and Tirole (2003, 2006), Caillaud and Jullien (2003), Evans (2003) and Armstrong (2006), to name just a few. Two-sided market models reflect one of the key characteristics of app platforms, namely, the prominent role of indirect network effects. Unfortunately, currently existing two-sided market models are not suitable to model Internet platforms such as app platforms. Hence, it is necessary to come up with an appropriate two-sided market model first. Also, a dynamic two-sided model which would be able to reflect dynamic and disruptive nature of two-sided markets is lacking. These are the first two research gaps addressed in the dissertation at
hand. The third research gap consists in developing strategies for app platforms based on two-sided market theory and existing management literature.

The objective of this thesis is to address these gaps in three research papers: “An integrated two-sided market model”, “Toward Understanding Dynamics and Disruptions in Two-sided Markets: A Dynamic Two-sided Market Model” and “App Store, Quo Vadis? Challenges and Strategies for App Platforms”. All three research papers are based on two-sided market theory and aim at providing insights for industries based on Internet platforms, in particular, for app platforms. The central objective of the first research paper is to develop a two-sided market model, which can be applied to analyze app platforms. In research paper I, we provide theoretical background and develop an integrated two-sided market model, which includes the most relevant parameters. We also provide a closed-form solution for this model and discuss how it can be used to analyze app platforms.

The second research paper builds on the results of the first one and extends it to the dynamic setting. This allows us to go beyond static solution and provide insights regarding strategies in a dynamic and disruptive setting. We consider a range of situations and research questions, for instance, “chicken-and-egg” problem, minimal number of agents necessary to kick-off a platform and external shocks through competitive entry.

In the third research paper, we discuss key challenges and central strategic decisions along the life-cycle phases. In addition to the two-sided market theory, we build on the platform management literature. The third research paper focuses on applying theoretical concepts to derive strategies and suggestions to mitigate challenges faced by app platforms.

The present thesis is structured as follows: part I includes an introduction to the research field, part II consists of the three stand-alone research papers. The first part begins with introduction to the research project motivation and structure. Background information on the app platform industry and overview of two-sided market theory follows. Then we provide derivation of research gaps and questions, summaries of the research papers and, finally, general discussion and conclusion. The second part of the dissertation at hand presents the three research papers, as they were (or will be) submitted for academic conferences and journals.

Supported by the extensive introduction to the research field, the three studies together provide insights on theoretical aspects of two-sided markets, as well as on application to the app platform industry (and other similar platforms). The integrated two-sided market model with its new parameters and a closed-form solution developed in the research paper I, and introduction of a dynamic two-sided
market model in the research paper II, represent main theoretical contributions. Insights regarding strategies for app platforms along the life-cycle stages are crucial from the managerial point of view. The most promising avenues for future research include further development of the models, such as introduction of stochastic parameters, and empirical testing of the models.
Thesis structure overview

This thesis consists of two parts, the first provides an overview of the research field, including description of the underlying industry, theoretical background, research gap analysis and general discussion. The second part includes three research papers which focus on extending two-sided market theory and modeling, analyzing and understanding app distribution platforms for mobile devices, like Apple’s App Store, Google Play (formerly Google Android market) and Amazon Appstore. The previous versions of these research papers were accepted and presented at academic conferences and are intended for publication in academic journals. Since these are stand-alone research papers, some repetitions and similarities are inevitable.

PAPER I: AN INTEGRATED TWO-SIDED MARKET MODEL FOR INTERNET PLATFORMS
Presented at:

- 10th International Industrial Organization Conference (IIOC), March 2012, Arlington, USA.
- V International Think Tank on Innovation and Competition (INTERTIC), October 2011, Venice, Italy.
- Network of Industrial Economists (NIE), Doctoral Student Colloquium, June 2011, Nottingham, United Kingdom.

PAPER II: TOWARD UNDERSTANDING DYNAMICS AND DISRUPTIONS IN TWO-SIDED MARKETS: A DYNAMIC TWO-SIDED MARKET MODEL
Presented at:

- Research Seminar in Economics, January 2012, Aachen, Germany.
- TIM Doctoral Student Seminar, June 2012, Wildenburg, Germany.
PAPER III: APP STORE, QUO VADIS? CHALLENGES AND STRATEGIES FOR APP PLATFORMS

Presented at:


- 12th European Academy of Management (EURAM), June 2012, Rotterdam, Netherlands.
### Contents

Summary ............................................. 5

Thesis structure overview ..................... 8

Contents ............................................. 10

List of Figures ..................................... 14

List of Tables ..................................... 16

List of Abbreviations ............................. 17

I  App platforms as two-sided markets – an introduction to the research field ............................. 18

1  Introduction ..................................... 19
   1.1  Motivation ................................. 20
   1.2  Research project outline ............... 22

2  The “app economy” ............................. 24
   2.1  Key concepts and definitions ........... 24
   2.2  Industry overview .......................... 29
   2.3  Key stakeholders of app platforms ..... 32
   2.4  Outlook .................................. 37

3  Two-sided market theory ...................... 39
   3.1  Introduction .............................. 39
   3.2  Historical context and related literature .... 41
   3.3  Definition of two-sided markets ......... 43
   3.4  Two-sided market models ............... 47
4 Research gaps and corresponding research papers
4.1 Derivation of research gaps ........................................ 50
4.2 Research questions and corresponding research papers .......... 52
4.3 Summary of research paper I ...................................... 53
4.4 Summary of research paper II ...................................... 56
4.5 Summary of research paper III ..................................... 59

5 General discussion and conclusion
5.1 Theoretical contribution ............................................ 61
5.2 Managerial implications ............................................ 65
5.3 Limitations and future research ...................................... 66
5.4 Conclusion .......................................................... 68

Bibliography ........................................................................... 71

II Research papers

1 Paper I: An Integrated Two-sided Market Model for Internet Platforms
1.1 Introduction ............................................................. 81
1.2 Two-sided markets ...................................................... 82
1.3 Canonical two-sided market model ..................................... 84
  1.3.1 General assumptions ............................................... 85
  1.3.2 Customer group utility ............................................. 85
  1.3.3 Platform's profit maximization .................................... 86
1.4 Extensions for the canonical model ..................................... 90
  1.4.1 Transaction fees and membership fees ......................... 90
  1.4.2 Review process and quality of participants ...................... 91
  1.4.3 Commission dependent on payments between market sides . 93
  1.4.4 Adjustments for the number of interactions ...................... 94
  1.4.5 Segmentation of participants ...................................... 96
1.5 Utility and profit functions for the integrated model ............... 97
  1.5.1 Sellers' utility equation ........................................... 97
  1.5.2 Buyers' utility equation ........................................... 98
  1.5.3 Platform profit function .......................................... 99
1.6 Solution for the integrated model ..................................... 100
  1.6.1 Optimal prices .................................................... 100
2 Paper II: Toward Understanding Dynamics and Disruptions in Two-sided Markets: A Dynamic Two-sided Market Model 118
2.1 Introduction 120
2.2 Literature and background review 121
  2.2.1 Two-sided market theory 122
  2.2.2 Background on dynamic modeling 124
2.3 Model formulation 126
  2.3.1 Population dynamics in continuous time 126
  2.3.2 Population dynamic in discrete time 130
  2.3.3 Expected utility and NPV 131
  2.3.4 Goal function: platform profit 133
  2.3.5 Optimization problem formulation 134
2.4 Matlab solution and simulation results 136
  2.4.1 Implementation in Matlab 136
  2.4.2 Analysis of population dynamics 137
  2.4.3 Platform profit maximization 139
  2.4.4 Platform kick-off and minimal number of participants 144
  2.4.5 Short-term versus long-term optimization 149
  2.4.6 Price adjustments 152
  2.4.7 Reaction to external shocks 153
2.5 Conclusion 155

Bibliography 158

3.1 Introduction 165
3.2 Literature Review and Background 166
  3.2.1 Platforms 167
List of Figures

1.1 Top 5 Vendors, Worldwide Media Tablet Shipments. . . . . . . . . . 20
1.2 Convergence of the mobile phone form factor. . . . . . . . . . . 21
1.3 Structure of the dissertation project. . . . . . . . . . . . . . . . 23

2.1 Evolution of smartphones. . . . . . . . . . . . . . . . . . . . . . . 27
2.2 Mobile phone sales worldwide. . . . . . . . . . . . . . . . . . . . . 28
2.3 Structure of the mobile industry. . . . . . . . . . . . . . . . . . . . 30
2.4 Global smartphone market, split by platform. . . . . . . . . . . . 33
2.5 Share of developers who work on apps full-time vs. part-time across
different app platforms. . . . . . . . . . . . . . . . . . . . . . . . . . . 35
2.6 Share of app developers across different OS; number of projects
developed simultaneously. . . . . . . . . . . . . . . . . . . . . . . . . . 35

3.1 Two-sided market structure. . . . . . . . . . . . . . . . . . . . . . 40
3.2 Examples of two-sided markets. . . . . . . . . . . . . . . . . . . . . 44
3.3 The key feature of two-sided markets: platform owner has to take
into account two interdependent demand functions. . . . . . . . . . 48

4.1 Research questions and corresponding papers. . . . . . . . . . . . 54

1.1 Sketch of the key determinants of the canonical model of Rochet
and Tirole (2003). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 87
1.2 Sketch of the power set $N^B N^S$ and the reduction to $N^B f(N^S)$ and
$X N^B f(N^S)$. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 96
1.3 Sketch of the key participants of an app platform and interactions
between them (exemplified here by the App Store). . . . . . . . . . . 109

2.1 Cumulated world-wide smartphone sales. . . . . . . . . . . . . . . . 127
2.2 Common modes of behavior in dynamic systems. . . . . . . . . . . 128
2.3 Discrete-time structure of the model dynamics. . . . . . . . . . . . 130
2.4 Rising population and utility. ........................................ 138
2.5 Decreasing population and utility. ................................. 139
2.6 Platform profit depending on membership fees. ........................ 140
2.7 Platform profit depending on membership fee $A^B$ and commission payment. ............................................................ 142
2.8 Platform profit in terms of membership fees $A^B$ and $A^S$. .............. 143
2.9 There are infinitely many combinations of developers and users numbers that are not sufficient to get the platform going. .............. 146
2.10 Adding a small number of agents (in this case one) to at least one of the sides might be sufficient to kick-off the platform. .............. 146
2.11 Platform dynamics over 30 periods. ............................... 150
2.12 Users’ dynamics over 30, 50 and 70 periods. ....................... 151
2.13 Developers’ dynamics over 30, 50 and 70 periods. ................... 151

3.1 The key feature of the two-sided market is that the platform owner has to take two interdependent demand functions into account. ... 170
3.2 Classification of app platforms. ........................................ 175
3.3 Native app platforms. .................................................. 176
List of Tables

2.1 Profit depending on the combinations of initial numbers of developers and users. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 148
2.2 Fees optimized for 30, 50 and 70 periods. . . . . . . . . . . . . . . 149
2.3 Adjustment of optimal fees depending on the time point (after 0, 10, 15, 20 and 30 periods). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 153
List of Abbreviations

**App** software application platform

**App platform** software application distribution platform (for mobile devices)

**MSP** Multi-sided platforms (two-sided markets with more than two sides involved)

**NPV** Net present value

**OS** Operating System

**PC** Personal Computer

**SDK** Software development kit
Part I

App platforms as two-sided markets – an introduction to the research field
Chapter 1

Introduction

“App platforms” are electronic software distribution markets for mobile devices like smartphones or tablet PCs. They gained popularity after Apple launched its App Store in 2008. Since then, app platforms have transformed the entire mobile communications industry, including mobile network operators, device producers, software suppliers, content providers, advertisers, etc. The focus of the mobile communication industry shifted from network operators and hardware providers to the app platform owners. We believe that the “app economy” (cf. MacMillan, Burrows and Ante, 2009), led by Apple and Google, currently belongs to the most exciting, dynamic and disruptive industries.

Platforms (like the App Store) which intermediate between two distinct affiliated groups of customers are called “two-sided markets” (cf. Rochet and Tirole, 2003, p. 990). Such platforms can be effectively analyzed by applying two-sided market theory. The research project presented here combines development of two-sided market theory and application of this theory to such Internet platforms as Apple’s App Store, Google Play (formerly Android market) and Amazon Appstore.

Part I of my research provides an overview of the research field, including motivation and research project outline, a description of the app economy and an overview of two-sided market theory, which is central for the research presented here. Building on that, we identify research gaps and show how the three research papers at hand address these gaps. Subsequently, we provide a brief summary of the research papers, which are included in Part II. We conclude with a general discussion. A more detailed outline of the dissertation follows in Section 1.2. Now we turn to the motivation (Section 1.1) and the research project outline (Section 1.2).
1.1 Motivation

Over the last five years, the mobile industry has undergone significant changes. All branches of the industry have been involved, including mobile devices, software, apps, mobile networks, etc. (Basole and Karla, 2011). The largest disruption in terms of hardware was probably the launch of Apple’s iPhone in 2007 with its innovative touchscreen concept. This was a breakthrough of a new generation of mobile devices, namely smartphones with large touchscreen. In the following years, some hardware producers managed to succeed (e.g., Apple, Samsung, HTC), others experienced considerable difficulties or even ceased to exist (e.g., Nokia, Palm), as Gassée (2012) suggests. The second disruption (cf. Crothers, 2010) was the introduction of tablet PCs with Apple’s iPad leading the way. With 25 million tablets sold in Q2 2012 worldwide (cf. Figure 1.1), these mobile devices managed to replace PCs in many ways, but also introduced entirely new usage opportunities.

![Top 5 Vendors, Worldwide Media Tablet Shipments](image)

**Figure 1.1:** Top 5 Vendors, Worldwide Media Tablet Shipments, unit shipments are in millions. Source: IDC (2012).

These changes in the hardware landscape went hand-in-hand with major shifts in the mobile software. New operating systems were established, like Apple’s iOS, Google’s Android, and previously successful operating systems were abandoned, like
Palm OS or Nokia’s Symbian. Besides operating systems, other type of software assumed a central role in the mobile ecosystem. This type of software were apps. Apps are small pieces of software built to perform certain tasks or fulfill concrete functions, like listening to music, playing games, watching news, translating or providing convenient access to different types of content and media (cf. Oxford Dictionary, 2012). Apps can be web-based or stand-alone programs. For mobile devices, stand-alone programs are currently leading the field (cf. Global Intelligence Alliance, 2010). App distribution platforms for mobile devices are used to make downloading apps simple and convenient.¹

The first app platforms go back as far as the end of the 1990s. For instance, PocketGear – one of the first app platforms – was introduced around 1999. Several other platforms like Handango, GetJar and MobiHand followed. But it was not until 2008, when Apple launched its App Store, that the app platform industry gained traction. Other platforms followed, inspired by the App Store’s success. Since then, the app platform industry has been booming. At the same time, hardware began to converge more and more, as Figure 1.2 illustrates.² These two developments together resulted in app platforms becoming the heart of mobile ecosystems. Gawer and Cusumano (2007) call this phenomenon “coring strategy”.³

Figure 1.2: Convergence of the mobile phone form factor.

---

¹A full definition for the term “app platform” will be discussed in Chapter 2. We will use the short form “app platform” instead of “app distribution platform for mobile devices” from now on.

²This is indicated by patent battle between Apple Inc. and Samsung Electronics Co. Ltd, documented in, for instance, Williams (2012).

³Cf. research paper III.
Most of the (management) literature on app platforms focuses on app development (e.g., Meier, 2010, Allan, 2010). Not much literature is available on the overall analysis of the industry or its theoretical background. The same holds for the strategic and managerial perspective from the platform owner’s point of view. We believe, that two-sided market theory provides a suitable approach to model app platforms. Since currently existing two-sided market models lack important features and parameters to model such markets as app platforms, this represents a second research gap from the theoretical point of view. Most two-sided market studies focus on static models. However, app platforms change over time in a non-linear and disruptive way. This requires possibility to adjust strategy taking market dynamic into account. This represents one more research gap. The next section provides an overview of the dissertation project in general and on how we address these gaps in particular.

1.2 Research project outline

The present dissertation focuses on building a connection between theoretical economic models and applications in electronic online markets as figure 1.3 illustrates. The underlying theoretical concepts are two-sided market theory, indirect network effects and complementary products. The motivating application industry are Internet platforms, in particular mobile app distribution markets, intermediary business models and e-business.

The structure of the first part of this dissertation is as follows. Chapter 2 is devoted to the applied side, namely to the app platform industry, which inspired all papers presented here. Chapter 3 provides general background information on the the theoretical basis of the papers. Then a chapter on research gaps, research questions, and the corresponding research papers follows (cf. Chapter 4). It includes brief summaries of the three research papers. We conclude this Part I with a general discussion of the three research papers. It includes theoretical contributions, managerial implications, limitations and suggestions for future research.

The second part of the dissertation at hand consists of three research papers corresponding to the research gaps mentioned in the previous section. We begin by developing an appropriate two-sided market model, which includes all parameters necessary to model Internet platforms, and app platforms in particular. This is in the focus of research paper I presented here: “An integrated two-sided market model”. The objective of the second research paper “Toward Understanding Dynamics and Disruptions in Two-sided Markets: A Dynamic Two-sided Market
The key goal of the dissertation is to develop a two-sided market model that is suitable for app platform analysis and exploration.

Application
- Internet platforms, especially app platforms for mobile devices
- Intermediary business model
- E-business

Dissertation project
- Introduction of extensions to the two-sided market model, necessary to model Internet platforms
- Construction of an integrated two-sided market model
- Development of a dynamic framework for two-sided markets
- Analysis of challenges and strategies for app platforms

Theory
- Two-sided markets theory
- Indirect network effects
- Complementary products

Figure 1.3: Structure of the dissertation project.

Model” is to provide a two-sided market model which would cover dynamic and disruptive behavior of app platforms. Research paper III presented here, “App Store, Quo Vadis? Challenges and Strategies for App Platforms”, connects two-sided market theory and platform management literature to analyze challenges and strategies for app platforms. The first two papers strive to further advance two-sided markets theory and address identified research gaps. Moreover, the three research papers together elucidate different aspects of Internet platforms and help to understand general structure, challenges and strategies for them, as will be discussed in detail in Chapter 5.
Chapter 2

The “app economy”

In this chapter, we consider key concepts of the “app economy” and provide definitions. Furthermore, we discuss the current state of the industry and the value chain of mobile ecosystems. Subsequently, we describe the main app platform stakeholders, namely app platform owners, developers and users. We conclude with an outlook, including some thoughts on arising research questions.

2.1 Key concepts and definitions

App platforms offer a channel for developers to distribute their apps for mobile devices. Hence, to understand app platforms, we need to know what apps are and what mobile devices are considered. This is the focus of the following section. We begin by discussing the terms “app” and “mobile device”. A definition for app platforms follows.

Apps

“App” is short for application. Applications are software programs that can run on different electronic devices. Apps are created to fulfill certain tasks, like visiting Internet pages, reading texts, editing tables or photos and playing different media. The word “app” gained popularity following the App Store launch. In 2010, the word “app” was even chosen “word of the year” by the American Dialect Society (cf. American Dialect Society, 2011).

In general, there are three kinds of software for mobile devices: operating system, middleware and mobile apps. The operating system controls the processor and memory, middleware is responsible for the interfaces between different software
and hardware parts, and apps are used to perform certain dedicated tasks (cf. Oxford Dictionary, 2012). In the context of mobile devices, apps can range from several kB and up to several GB, but since memory space on a mobile device is limited, they generally need to be small. Apps usually have a dedicated concrete use area, e.g., the Facebook app makes it more convenient to use a Facebook account on a mobile device than would be the case using a browser. Also, their functionality tends to be less broad compared to PC programs. An app is often arranged around content. For instance, 17% of apps in Apple’s App Store are categorized as books and education (cf. Scott, 2012), many newspapers and journals have own apps to share the content. Generally, there are many apps for entertainment purposes on all app platforms (17% are games and further 9% are entertainment on the App Store, as Scott (2012) asserts). This is not surprising given that mobile devices are mostly used on the go, between “real” activities.

Zheng und Ni (2006) suggest that there are two generations of mobile apps. The first generation comprises simple apps like ringtones, instant messaging and personal information management apps. Although many mobile phones available on the market in 2006 were able to run quite complex apps, ringtones were still the most popular ones, as Evans et. al. (2006, p. 198) point out: “Ringtones are by far the most popular application for mobile phones as of early 2006”. The second generation contained more sophisticated apps like mobile commerce, gaming, music streaming and mobile social networking. With the gap between reality and the virtual world becoming increasingly blurred, it can be said that the third generation of apps covers augmented reality, ubiquitous social networks and the merging of functions of different apps. What is key for the third generation of apps is seamless switching between reality and the virtual world, as well as the seamless switching between different functions. For instance, if navigation and social network apps are merged, it is possible to obtain recommendations for a restaurant based not only on objective information, but also on information from social networks, like recommendations of friends, location of friends, etc.

Mobile devices

Over the last five years, two new types of mobile devices have been introduced that changed the entire industry: touch smartphones and tablets. These are the main types of hardware used to run apps on. There are also other types of devices capable of running apps, e.g., computers or music players like iPod. We will focus on smartphones and tablets.
There is extensive debate on the precise definition of smartphones. This may be attributable to the fact that the meaning of this term has evolved considerably over time. As Zheng and Ni (2006, p. 4) point out, “smartphone” referred to a “then-new class of cell phones that could facilitate data access and processing with significant computing power. In addition to traditional voice communication and messaging functionality, a smart phone usually provides personal information management (PIM) applications and some wireless communication capability.”

Encyclopedia Britannica (2012) suggests the following definition:

**Definition 2.1.** Smartphone, also spelled smart phone, mobile telephone with a display screen (typically a liquid crystal display, or LCD), built-in personal information management programs (such as an electronic calendar and address book) typically found in a personal digital assistant (PDA), and an operating system (OS) that allows other computer software to be installed for Web browsing, e-mail, music, video, and other applications. A smartphone may be thought of as a handheld computer integrated within a mobile telephone.

Furthermore, older mobile devices like basic mobile phone used to have a small set of apps (like address book or calendar). But it was not until (touch screen) smartphones were introduced that apps became central for the mobile ecosystem. We would suggest to differentiate between three generations of mobile phones: basic mobile phones, feature phones and smartphones. The key features are summarized in Figure 2.1.

Basic mobile phones were primarily developed mostly for mobile telephony. Feature phones provided some extras, like an integrated camera, mp3-player or radio. Smartphones are characterized by strong computing power, large high-resolution screens, reliance on the Internet and media consumption and usage of third-party apps. As Figure 2.2 shows, smartphones managed to win out compared to other types of mobile phones and are now the driver of the entire mobile industry.

Tablets were pioneered by Apple with the introduction of the iPad in 2010. Meanwhile, a whole new industry has emerged. Figure 1.1 illustrates the development of the tablet industry over time, revealing high growth rates of more than 66% per year. Apple remains the dominant player in the market. Since tablets have more processing power than smartphones, as well as larger screens, many apps have been customized for tablets. Apple, for instance, has an own iPad App Store featuring apps that are adjusted to the iPad.

1Tablets are assumed to be a category on their own, placed between PCs and phones.
Simple mobile phones with simple functions
• Usually no additional features, only mobile calls available
• Key differentiating factors include size, weight and battery life

Additional multimedia features like FM radio, music player, camera central
• Integration of PDA features like calendar, address book, to-do-lists, maps, dictionaries
• A whole range of different form factors available

iPhone (introduced in 2007) caused a revolution in mobile devices with impact in all adjacent industries
• Strong computing power, large high-resolution screens, reliance on the Internet and media consumption and usage of third-party apps
• Convergence of form factor, differentiation driven by mobile apps and the mobile ecosystem (including content availability)

Figure 2.1: Evolution of smartphones in 3 steps: basic phone, feature phone and smartphone.

App platforms for mobile devices

In the previous two sections, we described what apps are, and which hardware they run on. We will now turn to the definition of app platforms. App platform is short for mobile app distribution platform. We follow a definition provided by Businessdictionary (2013):

Definition 2.2. An online marketplace where users of smartphones and other mobile devices can browse, purchase, and download applications, or “apps”, that augment the capabilities of their devices. While Apple, Inc. created the original “App Store” for iPhone apps, and claims copyright to the term, online stores selling mobile apps for other platforms are also referred to as “app stores”.

Many different names have been used for app platforms. The App Store is probably the most common one. As mentioned in the definition, the term App Store was coined by Apple to refer to that part of the iTune service where apps can be downloaded. Apple’s competitors adopted this term for their own services (cf., for instance, Carew, 2009, Furchgott, 2009, Ganapati, 2009). Apple filed a motion to use the term “App Store” as a trademark (cf. MacNN, 2008). This was granted
Figure 2.2: Worldwide mobile phone sales (million units). Development of the smartphone industry is driven by smartphones. In Q2 2013, smartphones outsold feature phones for the first time. Source: Gartner (2013).

at first, but Apple lost the case against the Amazon Appstore (cf. Foresman, 2011). Other terms like app shop, app market, app marketplace are used for app platforms as well. To avoid ambiguity, we use the term app platform. This also reflects the fact that there are many apps that are free of charge – using terms such as app shop or app market would thus be misleading.

As the definition above states, app platforms allow users of mobile devices to browse, purchase and download apps. Usually, app platforms do not program the apps themselves (apart from minor exceptions), but they let app developers design and program app which can be subsequently offered over app platforms.\footnote{We will discuss the processes which take place on an app platform in more detail in Section 2.3.} Therefore, app platforms connect app developers and user of mobile devices. By doing so, app platforms create indirect network effects and “create value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers” to quote Hagiu and Wright (2011, p.2). The fact that app platforms connect two groups of customers valuing each other’s presence is crucial for a market to be called “two-sided”, as we will see in Chapter 3.
2.2 Industry overview

We begin this section with a discussion of the mobile communication industry value chain and the overall structure of the mobile ecosystems. This helps elucidate the role of app platforms in the entire ecosystem. Subsequently, we briefly describe the current development of the app platform industry, providing information on the size of the market.

Mobile communication industry value chain

Mobile ecosystems as we know them today are combinations of many industries: hardware manufacturers, operating system and middleware providers, mobile network operators, content and media providers, app developers and app platform owners. In 2005-2006, mobile network operators were in the center of mobile ecosystem as Evans, et al. (2006, p. 186) suggest:

“These 'mobile operators' ultimately control what mobile telephones their subscribers use, what software platform runs those phones, and what applications can be downloaded onto them.”

Currently, mobile devices and software apps are at the center of customers’ attention, but other participants play an important role in the mobile ecosystem as well. For instance, content availability from iTunes may be an argument in favor of buying an iPhone and serves as a unique value proposition. There are many interdependencies between different parts of the mobile ecosystem, as illustrated in Figure 2.3. Consumers have to choose a mobile device, a mobile plan, the content and software apps.

While the industry used to be focused on the top part of the value chain with hardware playing a central role, we are now observing a shift toward software. As the “Gesellschaft für Konsumforschung” (GfK), the largest German consumer research agency, suggests in its press release from 7 October, 2010 (cf. GfK, 2010):

“Amidst a landscape where overall handset sales are declining, sales of smartphones have steadily increased as more consumers gravitate towards mobile applications. The survey of 1,000 adults found that the value of the smartphone and selection of mobile applications were greater priorities to consumers than reliable coverage and customer service. 'Our research shows that we are at a mobile application tipping point, where the applications are driving customer purchases of the
technology more so than the smartphones themselves,’ said [David]
Krajicek, [Managing Director of GfK Business & Technology].”

![Diagram of the mobile industry]

Figure 2.3: Structure of the mobile industry. Based on Evans et al. (2006).

Many well-established companies from the adjacent parts of the mobile
ecosystem want to profit from the growing popularity of app platforms. They
try to establish own app platforms building on their individual strengths. Apps
and app platforms can trigger consumption of other complementary areas of the
mobile ecosystem. For instance, iOS developers have to use Macs to program apps
for the iPhone or the iPad, therefore iOS apps development results in stronger
demand for Macs. For a potential platform owner it is much easier to set up a
platform if she has a payment process and customer relationships in place, as
is the case for Amazon, Apple or mobile network operators. Being a hardware
and software producer at the same time also brings advantages, like customer
knowledge and expertise in mobile technology. The strategies and objectives of all
potential app platform owners might differ. And this has to be reflected in the
classification of app platforms. For instance, Distimo (2012) suggests the following
four groups: device manufacturers, operating system developers, operators and
independent platforms. This classification is not clear-cut, since many hardware
manufacturers are also operating system providers. In fact, the most successful app

---

3Distimo is a market research company focusing on app platforms analysis.
platforms, like Apple, RIM, Nokia and Windows, belong to this category. Hence, we assume that the integration of software and hardware is an important factor which determines app platform success. Based on this hypothesis, we suggest the following classification: native (or integrated hardware and operating system providers), device manufacturers, mobile network operators and other (e.g., independent) app platforms. Figure 3.2 in section 3.3.2, Part II provides examples for each category.

**App platform industry**

Apple’s App Store and Google Play for Android are probably the most popular app platforms. In fact, many more app platforms aside from these two exist – and some of them were founded as early as 1990s. The launch of the App Store has changed the mobile phone industry in practically all dimensions. After three years on the market there were 425,000 apps available in the App Store. The number of downloads exceeded 14,000,000,000 (cf. Apple, 2011).

The app platform industry as a whole thrived especially in 2011, growing by around 150% and reaching USD 5.6 billion in revenues in 201. Apple managed to remain the market leader, accounting for 75% of total market revenues, by far outpacing other market participants (Kent, 2011). Projections for the future are positive as well: In 2013, total revenues are expected to reach USD 26 billion and this number is estimated to grow up to USD 77 billion in 2017 (Gartner, 2013b).

In 2011, Apple, Google, Nokia and RIM were the most important players in the market. Apple will probably remain the leader for the next 2–3 years, but other platforms will also gain traction. As Gartner (2013a) suggest, Google’s Android currently has the highest sales with over 70% in Q3 2012. Windows and Nokia are continuously loosing market share (Nokia from around 70% in 2006 to under 10% in 2012 in terms of number of handsets sold worldwide), however, together they

---

4 Several hypotheses can be provided to explain why it was not before 2008 that app platforms have gained momentum, for example, usability (size of screen), connectivity (3G and 4G coverage) or the hardware price could have contributed to the app platform success.

5 Cf. for instance, the remark by Steve Jobs, the founder and former CEO of Apple: “The App Store is like nothing the industry has ever seen before in both scale and quality.” (cf. Cohen, 2009) or this comment in Financial Times by Hagel and Brown (2010): “The Big Shift is a fundamental reordering of the way we live, learn, play, and work. A new technology infrastructure is a big part of this transformation. Consider technology platforms such as Amazon Web Services, Google Apps, Android, Facebook, Twitter, the iPhone App Store, and now the iPad... Just as the telephone, automobile, and aeroplane reshaped society in the first half of the 20th century, the digital infrastructure is reshaping life in the 21st.”
have an interesting value proposition for the future. Due to the consolidation and merging of mobile devices and computers, Windows could become the key player in this process. Nokia has the capacity to produce low-cost devices that can boost sales as soon as the high-end market is saturated (cf. Virki, 2012).

2.3 Key stakeholders of app platforms

In this section, we provide a brief description of app platform operations and key stakeholders. At this point, we only include the most important information which is required to understand the app platform structure and its connection to the two-sided markets. Please refer to research paper III for a more detailed analysis of key stakeholders and their strategies.

App platforms include three key types of participants: the platform owner, developers and users (cf. Figure 1.3 in section 1.7.2 of Part II). As we have seen in the previous section, there are other important players like content providers, mobile network operators, etc. Since app platform owners, developers and users are crucial for the app platform’s existence, we will primarily focus on them.

In a nutshell, the functions of the key stakeholders are as follows: platform owners connect developers and users and provide rules and services. Developers program apps and submit them to the platform, so that users can download them. At this point, we would like to provide some background information and explain the overall context. It is necessary to have a view on how app platforms operate, to understand which parameters are crucial and how they can be modeled and analyzed.

App platform owners

An app platform owner covers several functions. It provides the app platform infrastructure (like user interface, server space, etc.) and determines rules for the interaction between the two market sides. She can also provide information about apps and developers and serve as a trusted third party by controlling app quality. Belleflamme and Peitz (2010) refer to the business model used by platforms as an intermediary one, as is discussed in detail in research paper III.

Apple’s App Store was not created to yield high revenues, but rather to strengthen the ecosystem and drive demand for iOS-devices (cf. Ahonen, 2010). As we have seen, app platforms now are a business on their own, especially for the large native platforms (cf. Apple, 2012). The main source of app platform
revenue are commission payments obtained from developers as a percentage of the downloaded app’s price. Additionally, app platforms charge users membership fees in form of an annual lump sum payment and complementary products like mobile devices and software tools. This will be described in more detail in the following sections.

Native app platforms are probably the most important category of app platforms. They produce mobile devices as well as the operating system (and some other parts of software, like apps). Many native app platforms also license their operating systems to other mobile device producers. It is probably not by chance that the most important app platforms are offered by integrated hardware and operating system producers. The biggest advantage of native platforms is that they can develop a holistic strategy and perfectly align software and hardware requirements. The market of mobile operating system owners is highly concentrated as Figure 2.4 illustrates. But nonetheless, it is highly dynamic, as a comparison of the key players and their market shares in 2009 and 2012 shows.

Figure 2.4: Global smartphone market, split by platform. The smartphone market is highly concentrated and very dynamic as this comparison of 2009 Q2 and 2012 Q2 illustrates. Source: Canalys (2010, 2012).

Furthermore, the number of apps on different platforms shows interesting trends and developments. We observe different types of platform dynamics. Consider, for instance, sales development of smartphones by operating systems. This is basically equivalent to consideration of the number of app platform users. Figure 2.1 in section 2.3.1, Part II presents the development of the major operating systems...
over the last 5 years. Cumulated smartphone sales show how the customer populations for different smartphones have evolved over time. Some show exponential growth, like Android, others have grown only slowly over the last 5 years, like Nokia’s Symbian during the last 5 years.

Due to the upsurge in the number of app platforms, the challenges relating to platform competition are currently at the center of app platform owners’ attention. However, new platforms are also being launched. Platform launch and design are key for new platforms. But existing platforms should also reevaluate their design from time to time and consider adjustments in the pricing and/or quality to deter deter entry of new platforms.

**Developers**

Developers program apps and offer them via app platforms. The population of developers is highly heterogeneous: ranging from developers who program apps as a hobby to professional firms whose only business is app development. This is illustrated in Figure 2.5. There are also major differences between app platforms: 86% of RIM’s BlackBerry app developers are professionals, while only 39% are professional developers at Apple’s iOS (cf. GigaOM Pro, 2010).

Mobile operating systems are not compatible, that is, apps created for one operating system cannot be used with other operating systems. Also, the portability of apps from one operating system to others is not straightforward: a transition to another platform involves costs of around 50% of the development cost due to the differences in programming language, operating system and hardware (cf. GigaOM Pro, 2010). The possibility of programming universal apps that run on all platforms is still very limited (Newel, 2011). There are several engines like Titanium, Ramp or PhoneGap with which apps can be developed for more than one platform, but further work is still necessary to adopt the apps. Hence, each developer has to decide which operating system(s) to cater to. It is plausible to assume that hobby developers only develop for one operating system (the one they are using themselves) and that professionals typically develop apps for several platforms. iOS is by far the most popular app platform, however, many developers

---

6 Apple iOS includes only iPhones. To take the full impact of the operating system into account, iPads and iPods ought to be considered as well.

7 With regard to Nokia, we have to take into account that this is only a part of a larger picture. They have been part of the smartphone market since 1999, hence, in 2007–2012, their smartphones were in a different phase of the product life cycle compared to Android smartphones.
also develop apps for other operating systems, as Figure 2.6 illustrates. As many as 55% of developers only work on one or two app projects at the same time.

To participate in an app platform, developers have to pay a membership fee and commission. The membership fee is paid once a year. It can vary for different platforms and different segments of developers e.g., developers pay a membership fee of USD 99 for the App Store. The commission fee for the majority of app platforms is 30%.
platforms is currently 30% of the app price (cf. for instance Apple, 2013, Duryee, 2010). The developers set prices and receive 70% for each download. Some app platforms review apps before offering them in their store. For instance, Apple reviews apps. 95% of apps are reviewed in less than 7 days (cf. Apple, 2010). There are also cases in which the review procedure takes up to several weeks. The objective of the review process is to ensure that apps fulfill minimum quality requirements (e.g., that the app does not include viruses and that it is consistent with its description). If no quality review procedure is in place as is the case with Google Play, formerly Android market, it may result in redundancy and value erosion due to copying and danger of malware. App quality is an important factor that should be taken into account (cf. Developer Android, 2013).

Once the app is made available on an app platform, it can be downloaded, reviewed and rated by users. Developers and app platform receive payments for paid apps. We will describe the users’ role in detail in the next section.

Platform users

Platform users represent the second market side of app platforms. Users search and download apps, they pay for and rate them. Therefore, it is important for the platform to be able to attract as many users as possible, who are willing to pay for apps. Usually, native app platforms can be accessed through a pre-installed app on a mobile device. Some platforms also allow app searches and downloads on computers. Yet, in order to use apps, the user must possess a mobile device.\(^8\) Hence, mobile devices are complementary goods for apps (cf. Riley, 2010). Mobile devices can be considered a one-time membership fee (or in fact, a regular payment, if the mobile device is replaced every 1-2 years). Users tend to view mobile device and available apps as a package. They consider the entire ecosystem and then decide which hardware-software combination to pick.

The user interface of an app platform usually consists of different areas: a few featured apps, top lists and a search window. When searching for an app, a user can quickly see the amount of available apps, prices and date of last update. To obtain further information, like features and functionality, screen shots and rating, the app needs to be opened. Once the user decides which apps to obtain, she can download or buy them.

\(^8\)Here, we only consider app platforms for mobile devices. Other app platforms, e.g., for other devices, like PCs, follow similar principles.
Many app platforms use “one-click-shopping” (cf. Wolverton, 2000). In the present case, the account data has already been provided to the platform and the user only needs to confirm the password. This means that platforms are in the possession of the client’s contact data together with the credit card information. This is considered a measure of a platform’s influence. It also has an impact on other participants of the ecosystem. If earlier mobile network operators owned customer contacts (not the hardware producers), many hardware and OS producers have managed to leverage mobile network operators through own app platforms and have become key contacts. App platforms usually charge a commission fee, which depends on the number of interactions (or downloads) and the value of the app. The remaining part of the payment goes to the developers. Hence, besides membership fees, a model for app platform has to include usage fees (or commission fees) and payments between customer groups.

2.4 Outlook

Over the last 5 years, the mobile industry in general and app platforms in particular were experiencing extensive changes as was discussed in the Section on Mobile industry value chain. The role of each and every mobile communication value chain participant was altered. In particular, mobile network operators who reigned the industry by facing the customers, were crowded out by app platforms. The latter took over customer relationships and in the following became central for the new mobile ecosystems. Using the terms of Eisenmann (2007), we can say that app platforms have “cornered” the entire mobile industry thereby establishing the new “app economy” (cf. MacMillan, Burrows and Ante, 2009). We believe that these developments call for research which would help to analyze and better understand them.

The first challenge we are facing is to determine, which economic theories and models can be useful for our analysis. As was described in the previous section, App platforms are “creating value primarily by enabling direct interactions between two distinct types of affiliated customers”, developers and users (cf. Hagiu and Write, 2011, p.2). We will show in the following Chapter, that this qualifies app platforms as so-called two-sided markets.

We believe that two-sided market theory is central for modeling and understanding app platform. Further related economic theories include network economics and the theory of complementary and multi-product pricing (cf. Katz and Shapiro, 1985, 1986; Farrell and Saloner, 1986) and theory of information goods
(cf. Shapiro and Varian, 1999). All together, these economic theories and models allow us to approach questions like “How to model app platforms?”, “Which pricing instruments should be used by app platform owners?”, “How to combine different pricing instruments?”. The next Chapter provides an overview of two-sided market theory and research paper I addresses research questions mentioned above.

As was discussed in the “Industry overview” Section, the app platform industry is highly dynamic with several companies fighting for survival and leadership in the new mobile communication world. Therefore, we would like to understand, how to model app platform dynamics. Research paper II addressed these issues, answering such research questions as “How to model app platforms in a dynamic setting?”, “What is the difference between short-term and long-term strategies?”, “What is the optimal reaction to competitor’s entries and external shocks?”.

Overall discussion of strategies for app platform and differences between the life-cycle phases builds on strategic platform management literature (e.g., Gawer and Cusumano, 2008; Eisenmann, 2007). Research paper III combines the insights from all aforementioned economic theories and models to provide answers to questions related to app platform strategies along the life-cycles. In the following Chapter we will concentrate on two-sided market theory which is central for all three research papers mentioned above. Other aforementioned economic theories are discussed in more detail in the respective research papers.
Chapter 3

Two-sided market theory

Two-sided market theory is central for all three research papers presented here. It considers markets in which a platform connects two groups of customers who value each other’s presence. We begin by explaining the intuition behind the two-sided market concept. Then, in Section 3.2 we describe the historical context and the related literature and provide examples from various industries showing the huge range of possible applications. Section 3.3 focuses on providing a formal definition for two-sided markets. And finally, we discuss the two-sided market model provided by Rochet and Tirole (2003), which is considered canonical.

3.1 Introduction

Two-sided markets can roughly be defined as platforms that enable interaction between two groups of customers who value each other’s presence (cf. Rochet and Tirole, 2003; Evans, 2003, Tag, 2008). The underlying phenomenon is called “indirect externalities” or “indirect network effects”: the utility on the one side of the market increases with the number (and/or quality) of participants on the other side. Examples of platforms that can be interpreted as two-sided markets range from credit card systems and software platforms to night clubs and shopping malls.

The underlying structure of two-sided markets can be represented graphically as shown in Figure 3.1. A platform owner connects users/buyers $B$ with developers/sellers $S$. The owner charges membership fees$^1$ $A^B$, $A^S$ and usage fees$^2$ $a^B$ and $a^S$ for the given platform. In return, users obtain per transaction benefits $b^B$ and membership benefit $B^B$, and seller obtain $b^S$ and $B^S$. $r$ stands for the

$^1$Membership fees are also called lump sum or upfront registration fees.
$^2$Usage fees are also called transaction fees.
amount, which a buyer pays for a good bought from a seller. Some platforms use commission fees, allowing for direct payments between users and developers and charging a certain percentage \((1 - \gamma)\), with \(\gamma\) being the share of payments obtained by developers.

Figure 3.1: Graphical representation of the two-sided market structure includes the platform owner, sellers and buyers.

The presence of indirect network effects that cannot be internalized by sellers and buyers themselves represent the basis for the platform’s existence. As Evans (2011, p. 5) asserts:

“Generally, one can think of two-sided platforms as arising in situations in which there are externalities and in which transaction costs, broadly considered, prevent the two sides from solving this externality directly. The platform can be thought of as providing a technology for solving the externality in a way that minimizes transactions costs.”

The two-sided market’s owner has an intermediary role. She acts as a gate keeper, providing a platform where two groups of agents can interact (cf. Belleflamme and Peitz, 2010). A two-sided market functions as a substitute for direct interaction between the two customer groups. It also acts as a substitute for dealers who buy and sell the product. Two-sided market owners charges for access to the platform and/or for transactions via the platform.

In addition to providing the possibility to interact, two-sided markets can provide information about the products and services offered by one side. Consider, for instance, Amazon product reviews. Other platforms provide information about
the agents, e.g., on eBay, evaluations of the interaction on both sides can be submitted: sellers can provide feedback on transactions and similarly, buyers can rate and comment on the interaction with the seller. This results in reputation building and makes information on agents’ reliability and other characteristics available to future buyers and sellers. That is, the platform offers trusted third-party services (cf. Belleflamme and Peitz, 2010). Most app platforms perform three functions: they act as platform operators by connecting the agents and charging for access and transactions, but they also act as infomediaries and trusted third-parties providing information about the products and the agents.

### 3.2 Historical context and related literature

The two-sided market concept appears quite simple. What is more surprising is the fact that two-sided market theory originated around 2001 – only a decade ago. In 2001, the first research papers on two-sided markets were circulated by Rochet and Tirole, Caillaud and Jullien. They were published in 2003, initiating a boost of literature on two-sided markets.

The studies of Rochet and Tirole (2003, 2006) are considered the “most influential” (Jullien, 2012, p. 163). They coined the term “two-sided market” for platforms that connect “two distinct sides whose ultimate benefit stems from interacting through a common platform” (cf. Rochet and Tirole, 2003, p. 990). Based on the credit card market, they developed a model which describes price allocation between the two market sides. They only consider usage fees $a^B$, $a^S$, and no membership fees, and assume that the number of interactions is the power set of the number of participants, that is, each seller interacts with each buyer. This model has become the canonical model for two-sided markets. Over time, many extensions were developed for it. We will provide a detailed discussion of this model in Section 3.4.

The research paper by Caillaud and Jullien (2003, p. 309) discusses “imperfect price competition between intermediation service providers”. They model a Bertrand game between two matchmakers, taking into account indirect network effects, usage and membership fees, multi-homing possibilities and bargaining over usage fee allocation between the two market sides. The main contributions by Caillaud and Jullien (2003) include the calculation of equilibrium market structures and determination of entry deterrence strategies, like usage of transaction fees instead of membership fees.
Two-sided market theory developed very rapidly, covering various settings, modeling approaches and application areas. The main reason why two-sided market theory has recently gained such significance is explained by Eisenmann et al. (2006, p. 101) as follows:

“In the past, this lack of understanding was less problematic because executives usually had the luxury of formulating strategies for two-sided markets through trial and error. Markets today are less forgiving. Many opportunities for platform creation arise in high-tech sectors with short product life cycles. Opportunities also abound in traditional industries reconceived as two-sided networks. And, thanks to the Internet, firms have easy access to both sides of new markets. In this environment, if you draw attention to a platform opportunity and don’t get it right the first time, someone else will.”

Two-sided market theory has its origins in network economics and the theory of complementary and multi-product pricing. Network economics introduced the concept of network externalities, where the utility of consumers depends on other consumers joining the network (cf. Katz and Shapiro, 1985, 1986; Farrell and Saloner 1986). Two-sided markets extend the concept of network externalities to indirect (intra-market) network effects, the main difference being that the utility of consumers depends on the number of consumers on the other market side, and not the same side as for direct network effects. For instance, users might value other users joining an app platform because they can exchange information or play games together, but what they ultimately care about, is the number (and quality) of available apps on the platform. Hence, it is necessary to differentiate between inter-market and intra-market network effects.

Complementary products theory suggests that not only the total price for the complementary product is relevant, but also the allocation of prices to the single complementary product (cf. Baumol et al., 1982; Wilson, 1993). This is also the core element of the two-sided market pricing theory: on two-sided markets, it is necessary to attract users as well as developers, and it might be useful to subsidize one side at the cost of the other. The correct fees allocation is crucial for two-sided markets and the consequences of failing to do so can cause a platform to go out of business in a short time. For instance, when Yahoo raised seller fees in 2001, the result was a reduction in listings by 90%. The higher fees for Yahoo caused the sellers to switch to eBay.
The literature on two-sided markets exploded during the last decade along four main directions of research:

- Introduction of new extensions for a static monopoly model (see Armstrong (2006) and Rochet and Tirole (2006) on membership fees, Hagiu (2009), Jeon and Rochet (2010) on quality preference of participants);

- Analysis of duopoly setting and development of extensions for it (see Armstrong (2006) on “competitive bottlenecks”, Choi (2010) on tying and multi-homing, Tag (2008) on comparison of open and closed platforms);


The emphasis has clearly been on the first two research directions — development of extensions for monopoly and duopoly cases. The majority of studies investigates one extension at a time: they either consider the impact of preference for quality or payments between market sides, namely usage fees or membership fees.

Many markets can be interpreted as two-sided. Figure 3.2 contains some particularly prominent examples, like credit card, night clubs or operating systems. The variety of markets that can be interpreted as two-sided has fostered the discussion about the appropriate definition for two-sided markets. We will discuss the definition attempts in detail in the next section.

### 3.3 Definition of two-sided markets

Various attempts have been made to provide a definition for two-sided markets. The “intuitive” definitions refer to the bringing together of two distinct groups of customers, two market sides that value each other’s presence, or they explicitly cite indirect network effects.

One of the first attempts by Roche and Tirole (2006, p. 645) is as follows:
Examples for the two-sided markets range from auction platforms over night clubs and to operating systems.

<table>
<thead>
<tr>
<th>Intermediary</th>
<th>Market side 1</th>
<th>Market side 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auction platform</td>
<td>Buyers</td>
<td>Sellers</td>
</tr>
<tr>
<td>Bank</td>
<td>Credit card user</td>
<td>Merchants</td>
</tr>
<tr>
<td>Night club</td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Magazines, TV</td>
<td>Readers</td>
<td>Advertisers</td>
</tr>
<tr>
<td>Operating system</td>
<td>User of software programs</td>
<td>Software developer</td>
</tr>
</tbody>
</table>

Figure 3.2: Examples of two-sided markets. Source: based on Parker and Van Alstyne (2005).

Definition 3.1. Two-sided (or, more generally, multi-sided) markets are roughly defined as markets in which one or several platforms enable interactions between end users, and aim to get the two (or multiple) sides “on board” by appropriately charging each side. That is, platforms court each side while attempting to make, or at least not lose, money overall.

Evans et al. (2006, p. 54) consider the aspect of “valuing each others’ presence” central for two-sided markets:

Definition 3.2. Multisided platforms\(^3\) cater to two or more distinct groups of customers. Members of at least one customer group need members of the other group for a variety of reasons. Platforms help these customers get together in a variety of ways and thereby create value that the customers could not readily obtain otherwise.

Something similar is true for Tag (2008, p. 5):

Definition 3.3. On two-sided markets, platforms intermediate transactions between two groups of agents valuing each other’s presence.

Furthermore, indirect network effects can be considered a crucial feature of two-sided markets. The following definition was provided by Choi (2010, p. 608):

\(^3\)Evans et al. (2006) use the terms “multi-sided markets” and “multi-sided platforms” in addition to “two-sided markets”. Sometimes more than two customer sides can be connected through one platform.
Definition 3.4. The defining characteristic of two-sided markets is indirect network effects or inter-group network externalities that arise through improved opportunities to trade with the other side of the market.

The first formal definition of two-sided markets was developed in Rochet and Tirole (2006, p. 648), based on the importance of fee allocation as opposed to the overall level of the fees:

Definition 3.5. Consider a platform charging per-interaction charges $a^B$ and $a^S$ to the buyer and seller sides. The market for interactions between the two sides is one-sided if the volume $V$ of transactions realized on the platform depends only on the aggregate price level $a = a^B + a^S$, i.e., it is insensitive to reallocations of this total price $a$ between the buyer and the seller. If by contrast $V$ varies with $a^B$ while $a$ is kept constant, the market is said to be two-sided.

Furthermore, Rochet and Tirole (2006) discuss the possibility of defining two-sided markets as those markets where Coase theorem does not hold. Assume a situation where externalities exist, transaction costs are zero, bargaining is possible and property rights are established. Then, according to Coase (1960), the outcome of negotiations would be efficient and independent of the initial allocation of goods/fees. Rochet and Tirole (2006, p. 649 ff.) show that, unfortunately, the failure of Coase theorem is necessary but not sufficient for a market to be two-sided.

Later, Roche and Tirole (2006, p. 657 ff.) show that their formal definition only described the case where membership fees are zero. They therefore extend the formulation to the case where usage fees are neutral, but membership fees allocation plays a role. The verbal formulation of this definition is as follows:

Definition 3.6. Factors making a market two-sided include (a) transaction costs among end-users or, more generally, the absence of, or limits on the bilateral setting of prices between buyer and seller, (b) platform-imposed constraints on pricing between end-users, and (c) membership fixed costs or fixed fees.

The most recent definition has been proposed by Hagiu and Wright (2011, p. 2):

Definition 3.7. We define MSP to be an organization that creates value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers.
One important implication of this definition is that indirect network effects are not assumed to be central for a market to be two-sided. Hagiu and Wright (2011, p. 3) also show that indirect network effects are neither necessary nor sufficient. The second implication is that they do not consider price structure to be defining for the two-sided markets:

“[...] our definition suggests that the focus on price structure across the multiple sides may not be the only (or even the main) point of difference when comparing MSPs with other organizational forms. Rather, the economics of MSPs as analysed from the vantage point we propose emphasizes their role as an alternative form of intermediation that directly brings together different affiliated customers rather than acting as a middle-man standing between them, which we call a re-seller. By requiring that MSPs enable direct interactions, we are able to clarify what distinguishes MSPs from re-sellers (e.g. grocery stores, retailers). By requiring that multiple customer types be affiliated, we are able to clarify what distinguish MSPs from input suppliers.”

It remains to be seen whether this definition will be adopted by the two-sided markets research. From our point of view, this is a simple yet powerful definition of two-sided markets, that can be helpful in various contexts. Hence, we will follow Hagiu and Wright (2011) and use their definition of two-sided markets.

On the whole, the discussion regarding definition of two-sided markets shows that this phenomenon, although easy to grasp intuitively, is still not straightforward to define. All provided definitions seem to be contestable, in some settings they may appear too broad or too narrow, too rigorous or too fuzzy. As Rysman (2009, p. 127) suggests, a way out may be to concentrate on the impact of the “two-sidedness”:

“The interesting question is often not whether a market can be defined as two-sided – virtually all markets might be two-sided to some extent – but how important two-sided issues are in determining outcomes of interest.”

This implies that analyzing a certain industry, we should concentrate on understanding the influence of the two-sided effects. Consider, for instance, app platforms. They connect users and developers, as was described in Chapter 2. Users value developers’ presence, since developers offer apps. In turn, developers’ revenue depends on the users’ demand for apps. Therefore, app platforms are
two-sided markets according to simplified definitions like 3.1, 3.2, 3.3 or 3.7. Also, indirect network effects are present on the app platforms. Hence, app platforms also comply to the definitions based on indirect network effects like 3.4. Similar holds for definitions, where price allocation is central, like those provided in Rochet and Tirole (2006). Overall, we observe that app platforms seem to exhibit all typical two-sided market features. Therefore, in this case it does not really matter, which definition we pick. Hence, we have to agree with Rysman’s (2009) conclusion that it is not central, if an industry at hand can be considered two-sided by definition, it is rather the fact, that it is affected by two-sided issues.

3.4 Two-sided market models

This section introduces two-sided market models. Several parts of this section are used in the research papers included in Part II. We begin with the canonical two-sided market model by Rochet and Tirole (2003). Then we briefly discuss extensions to this model. The canonical model developed by Rochet and Tirole (2003) conveys the key idea of two-sided markets. At the same time, it is not particularly complicated and provides the common denominator for several two-sided market models. This characteristic is crucial for us, since our aim is to integrate the most important extensions into one model. In the following, we describe the model of Rochet and Tirole (2003). We begin with customer utility and proceed with platform profit and its maximization.

The model of Rochet and Tirole (2003) was motivated by credit card systems. In their canonical model, the authors include usage fees \( p_B \) and \( p_S \) as decision parameters for both market sides and take into account costs per interaction for platform \( c \). Two-sided market models are usually based on three equations: the platform profit equation and the two utility equations for the two market sides (cf. Rochet and Tirole, 2003). All of them can have a membership and a usage part. Membership benefits, fees and costs are induced only once, usage benefits, fees and costs are recurring and depend on the number of transactions, e.g., downloads.

The key insight of two-sided market models is that the solution does not only depend on the total fee level, but on the pricing structure. Hence, total demand (and total revenue) depend on the allocation of fees among the two market sides. Imagine two customer groups (sellers and buyers) with their respective demand curves shown in Figure 3.3. Assume that the buyers’ fees are reduced and sellers’ fees are increased by the same amount. As a result, the number of buyers increases significantly, attracting new buyers so that the sellers’ demand curve shifts. The
total effect is a relatively minor revenue reduction on the buyers’ side, leading to a strong revenue increase on the sellers’ side. This example shows the interdependence between the market sides and the importance of finding optimal fee allocation.

![Diagram](image)

Figure 3.3: The key feature of two-sided markets is that the platform owner has to take into account two interdependent demand functions.

Traditional economic intuition suggests that if the prices for both sides are equal in the beginning, a price increase is more effective on the side that has a steeper demand curve, while a reduction will be more effective on the side with the flatter curve. This still holds for two-sided markets. One prominent example are free drinks for women at night clubs. Often, women not only have free entry, they are even offered a free drink. If there are many women in a night club, men are willing to pay more due to a steeper demand curve, thus compensating for the revenue loss when offering free drinks.

What is new in two-sided market theory is that in equilibrium, the ratio of fees for the two market sides ought to be proportional to the ratio of their price elasticities (not the other way around). The side with the lower price elasticity pays less than the other side and is often even subsidized (“subsidy side”) to attract the other side (“money side”). This result was first reported in Rochet and Tirole (2003). It is often seen as counterintuitive, as the more elastic market side is supposed to pay more (Bolt and Tieman, 2005). Price elasticities cannot be treated as constants, but should be seen as functions of prices. The inverse slopes of demand curves are not equivalent to price elasticities. As Krueger (2009) shows, this resolves the seeming contradiction.
For the model to reflect the app platform’s structure, we have to adjust the canonical model of Rochet and Tirole (2003). We have to consider additional parameters and extensions, such as usage fees, membership fees, payments between customer groups, quality review of participants, which were discussed in different research papers on two-sided markets in a different context or industry. Armstrong (2006) and Rochet and Tirole (2006) introduce membership fees and payments between customer groups, and Hagiu (2009) and Jeon and Rochet (2010) analyze quality reviews. New parameters must be introduced, like segmentation of participants, commission payments and adjustments for the number of interactions.

For the competition between platforms, multi-homing is an important issue. “Multi-homing” occurs when participants potentially join more than one platform (Rochet and Tirole, 2003, 2006; Armstrong, 2006; Armstrong and Wright, 2007; Sun and Tse, 2007). Market participants might choose between three possibilities: to not join any platform, to join only one platform (“single-homing”) or to joint more than one platform (“multi-homing”). The decision is taken at the individual participant’s level, that is, in the multi-homing case not all participants need join more than one platform, only some. For the single-homing, not all agents have to be part of the same platform, but they might decide to join different platforms (albeit only one at a time). Single-homing behavior can be driven by requirements imposed by platforms, like exclusive contracts. Alternatively, it can be driven by costs of multi-homing, for instance, when platforms are incompatible or require high membership fees. The more single-homing behavior is observed, the more likely the domination of a single platform (“winner-takes-all” dynamics).

Although many parameters were introduced to extend the canonical two-sided market model, some parameters that are necessary to reflect app platform structure are still missing. Also, to be able to analyze all parameters simultaneously, they have to be integrated into one model. This leads us to research gaps which will be discussed in the next chapter.
Chapter 4

Research gaps and corresponding research papers

We begin this chapter with the derivation of research gaps. To these research gap, we provide the corresponding research questions and research papers presented here. Brief summaries of the three research papers follow in Sections 4.3, 4.4 and 4.5 for the three research papers respectively.

4.1 Derivation of research gaps

As was mentioned in Chapter 1, this theses is rooted in two areas: on the one hand, it is motivated by the need to analyze and understand emerging Internet platforms, especially, mobile app distribution platforms. On the other hand, it aims at further developing two-sided market theory, which can be used to model Internet platforms. Hence, the motivation and research gaps derivation are also two-fold, including both applied and theoretical aspects.

The first research gap concerns analysis and modeling of emerging Internet platforms, such as the App Store, Amazon and Google Play. There are many books describing how to develop apps for the App Store, or how to be successful selling on the Amazon. But what is missing, is a model, which would help to analyze key aspects of these platforms. The App Store, Amazon and Google Play connect two groups of customers who value each other, and hence these markets are based on indirect network effects. Two-sided market theory provides models for the markets. Two-sided markets theory was evolving over a decade by now. Many extensions were introduced, many industries were interpreted as two-sided markets. But emerging Internet platforms were not yet covered. To be able to model behavior of
the platform participants and to understand strategies from the platforms’ point of view, the following parameters ought to be included: membership and usage fees, payments between the two market sides (e.g., users and developers), quality of products, customer segmentation and the number of market participants and their interaction patterns.

Furthermore, all these parameters ought to be considered simultaneously. Research papers on two-sided markets usually concentrate on one parameter at a time. For instance, Jeon and Rochet (2010) introduce parameter “quality”, but they interpret it in a context without payments between customer groups. Hence, a model is needed which would combine in one model as many relevant parameters as possible. This would allow to consider trade-offs between different parameters and analyze how they influence each other.

As was described in Chapter 3, two-sided market theory evolved along four major directions: i) introduction of new extensions for a static monopoly model, ii) analysis of duopoly setting and development of extensions for it, iii) introduction of dynamic view, and iv) conducting of empirical research. The majority of research papers on two-sided markets are concerned with a static view. Dynamic models are just beginning to receive attention. Since such industries as Internet platforms are highly dynamic in a non-linear way and prone to disruptions, static models are not sufficient to capture and ensure full understanding of Internet platforms. Therefore, we believe that a dynamic model need to be developed, which would reflect dynamic and disruptive nature of Internet platforms. Currently available models, e.g., Sun and Tse (2007) or Cabral (2011) do not include parameters necessary to model app platforms, such as commission fees, and are not well-equipped to answer research questions relevant for app platforms.

The next area which required additional attention from our point of view, is application of two-sided market theory and platform management literature to such emerging markets as mobile app distribution platforms. Currently available literature on app platforms does not cover such aspects, but rather focuses on app development (e.g., Meier, 2010, Allan, 2010). What is also lacking, is an industry description and analysis. We apply management literature developed by Gawer and Cusumano (2007) and Eisenmann (2007) to the app platform context and develop strategies for app platforms.

The aforementioned research gaps range from purely theoretical two-sided market models development and to such applied aspects, as app platform industry description and analysis. Hence, all of them require a different approach. Our proposal of how to begin covering these gaps follows in the next section.
4.2 Research questions and corresponding research papers

The papers presented here are organized along three lines according to the research gaps identified in the previous section. The first research paper presented here, “An Integrated Two-sided Market Model for Internet Platforms”, depicts a general integrated two-sided market model for online platforms building on research from Rochet and Tirole (2003, 2006), Armstrong (2006), Hagiu (2009), Jeon and Rochet (2010) among others. We derive a close-form solution for it. This is supposed to cover the gap of developing a two-sided market model suitable for Internet platforms. Also, it provides an integrated model, tying the most relevant parameters into one model. Research questions addressed in research paper I are as follows:

• How to model two-sided markets (esp. app platforms)?

• Which additional parameters are needed to model such online platforms as app platforms?

• Is it possible to integrate all necessary parameters into one model?

• Is there a closed-form solution for this integrated model?

Research paper I is a mostly theoretical, it is rooted in Industrial Organization theory. One of its key objectives is to further develop two-sided market models. At the same time, it provides a basis for analyzing and understanding Internet platforms, in particular app platforms.

The next research gap identified in the previous section concerns possibilities of developing a dynamic two-sided market model presented in research paper II. This is needed to reflect dynamic and disruptive nature of Internet platforms. This model helps to answer such research questions as

• How to model two-sided markets in a dynamic setting?

• How to model platform population dynamics?

• What is the difference between the short-term and long-term optimization?

• What is the optimal reaction to competitors’ entries and external shocks?

• Is the result of optimization consistent with our observations in the real world?
Research paper II “Toward Understanding Dynamics and Disruptions in Two-sided Markets: A Dynamic Two-sided Market Model” develops a dynamic two-sided market model based on dynamic systems and optimization theories. Since this model is too complex to be solved analytically, we use Matlab simulation to obtain the results. The dynamic model at hand shows, how platform decisions are impacted by consideration of population dynamics. This enables us to derive strategies which remain valid over time, as opposed to static models.

The third research paper, “App Store, Quo Vadis? Challenges and Strategies for App Platforms” is devoted to the challenges and strategies for app platforms. It provides an industry description and an overview of key app platform stakeholders. Research paper III connects two-sided market theory and platform management literature. Based on these theories and app platforms analysis, it identifies challenges and develops strategies to mitigate these along the life cycle phases. Therefore, research questions addressed in research paper III include:

- How can two-sided market theory and strategic platform management literature be combined to derive strategies for app platforms?
- What are the key challenges and strategies for app platforms?
- How do app platform strategies evolve in different life-cycle phases?

Figure 4.1 summarizes the research questions along the identified research gaps. The three research papers presented here correspond to these three areas of research questions. In the next three sections we provide brief summaries of the three research papers.

4.3 Summary of research paper I

As was pointed out in Chapter 3, a broad range of two-sided market models evolved over the last decade. Most of the models add one parameter at a time. However, in order to take account of the trade-offs between different parameters, such as quality and various pricing instruments, all of them need to be integrated into one model. One main objective of the research paper I is to elaborate an integrated model, which includes such prevalent parameters as usage and membership fees (Rochet and Tirole, 2003, 2006; Armstrong, 2006), payments between customer groups (Rochet and Tirole, 2006) and quality review of participants (Hagiu, 2009). Furthermore, we introduce three new parameters: i) commission payment dependent on payments
between customer groups, ii) segmentation of participants, and iii) adjustments for the number of interactions.

Commission payment dependent on payments between customer groups is crucial for such platforms as the App Store or eBay. Since the price of apps at the App Store and the value of goods sold on eBay vary considerably, platform owners link their commission to the price of the apps/goods. On the one hand, this makes selling cheap (or even free) apps and goods profitable for the seller/developer side. This drives traffic. On the other hand, it ensures that platform owner obtains big profits for high-priced apps and goods.

The second extension – segmentation of participants – makes it possible to apply price discrimination inside one market side. This reflects the differentiation available on many platforms, including app platforms and e-commerce platforms. For instance, the App Store membership fee varies for different developer groups: usually, developers pay USD 99 per year, while an enterprise developer license costs USD 299, and universities can join for free. Amazon or eBay typically differentiate between private and professional sellers, offering different services and providing different pricing models for them.
Usually, two-sided market models assume that on platforms, each participant on one side of the market interacts with each participant from the other side exactly once. The mathematical term for the number of interactions in this case is the “power set”. This would be equivalent to each and every iPhone owner downloading all available apps on her smartphone. The third extension we introduce is crucial for modeling real-world platforms, where participants on the one side of the market interact with only a small fraction of participants on the other side. In this case, using the power set would lead to highly implausible results. Imagine what would happen if each and every iPhone owner would download all available apps on her smartphone. Hence, it is necessary to make an adjustment. We assume that the interaction (or purchase) decision is a two-step process: the first step is taken by buyers. It includes scanning for possible interaction partners or apps. The second step is the selection of partner(s) from all those scanned. To better illustrate the importance of this adjustments, we present an example. If each of the 125,000,000 iPhone owners bought or downloaded each of the 300,000 available apps, this would result in 37.500,000,000,000 downloads instead of the registered 7,000,000,000 downloads, which is less than 1/5300.\(^1\) The power set rule does not take into account the crowding out and the search effects: at the beginning, users/buyers are pleased to have a variety of choices, but at a certain point in time the effect reverses, since they start experiencing difficulties to find what they want. Also, due to the law of diminishing marginal utility, the increase from 100 to 200 participants will have much more impact than the increase from 100,100 to 100,200 participants. The adjustments for the number of interactions allows taking this into account.

Despite the high number of parameters, the new integrated two-sided model can still be solved analytically. We derive equations for buyers’ and sellers’ utility and platform profit and transform them so they can be solved, similar to the extended canonical model of Rochet and Tirole (2003, 2006). In the core of this solution is the argument, that usage and membership fees are interdependent. That is, if one of them is fixed (e.g., membership fee), the other part (usage fee) cannot vary arbitrary in the optimal case. The other consequence is that the solution is not unique (cf. Armstrong, 2006; Reisinger, 2010), there exists more than one combination of usage and membership fees. This interdependence is one important point, which becomes visible once we consider an integrated model, which includes both, usage and membership fees.

Considering quality reviews, we realize that there is a trade-off between high overall price level, higher average quality and lower number of participant

\(^1\)All numbers as of November 2010, see www.148apps.biz.
on the one hand, versus low overall price level, lower average quality, but higher number of participant on the other hand. These trade-offs become clear through the simultaneous consideration of all parameters.

Finally, we show an example of how to apply the integrated model to app platforms. The model at hand advances two-sided market theory, proposing new extensions and integrating all parameters in one model. At the same time, it creates a basis for analyzing and modeling newly emerging Internet platforms.

4.4 Summary of research paper II

Most two-sided market models focus on pricing strategies in a static setting (see, for instance, Rochet and Tirole, 2003, 2006; Armstrong, 2006). As was mentioned in the previous sections, a static model is not sufficient to reflect development of Internet platforms. To provide suggestions which would be relevant for the real-world applications, we need to take dynamics and disruptions into account. Therefore, a dynamic two-sided market model is required to reflect these aspects. Research paper II “Toward Understanding Dynamics and Disruptions in Two-sided Markets: A Dynamic Two-sided Market Model” addresses this issue.

The dynamic two-sided market model at hand is based on dynamic systems theory (cf. Stermann, 2000), population diffusion and evolution examples from life sciences (cf. Schoen, 2006), and finally, on differential game theory \(^2\) (cf. Dockner et. al, 2000). This theories help us to define problem structure and to develop equations which reflect dynamics of the two market sides. We consider a platform, which distributes goods (e.g., software apps), offered or even produced by the seller side (e.g., developers) to the buyers (or users). Our goal is to determine fees, so that platform profit is maximized. Hence, platform profit is the first equation we need. It represents our goal function. Compared to the static case, we have to consider cumulative profit over time, not only current profit. Furthermore, we have to take into account constraints reflecting population dynamics. For that, we have to define how amounts of participants on both market sides evolve over time. Based on system dynamics, examples from life sciences and differential game theory, we develop population dynamic equations. They represent the core of the dynamic model. Model’s behavior is contingent upon them. Hence, it is important to carefully examine possible dynamics and explain, which dynamics are chosen and why.

\(^2\)Differential game theory is basically optimal control theory applied in economic settings.
Based on the dynamic types suggested by Sterman (2000), we assume that platform’s population growth follows an S-curve pattern in the long run, that is, after a period with exponential growth, it slows down at a certain point of time. Potential number of users is restricted by total population with income high enough to buy a mobile device (this restriction is called carrying capacity), hence, there will be a growth limit. Similar suggestion holds for developers. Once assumptions on the shape of the population dynamics curve are determined, the next challenge is to provide a mathematical formulation for it.

In life sciences, birth and death rates are usually used to model population diffusion (cf. Schoen, 2006). Birth rate determines population size growth and directly depends on the current number of participants. Every participant “produces” future participants with a certain probability at a certain point in time. For the platforms under consideration, what is crucial are not necessarily the platform participants on the same market side, but rather the number of participants on the other market side. This is the manifestation of the indirect network effects. More specifically, the dynamics of the number of participants on the one market side depends on the expected utility based on the number of participants on the other side. The expected utility equation we propose is based on the results developed in research paper I on the integrated two-sided market model and some additional assumptions that reflect the dynamic nature of the model.

We propose to use optimization theory instead of optimal control theory\(^3\) which was used in Sun and Tse (2007). This has two reasons: i) solution for the optimal control problems as proposed by Sun and Tse (2007) is proven to be unstable and highly dependent on assumed initial and end conditions (cf. Pickenhain and Lykina, 2006, Pickenhain et al., 2006); ii) it requires constant price adjustments. To overcome these two challenges, we transform this continuous time control dynamic into a discrete-time optimization dynamic.

Since the model is too complex for an analytical solution, we use Matlab simulation to determine the optimization result. With the help of Matlab we provide answers for a range of research questions. We begin with research questions that are central for static models, i.e., “Which side to charge and how much?” , “How to divide fees into usage/commission and membership fees?”, “Is the solution unique?” We discuss this questions in the dynamic setting. Further research questions concern the “chicken-and-egg” problem, that is, the question of how to start-off a platform (cf. Caillaud and Jullien, 2003). We also show how to determine the minimal number of participants on both sides (and comment on its

\(^3\)For a more detailed explanations see research paper II.
uniqueness). This is important for potential platform owners who want to launch a platform and want to know how many participants (and, consequently, resources) are needed to get the platform up and running.

The dynamic nature of the model leads to further changes, such as representation of platform dynamics and profit calculation in a dynamic setting. We can show that there is still a trade-off between usage (or commission) fees and membership fees, but the solution is unique due to the dynamic nature of the model. Furthermore, we show that in our setting it is better to use commission fees instead of usage fees. This is consistent to the the real-world observations, for instance, the App Store employs commission fees instead of fixed usage fees.

Since we have assumed non-linear platform dynamics and existence of carrying capacity, pricing strategies might change over time. That is, price setting for 30 periods would be different compared to prices chosen for 50 or 100 periods. This is confirmed by Matlab simulation. We observe that short-term and long-term profit maximization leads to quite different results. Therefore, it is necessary to evaluate carefully the differences and to clearly define, which perspective to focus on.

The next aspect under consideration is price adjustment over time. We model a setting, where after a certain period of time the platform obtains the opportunity to adjust its prices. In the reality, we have observed that app platform fees did not change much, at least not in an obvious way, that is, commission fee remains the same over time and across most app platforms. Also membership fees, which are the costs of the devices, seem not to change much. But a more close look shows that there are some changes going on. For instance, recently the App Store adjusted the app price levels (Essers, 2012). This has a similar effect to increasing commission fees. Our Matlab simulations confirms this, showing that the optimal platform owner behavior is to increase fees if given a chance. Also, simulations show that fees increase should be the higher, the later it occurs, since platform owner can afford to set the higher prices if more agents have already joined the platform.

Reaction to competition is one more important aspect (cf. Armstrong, 2006; Sun and Tse, 2007) and is analyzed here as external shocks. We focus on the optimal behavior of platform owners in the case of competitor entry. Matlab simulations show that optimal price reduction due to the entry of new competitors might turn out to be surprisingly small (less than 5%), although the competitor is assumed to claim as much as 1/2 of the new potential participants. This is in line with real-world observations: despite of fierce competition prices do not change
much. On the whole, the dynamic model proves to be a powerful instrument for understanding the behavior of two-sided markets, and app platforms, in particular.

The dynamic two-sided market model is a first step in the direction of understanding platform dynamics. Future research could focus on further uncovering the potential of dynamic two-sided market modeling introducing further extensions. A comparison of optimal control and optimization modeling approaches could deliver new insights. However, the most interesting avenue for future research would be an empirical validation of the model at hand. This could be especially valuable from applied point of view, providing insights on the future of platform businesses.

4.5 Summary of research paper III

The third research paper is devoted to challenges faced by the app platform industry and potential strategies to master these challenges. We combine the insights from the literature on strategic management of platforms with the economic literature on two-sided markets. Strategic management literature on platform management (e.g., Gawer and Cusumano, 2008; Eisenmann, 2007) provides practical guidelines on to take network effects into account. However, it does not provide an adequate theoretical framework to thoroughly analyze complex interactions. Economic literature, on the other hand, analyzes two-sided markets focusing on theoretical aspects, and does not consider the managerial implications of these theories in detail. With the research paper III, we aim to bring these two streams of literature closer together.

Following a literature review, we provide an overview of the app platform industry, including the current situation and trends, platform business model and key stakeholders. The three key stakeholders are the platform owners, developers and users. For each stakeholder type, we provide a description of their role in the app platform industry and add a brief analysis of the key strategic aspects from their point of view. The main contribution of this research paper is the application of the theoretical findings to the app platform industry: we illustrate which strategic decisions are most important in the different life-cycle stages of an app platform. We mainly cover the app platform owner’s perspective, leaving the developer and customer perspective for future research. Following Eisenmann (2007), we consider three phases of the platform life-cycle – design, launch and competition.

For each phase we develop several management recommendations. For platform design, pricing represents the key strategic challenge. Two-sided market
theory suggests that in equilibrium, fees should be proportional to price elasticities. Furthermore, it provides suggestions regarding types of fees to charge (usage, membership, one-time or periodical fees). We also discuss the impact of quality on platform design. Quality, besides price, is the key parameter that determines platform design. On two-sided markets, the side that requires higher quality is subsidized.

During the second phase – the platform launch – the “chicken & egg” problem occurs. Two-sided market theory helps elucidate and reduce or avoid the problem by determining an optimal membership component. Here, we build on insights gained from simulations of the dynamic model presented in the research paper II.

The third life-cycle phase is competition. It pertains to the possible market structure, including “the winner takes all” dynamics and the number of competing platforms that can share the market. We identify four factors which determine the market structure for app platforms: multi-homing, size of indirect network effects, same-side effects, and differentiation opportunities. By analyzing these factors, we demonstrate that the app platform industry reveals a high tendency toward convergence, but leaves room for niche building and differentiation. The key implication for the incumbent app platforms is to push for further consolidation while possible challengers have to find their niche to be successful. It is crucial for developers to scan the market for disruptions and trends toward consolidation in order to efficiently allocate their resources.

Based on this analysis, several thrusts for future research emerge. They include, for instance, evaluation of price change over time (partially covered in paper II on dynamic two-sided market models), empirical evaluation of compliance to the fee allocation rule, and the impact of platform openness and compatibility.

The combination of the economic two-sided markets literature and the strategic management literature provides valuable insights for the app platform industry. Although we focus on app platforms for mobile devices, this approach and the developed strategies apply to many other Internet-based platforms.
Chapter 5

General discussion and conclusion

All three research papers presented here are based on the two-sided market theory and aim at providing insights to such industries as online platforms, especially app platforms. The three studies together provide insights on theoretical aspects of two-sided markets, as well as on the application to the app platform industry (and other similar platforms). Extensions to the two-sided market models proposed in the first research paper, solutions for the integrated two-sided market model and the introduction of a dynamic two-sided market model are the main theoretical contributions. Insights on strategies for app platforms along the life-cycle phases are crucial from the managerial perspective. In the following, we discuss the overall contribution of these papers from the theoretical and the managerial points of view. We discuss limitation and thoughts on future research in Section 5.3. Section 5.4 concludes.

5.1 Theoretical contribution

Two-sided market theory started to develop in the early 2000s as was mentioned in Chapter 3. Since then many industries were covered and many parameters and extensions were introduced. Newly emerging Internet platforms like the App Store, Amazon, Google Play are calling for new extensions and research methods. In particular, there are some aspects, which require further examination and research, since they were not covered sufficiently in the existing literature on two-sided markets. These parameters include i) commission payment dependent on payments between customer groups, ii) segmentation of participants, and iii) adjustment for the number of interactions.
Furthermore, papers on two-sided markets tend to consider different extensions one-by-one, isolated from the others. In this case, it is not possible to understand the interdependencies between the parameters. For instance, if models include only membership fees, but not commission fees, it is not possible to survey the interdependence between these parameters. Also optimization with respect to one of these parameters lacks the insights as to how the overall impact of both parameters on the optimal pricing would look like.

In research paper I we introduce new parameters including i) commission payment dependent on payments between customer groups, ii) segmentation of participants, and iii) adjustment for the number of interactions. This allows us to represent Internet platforms as two-sided markets and therefore answers the first and the second research questions mentioned in Section 4.2. Moreover, we integrate all these parameters into one model instead of considering them isolated from each other. This answers the third research question. We find out, that it is still possible to apply similar methodology as Rocher and Tirole (2006) to provide a general solution to obtained problem. This addresses the fourth research question that was formulated in Section 4.2.

Two-sided market models are rooted in comparative static approach. In general, they attempt to offer the optimal pricing solution at a certain point of time. This is a large limitation from the theoretical, as well as the applied point of view. Based on the integrated two-sided market model which was developed in the research paper I, we aim at overcoming this limitation in the research paper II.

Most research papers on two-sided markets tend to employ purely analytical techniques for solving of developed models. This limits possible approaches considerably to pretty simple models. Otherwise, analytical solution is not possible. The dynamic modeling approach we are interested in leads to a formulation of a complex dynamic two-sided market model. This model cannot be solved analytically, therefore, we need to part ourselves from the purely analytical approach and rely on computer simulation techniques. We use Matlab simulations to provide a solution for the proposed model. This allows us to consider a much more complex dynamic setting compared to the majority of static two-sided market research papers. As a result, our model extends two-sided market methodology to the cases where dynamic approach is required.

The first two research questions we were covering in the research papers II are “How to model two-sided markets in a dynamic setting?” and “How to model platform population dynamics?”. The answers to these two questions are as follows. The dynamic model proposed in the second research paper develops an approach
which relies on a different mathematical background, as well as on different modeling and simulation technique compared to other dynamic models, such as Lee (2010), Kumar et al. (2010), Cabral (2011). The first dynamic modeling approach – the continuous time optimal control model – is inspired by Sun and Tse (2007), but uses different principles for the goal function and population dynamics, which are better adapted for online markets. For instance, we assume that population growth is proportional to the expected utility of participants, not only to the current prices and number of participants on the other market side. This allows for a general formulation, where expected utility can be defined depending on the market under consideration. The second discrete time optimization approach is entirely new in two-sided market theory, and is the central contribution of the research paper to the development of the dynamic two-sided market models.

Further research questions we are addressing in research paper II pertain to the number of participants necessary to start off the platform, comparison of short-term and long-term optimization, adjustment of prices over time and optimal reaction to competitors’ entries and external shocks. With help of Matlab simulations we show how the number of agents necessary to start off the platform can be determined and we show that this number is not unique, but represents a trade-off between the number of users and the number of developers. Furthermore, we calculate optimal prices depending on the time horizon, showing that for short horizons optimal platform owner behavior consists in exploitation of the initially available number of participants. For longer time horizons we show that platform owner begins with lower initial prices and increases the prices over time if given a chance.

The next research question was investigating optimal platform strategy in case there is a possibility to adjust prices after a certain period of time. In the real world we observe that some platforms, e.g., eBay (cf. Steiner, 2010), adjust prices considerably over time, others do not (e.g., the App Store). With the help of Matlab simulations we were able to show that platform owner should increase prices if there is a chance to do so, in particular, membership fees for the users. The later this price adjustment happens, the higher fees platform owner should chose. One more research question we consider in paper II is optimal reaction to competitor’s entry. We are able to show that competitor’s entry has comparably low impact on optimal platform pricing. This is consistent with the real-world observations, for instance, Apple Inc. did not reduce their fees after other competitors like Android have entered the market.
As was mentioned before, research paper II builds on the extensions introduced in research paper I. The two research papers together provide a way to consider the most important parameters simultaneously and show how platform dynamics can be taken into account for two-sided market models. In particular, two-sided market models elucidate trade-off between membership fees, per-interaction usage fees and commission fees in a dynamic setting. The key prerequisite to answering these questions is integration of the relevant parameters into the model. The dynamic model offers in addition answers to research question which arise in a dynamic setting and were not considered for the static two-sided models. For instance, in research paper II we analyze how pricing strategies evolve over time as more participants join the platform or if there is a chance to adjust prices over time. Since optimal prices depend on the point of time under consideration and also on the length of the time horizon, this illustrates the importance of dynamic models. Static models cannot provide these insights, since they do not consider these developments. The dynamic model also provides insights for the real-world Internet platforms. We will elaborate on this in the following section.

The third research paper is devoted to applying two-sided market theory and strategic platform management literature to app platforms. Therefore, it focuses rather on managerial perspective than on developing two-sided market theory. The main theoretical contribution of the research paper III is that it connects two-sided market theory and strategic platform management literature, pointing out how they can profit from each other. We also build on and further develop the life-cycle phase analysis suggested by Eisenmann (2007). The insights from research paper II on how two-sided platforms evolve over time allow us to extend and enrich the life-cycle phase analysis. We subdivide platform life in three phases – platform design, launch, and competition, – and discuss key challenges along these phases. One of the insights from the dynamic two-sided model analysis is that in a later phase when there are many platform participants, it is optimal for the platform owner to adjust her pricing strategy.

The three research papers together provide a theoretical modeling approach for online market places such as the App Store. The integrated model introduces hitherto unresearched extensions and bundles the prevalent parameters in one model. The dynamic model builds on the integrated model and extends it, thereby helping to cover dynamic aspects of two-sided markets. The third research paper builds on the insights derived in first two research papers, combining two-sided market theory and strategic management literature.
5.2 Managerial implications

The ultimate objective of the three research papers presented here is to drive further the understanding of the emerging app platform industry and other online platforms with a similar structure. Since the industry is quite young, not much scientific literature on this topic is available. The objectives of the work presented here include providing an initial overview of the industry, developing models to describe and analyze platforms, and, finally, to provide strategies for the challenges app platforms face at different points in time.

A brief industry overview of app platform strategies is provided in research paper III. We describe the current state and trends of the app platform industry and discuss app platform business models and key stakeholders. In the introduction to this dissertation we also provide a comprehensive overview (cf. Section 2). Section 2 discusses key concepts and definitions, presents a detailed industry overview and a broader stakeholder analysis.

Both research papers I and II are devoted to modeling and analyzing app platforms. The first research paper proposes extensions necessary to model app platforms and integrates the prevailing parameters into one model. In Section 1.7.3, we show how the proposed integrated model can be applied to app platforms. The second research paper focuses on the dynamic aspects of app platforms. Since the app platform industry is developing extremely fast and is also prone to disruptions, this is an important part of the analysis. The second research paper aims to provide a dynamic model for app platforms and undertakes first attempts at explaining some paradoxical observations of app platforms, for instance, the fact that app platforms do not significantly reduce prices when a new competitor enters the platform.

Both the integrated model as well as the dynamic model are formulated in a general way. Hence, they can also be used to model other types of two-sided markets, not only app platforms. For instance, such online platforms as Amazon and eBay have a similar structure and (to the best of our knowledge) have also not yet been modeled as two-sided markets.

The third research paper on challenges and strategies for app platforms takes a managerial perspective. It combines insights from two-sided market theory and strategic platform management literature. In the third research paper, we consider the challenges for app platforms along the life-cycle phases, determining what challenges may arise when and how they can be dealt with. For instance, we derive
the four conditions that make the “winner-takes-all” dynamics likely (based on Eisenmann et al. 2006, Sun and Tse 2007). They include:

- It is costly to multi-home – at least for one market side,
- There are high indirect network effects – at least for the side with high multi-homing costs,
- Same-side effects are not negative and strong, that is, the congestion effect is not too high,
- The goods are rather homogeneous and there is no demand for differentiation.

Such considerations are important for incumbent platforms aiming to defend their position and to deter the entry of competitors, but also for the competitors who want to understand whether it makes sense to enter the market and how best to do it. Compiling strategies for app platforms, many factors need to be taken into account: direct and indirect network effects, pricing of information goods, complementary products pricing, multi-homing vs. single-homing situations, platform openness, adjacent industry and the entire ecosystem. The third research paper attempts to structure the challenges app platforms face and introduces strategies to deal with these, while taking as many factors into account as possible.

5.3 Limitations and future research

In this section we will discuss limitations of our research and provide some thoughts on future research possibilities. We describe limitations of single papers and the overall research. We comment on how these limitations are addressed in other parts of our research and which research opportunities arise from the limitations of the research at hand.

One of the biggest limitations of the integrated two-sided market model developed in research paper I is that it concentrates on the static aspects of two-sided markets. That means, it is assumed that the number of platform participants remains constant over time and therefore optimal pricing strategy for the platform needs to be determined once and for all. In the real world we observe that many two-sided markets, in particular, app platforms are highly dynamic. Therefore, a strategy adjustment might be required. This means that optimal prices might change over time, that is, platform might prefer to set low fees in the beginning
to attract more users and developers and then increase the fees once lock-in took place.

One more shortcoming of the static two-sided market models is that they cannot analyze strategies for competitive entry and further external shocks like new regulations or technologies. We overcome the limitations of the comparative-static nature of the integrated two-sided market model in research paper II. The last relies on a dynamic approach and allows to investigate how platform platform strategy might change over time, in particular, in case of external shock like competitive entry.

Research paper II provides one possible approach to building a dynamic two-sided market model, it builds on dynamic system theory, examples from life sciences and differential game theory. Other promising avenues to dynamic two-sided models were presented in the research of Sun (2006), Sun and Tse (2007), Vogelsang (2010) and Cabral (2011). It would be interesting to compare different dynamic modeling approaches and their results, including continuous vs. discrete modeling, optimization vs. optimal control approach, etc. Currently, these models target different research questions and use different parameters and mechanisms, not only different mathematical theories. We believe, it would be insightful to see if the results developed with the help of different approaches are compatible. If they are not, it would be necessary to analyze, how this can be overcome to arrive at viable recommendations for the real world platforms.

The integrated two-sided market model solution depends strongly on price elasticities. Hence, in order to determine optimal pricing strategy, the platform owner requires high transparency for existing price elasticities. In the real world situations this might be challenging, especially if the platform owner wants to determine pricing strategies for a new platform she is trying to set up. The dynamic model presented in research paper II does not require explicit knowledge of price elasticities, but makes use of other parameters instead, which are less abstract and therefore might be easier to estimate.

The dynamic model presented in paper II is too complex to be solved analytically. Therefore, we have employed Matlab simulations to provide answers to the research questions. As computer simulations mostly do, our Matlab simulations provide an indication of solution for certain parameter ranges. Although we did our best to extend parameter ranges as far as possible, it is necessary to be aware of the fact that this is not equivalent to a closed-form analytical solution.

One more important limitation of our research, is the perspective we employed. In all three research papers we considered strategic issues from the platform owner’s
point of view. It would be of particular interest to connect this with customers, and in particular with developers’ perspective. They also are facing strategic decisions (e.g., for which platforms to develop, how to set monetization strategy and prices, how much to invest in advertising and promotions). There is an interdependence between platform owners’ and developers’ decisions, which would be very interesting to further elucidate.

In our research, we tried to include as many relevant parameters as possible. Integration of different parameters discussed in two-sided market research into one model belongs to the main theoretical contributions of research paper I. Nonetheless, a model remains a simplified version of the real world. Clearly, there are many more parameters and factors affecting real world app platforms. Examples include explicit consideration of additional impact of available content (e.g., music, films, news) as opposed to apps, explicit modeling of open vs. closed platform.

Internet platforms in general, and app platforms in particular are multi-sided markets, connecting many more stakeholders, than just platform owner, users/buyers and developers/sellers. As was described in section 2.2, mobile operators, content providers, advertisers and many more other participants contribute and depend on mobile ecosystems around app platforms. These stakeholders can have significant impact on the mobile ecosystem, platform owner decisions and pricing strategies. Although we refrained from including further stakeholders in our models to avoid further complexity, we believe that it would be a great opportunity for future research to include these stakeholders in two-sided market models and thereby develop a real multi-sided model.

One of the most interesting opportunities for future research consists in conducting empirical surveys and evaluating how models presented here fit to existing real platforms. Empirical research can be used to estimate parameter values for the developed models. This would enable a realistic calculation of pricing strategies. Also, it would help to test assumptions and hypotheses used in the models. And finally, an empirical survey would allow us to see, if developers, users and platform behavior “observed” in our Matlab simulations provide an adequate representation of the real world.

5.4 Conclusion

On the whole, this thesis contributes to describing, analyzing and understanding newly emerging app platforms, while at the same time extending two-sided market theory. The three research papers represent three different approaches, relying on
different mathematical backgrounds and methodologies. This allows us to elucidate different parts of the app platform industry and two-sided markets theory. Also, it helps to compensate for limitations connected with each methodology.

The first research paper introduces a new two-sided market model and a solution for it as its centerpiece. The new model introduces parameters necessary to reflect the app platform structure, and it also combines all these parameters in one integrated model. The methodology behind this model is totally rigorous, still allowing for a closed-form solution, despite the number of introduced parameters. But this model, as the majority of two-sided market models, is built for static environments. However, app platforms are exhibiting strong and non-linear dynamic and are prone to disruptions. Therefore, a static model is not sufficient to provide valid long-term strategies for app platform.

Based on this observation, in addition reinforced by the fact, that there is a rising appetite for dynamic models in two-sided market theory itself, we develop a dynamic model for app platforms to compensate for these limitations. The second research paper builds on optimal control, optimization, differential and differences game theory and system dynamics. Moreover, in this research paper we revert to Matlab simulations to provide insights for the dynamic case.

The dynamic model at hand provides several insights which were not possible with the static model. For instance, it suggests, how many participants on both market sides are needed to start of a platform. Also, it shows how prices should be adjusted if a competitor enters the market or other disruptions occur. Clearly, simulations are not as rigorous as closed-form solutions, since they rely on assumptions regarding appropriate parameter ranges.

The need for research paper III results from the observation that two-sided market literature should have the aspiration to provide insights for the underlying industries. Two-sided market theory belongs to Industrial Organization research, and therefore, one of its main objectives is to provide insights for various industries, not only developing economic models. Following this aspiration, in the third research paper we focus on analyzing app platform industry based on the two-sided markets theory and platform management theory (cf. Gawer and Cusumano, 2007, 2008). Research paper III aims at identifying key challenges and developing strategies to mitigate these.

As discussed in the previous section, there are many interesting avenues for future research. They include introduction of new parameters and inclusion of new stakeholders. Furthermore, usage and comparison of different mathematical
approaches might provide interesting insights. Empirical approach would be also a promising avenue for future research.

We believe that the combination of the approaches applied in the three research papers at hand, provides a better overview and understanding of the app platform industry, than each individual one. They elucidate different aspects of app platforms and at the same time contribute to different research areas and show how these can be connected to develop new insights.
Bibliography


Part II

Research papers
1

Paper I: An Integrated Two-sided Market Model for Internet Platforms

Abstract

On two-sided markets, a platform intermediates between two distinct groups of customers linked by network effects. Over the last decade, a large body of literature on theoretical as well as applied aspects of two-sided markets has been published, for example, Rochet and Tirole (2003, 2006), Caillaud and Jullien (2003), Evans (2003) and Armstrong (2006), to name just a few. At the same time, newly launched Internet platforms such as Apple’s App Store call for new extensions and provide motivation for the further development of two-sided market models. This is the area of research to which this paper contributes. The objectives of this study are: i) the integration of prevalent parameters for monopoly two-sided markets models (like usage fees, membership fees, payment between customer groups, quality review of participants) into one model; ii) the introduction of new parameters such as commission fee, the segmentation of participants and adjustments for the number of interactions, and iii) development of a solution for the new model. Subsequently, we demonstrate how the integrated model can be applied to model app distribution platforms like Apple’s App Store.

Keywords: Two-sided market, platform, app, mobile software distribution platform.

JEL classification numbers: L8, L81, L82, L86, L96.
1.1 Introduction

Over the last decade, platforms have become the “invisible engines” (cf. Evans et al., 2006) of our economics. Amazon, eBay and Google have advanced to the top brands worldwide.\(^1\) One of the key aspects of these companies’ business models is their intermediary role. Instead of producing goods themselves they connect two distinct groups of customers – sellers and buyers, developers and users, men and women, who can profit from each other.\(^2\) New challenges arise in the area of platform design (pricing strategy, quantity vs. quality of participants) and platform competition (e.g., the winner-takes-all dynamics, open source vs. proprietary design, emergence of new players like wholesalers). Two-sided market theory can help us both better understand and overcome these challenges, while also being an interesting research area on its own.

This paper is devoted to the two-sided market models for monopoly platforms. We integrate prevalent parameters (such as usage fees, membership fees, payment between customer groups, quality review of participants) that have been proposed in different papers on two-sided markets into one model. Furthermore, we introduce three new parameters: i) commission fee, which is proportional to payment between customer groups, ii) segmentation of participants and iii) adjustments for the number of interactions. Finally, we develop a solution for a integrated model. Hence, the resulting model integrates all prevalent parameters of the monopoly two-sided markets models into one so they can all be considered simultaneously.

The paper is organized as follows: Following a brief introduction to two-sided market theory in the next section, we discuss the canonical two-sided market model of Rochet and Tirole (2003) for a monopoly platform with usage fees (Section 1.3). Next, possible extensions of this model are considered (Section 1.4). Some of them are new and some have already been discussed in the literature. The parameters that have already been identified include membership fees (cf. Armstrong, 2006, Rochet and Tirole, 2006), payments between customer groups (cf. Rochet and Tirole, 2006), and quality review of participants (cf. Hagiu, 2009, Jeon and Rochet, 2010). The new extensions are commission fees, segmentation of participants and adjustments for the number of interactions between customer groups. Commission payment dependent on payment between customer groups is crucial for such platforms as the

\(^1\)Cf. www.interbrand.com.

\(^2\)For an introduction to the intermediary theory, see Peitz and Belleflamme (2010).
App Store or eBay, since it allows to take into account high variation of prices for goods sold over these platforms. Customer segmentation allows us to set different prices for the different customers on the same market side. Adjustment of the number of interactions reflects the fact that it is unusual for all participants on one side of the market to interact with all participants on the other side, as is often assumed in the literature (cf. Rochet and Tirole, 2003, 2006, Caillaud and Jullien, 2003, Armstrong, 2006, Tag, 2008). We introduce a two-step adjustment: first, we calculate how many “scannings” there are and then assume that only a fraction of these “scannings” actually leads to an interaction.

In Section 1.5 all parameters are integrated into one model. The main contribution of the integrated model is that it allows consideration of all parameters simultaneously. We then apply the methodology of Rochet and Tirole (2003, 2006) and Armstrong (2006) to derive a solution for the new model (Section 1.6). The solution represents a general case of the underlying models, so the price level equation resembles Lerner’s index and the allocation of fees is proportional to the price elasticities up to a certain factor. Key differences compared to Rochet and Tirole (2003) include an increased number of equations due to segmentation and correction terms for the proportionality of fees to the price elasticities. Subsequently, we show how the integrated model can be applied to model app distribution platforms like Apple’s App Store (Section 1.7). A discussion of the results and conclusion follow in Section 1.8.

1.2 Two-sided markets

The following rough definition can be provided for the two-sided markets: two-sided markets are platforms that enable interaction between two groups of customers who value each other’s presence (cf. Rochet and Tirole 2003, Evans 2003, Tag 2008). The underlying phenomenon is called “indirect externalities”: The utility on the one side of the market increases with the number (and/or quality) of participants on the other side.\footnote{For a precise definition of two-sided markets, see Rochet and Tirole (2006) and Hagiu and Wright (2011).}

\footnote{By “scanning” we mean a situation in which one participant gathers information about other participants, but the interaction has not yet taken place.} Examples of platforms that can be interpreted as two-sided
markets range from credit card systems and software platforms to night clubs and shopping malls.

The platform owner is confronted with two different groups of customers with corresponding demand functions that are interdependent. To set prices (and other parameters like quality requirements) properly, the platform owner has to maximize joint profit from both market sides simultaneously. The theory of two-sided markets provides models and solutions to deal with this challenge. Due to the diversity of two-sided market examples, various extensions are needed to describe different kinds of platforms. In this study, we integrate all prevalent extensions that have already been discussed in the literature and propose a new combination of parameters that can be used to model platforms like Amazon, eBay and Apple’s App Store.

The research on two-sided markets builds on network economics and complementary product pricing. Since the first papers by Rochet and Tirole, and Calliaud and Jullien started circulating around 2001, a large body of literature on two-sided markets has emerged, for example, Rochet and Tirole (2003, 2006), Caillaud and Jullien (2003), Evans (2003) and Armstrong (2006). The main directions of the two-sided market research have included:

- Introduction of new extensions for the static monopoly model (e.g., Armstrong (2006) on membership fees, Hagiu (2009), Jeon and Rochet (2010) on quality preference of participants);

- Investigation of static duopoly as opposed to monopoly and the development of various extensions for it (e.g., Armstrong (2006) on “competitive bottlenecks”, Choi (2010) on tying and multi-homing, Tag (2008) on comparison of open and closed platforms);

- Introduction of dynamic view (e.g., Lee (2010) on dynamic demand estimation, Kumar, Lifshits and Tomkins (2010) on evolution of two-sided markets, Vogelsang (2010) on representation of dynamic with the help of differential equations);

- Conducting of empirical research on two-sided markets (e.g., evaluation of the indirect network effects by Rysman (2004), Sokullu (2010) on non-parametric analysis of two-sided markets).

The emphasis has clearly been on the first two directions – development of extensions for cases of monopoly and duopoly. The majority of studies investigate one extension at a time: They either consider the impact of the preference for quality or payments by the two market sides, or for usage / membership fees. Hence, in order to analyze various features, several different models are needed and it is not possible to consider all extensions simultaneously and determine how they influence each other.

The first objective of this paper, namely the integration of parameters in one model, arises from this observation. The second objective of this paper follows from the fact that two further extensions exist which could be crucial for real world platforms. The first consists of adjustment of the number of interactions. The second includes the introduction of the segmentation of participants of one market side.

Less attention has been given to the last two aspects – the dynamic view and the empirical research of two-sided markets – in the past, but they are gaining in popularity. They are especially important for the application of two-sided market theory and provide promising directions for future research.

1.3 Canonical two-sided market model

This section is devoted to the canonical two-sided market model of Rochet and Tirole (2003). This model conveys the key idea of two-sided markets, namely the indirect network effects. At the same time, it is not too complicated and provides the common denominator for several two-sided market models. This property is crucial, since this study’s objective is to integrate all prevalent extensions into one model. In the following, we describe the model of Rochet and Tirole (2003). We begin with general assumptions and a model description. Then we describe customer utility functions and proceed with platform profit and its maximization.

The model of Rochet and Tirole (2003) was motivated by credit card systems. The authors include usage fees $p^B$ and $p^S$ as decision parameters for both market sides in the canonical model and take into account costs per interaction for the platform $c$. 

1.3.1 General assumptions

Rochet and Tirole (2003) consider a monopoly platform that intermediates between two customer groups \( i \in \{B, S\} \). These could be buyers and sellers, developers and users, or men and women. We follow the authors and name one market side \( B \) for “buyers” and the other side \( S \) for “sellers”. The two market sides want to interact with each other and profit from the presence of the other side. The more participants there are on the one side of the market, the more choices the other side has, and the higher its utility. It is assumed that there are no congestion costs or search costs. Both market sides experience indirect network effects. The platform owner enables interactions between the two market sides and obtains payments for this service. There is no other way for the two customer groups to interact except via the platform. This assumption implies that other possible opportunities and their costs and benefits can be neglected.

The timing of decisions in the canonical model are as follows: First, the platform owner sets her fees. Then participants of the two customer groups calculate their utility based on these fees and decide whether to join the platform or not. The second decision the customers take pertains to interaction with the other side. At this point, Rochet and Tirole (2003) assume that every customer on the one side interacts with every customer on the other side as soon as they join the platform. Hence, this decision is automated.

Rochet and Tirole (2003) assume that no fixed costs or benefits are incurred. There is total transparency regarding pricing structure, costs and utilities. Based on these assumptions, the platform owner can predict the reactions of platform participants and can set her prices in the optimal way to maximize her profit. The next sections are devoted to this procedure.

1.3.2 Customer group utility

The utility of customers on a platform may stem from two sources: First, their participation in the platform, and second, platform usage. For instance, if you are a member of a fitness club, you might obtain benefits from belonging to it (the feeling of being in better shape), even if you never actually use the club’s facilities. In other cases, usage is the main source of customers’ utility, for instance, as it is with credit cards. Taking such considerations into account, the platform owner can decide what type of fees – usage and/or membership fees – to charge. Rochet
and Tirole (2003) assume that there are no membership fees, only usage fees $p^B$ and $p^S$. This means that the platform obtains a total fee $p = p^B + p^S$ when a customer from one market side interacts with a customer from the other, whereby the seller pays $p^S$ and the buyer $p^B$.

Furthermore, there are benefits, that are derived from interactions $b^i$. These can vary among customers, that is, customers are assumed to be heterogeneous. The number of customers participating in the platform is denoted by $N^i$. Only those customers whose benefit per interaction $b^i$ is higher than the cost per interaction will be willing to participate in the platform:

$$N^i = Pr(b^i \geq p^i) \equiv D^i(p^i).$$ (1.3.1)

$D^i(p^i)$ is the demand function of the group $i$. It depends on the usage fee $p^i$. Rochet and Tirole (2003) assume that each participant on the market side $i$ interacts with each participant on the market side $j$ exactly once. Therefore, the utility of a market participant equals the surplus per interaction multiplied by the number of interactions, which is identical with the number of participants on the other market side:

$$U^i = (b^i - p^i)N^j.$$ (1.3.2)

The utilities are assumed to be symmetrical for both market sides. The utility $U^i$ of participants on the one market side depends on the number of participants $N^j$ on the other side $j$ and this is a manifestation of the indirect network effects.

### 1.3.3 Platform’s profit maximization

The aim of the platform is to maximize its profit through optimal price setting and the allocation of fees. In Rochet and Tirole (2003), the platform has to set usage fees that attract as many participants as possible from both market sides. Due to the indirect network effects, the platform has to consider both market sides.

---

6 Clearly, there are many two-sided markets to which this assumption does not apply. In the integrated model, membership fees is one of the extensions that will be taken into account based on the work of Armstrong (2006) and Rochet and Tirole (2006).

7 For many two-sided markets, this assumption is not realistic. The adjustment of the number of interactions is one of the new extensions introduced in Section 1.4.
simultaneously and take the aforementioned dependence between the two market sides into account.

The profit sources for the platform are limited to the usage fees from interactions, since no membership fees are charged. The margin per interaction amounts to \( p - c = p^B + p^S - c \) with \( c \) costs for the platform per interaction. The number of interactions is the power set \( D^B(p^B)D^S(p^S) \) which consists of the number of participants on each market side. This is the implication of the assumption that each participant of the market side \( i \) interacts with each participant of the market side \( j \) exactly once.

Rochet and Tirole (2003) obtain the following profit equation for the platform:

\[
\pi = (p^B + p^S - c)D^B(p^B)D^S(p^S). \tag{1.3.3}
\]

This equation completes the canonical model of Rochet and Tirole (2003). A schematic illustration of the model including utility and profit functions is presented in Figure 1.1. The arrows represent the flows of usage fees and benefits between the platform and its customers.

![Figure 1.1: Sketch of the key determinants of the canonical model of Rochet and Tirole (2003).](image)

The solution of this equation is provided in the following proposition:\(^8\)

---

\(^8\)Cf. proposition 1, p. 997 in Rochet and Tirole (2003).
Proposition 1.1. 1. The total usage fee \( p = p^B + p^S \) charged by the platform is given by the following equation:

\[
\frac{p - c}{p} = \frac{1}{\eta}, \tag{1.3.4}
\]

with \( \eta = \eta^B + \eta^S \) being total price elasticity, including

\[
\eta^B = -\frac{p^B}{D^B} \frac{\partial D^B}{\partial p^B},
\]

\[
\eta^S = -\frac{p^S}{D^S} \frac{\partial D^S}{\partial p^S}
\]

price elasticity of buyers and sellers accordingly.

2. The allocation of usage fees is proportional to the price elasticities:

\[
\frac{p^B}{p^S} = \frac{\eta^B}{\eta^S}. \tag{1.3.5}
\]

Proof. In this proof we follow Rochet and Tirole (2003, pp. 996-997). Since we will apply the same methods in Section 1.6 for the integrated model, it is helpful to review this proof in detail.

The first step consists of logarithmizing the platform profit function \( \pi \). We obtain:

\[
\log \pi = \log(p^B + p^S - c) + \log D^B(p^B) + \log D^S(p^S) \tag{1.3.6}
\]

Then the first derivative is taken and set to zero:

\[
\frac{\partial (\log \pi)}{\partial p^B} = \frac{1}{p^B + p^S - c} + \frac{(D^B)'}{D^B} = 0, \tag{1.3.7}
\]

\[
\frac{\partial (\log \pi)}{\partial p^S} = \frac{1}{p^B + p^S - c} + \frac{(D^S)'}{D^S} = 0. \tag{1.3.8}
\]

This yields:

\[
\frac{(D^B(p^B))'}{D^B(p^B)} = \frac{(D^S(p^S))'}{D^S(p^S)}. \]

From the last equation it follows that the usage fees \( p^B \) and \( p^S \) should be chosen such that their relative variation has the same effect on both market sides. Next, Rochet and Tirole (2003, p. 996) introduce price elasticities:

\[
\eta^B = -\frac{p^B(D^B)'}{D^B} \quad \text{und} \quad \eta^S = -\frac{p^S(D^S)'}{D^S}. \tag{1.3.9}
\]

\footnote{We only consider the log-concave functions \( D^B \) and \( D^S \). Hence, \( \pi \) is also log-concave as a product of two log-concave functions. The profit function \( \pi \) can thus be logarithmized without change of extrema.}
Hence, from equations 1.3.7 and 1.3.8 follows:

\[ p^B + p^S - c = \frac{(D^B)'}{D^B} = \frac{p^B}{\eta^B} = \frac{(D^S)'}{D^S} = \frac{p^S}{\eta^S} \]

Therefore, for the total usage fee \( p = p^B + p^S \) and total price elasticity \( \eta = \eta^B + \eta^S \) with \( \eta > 1 \), the following equation holds:

\[ \frac{p - c}{p} = \frac{1}{\eta}, \quad \text{or} \quad p = \frac{\eta}{\eta - 1} c, \]  

(1.3.10)

which is also referred to as Lerner’s index. For the allocation of usage fees to the two market sides, We obtain:

\[ p^B = \frac{\eta^B}{\eta} p = \frac{\eta^B}{\eta - 1} c, \]

and

\[ p^S = \frac{\eta^S}{\eta} p = \frac{\eta^S}{\eta - 1} c. \]

This yields:

\[ \frac{p^B}{\eta^B} = \frac{p^S}{\eta^S}. \]  

(1.3.11)

\[ \Box \]

The first statement of the proposition relates to the total price per interaction charged by the platform. Equation 1.3.4 reminds us of Lerner’s index known from the monopoly theory, with the difference that the firm’s marginal cost is replaced by cost per interaction \( c \). Usually, Lerner’s index indicates the firm’s market power.

The second part of the proposition specifies how the total fee \( p \) should be divided between the market sides to achieve the highest possible platform profit. Equation 1.3.5 suggests that the market side with more elastic demand should be charged more.\(^{10}\)

\(^{10}\)This might seem to contradict demand theory where prices have to be cut if demand is more elastic in order to maintain the same demand level. As Krueger (2009) shows, there is actually no contradiction if elasticity is understood as a function of price and not as a constant.
1.4 Extensions for the canonical model

In the following, we describe the extension parameters and how they can be integrated into the canonical model of Rochet and Tirole (2003). We begin with established parameters like membership fees, payment between market sides, and preference for quality. Subsequently, we introduce three new parameters – commission fees, segmentation and adjustment of the number of interactions. Unless stated otherwise, all assumptions made in the previous sections (such as consumer heterogeneity and decision timing) remain the same.

1.4.1 Transaction fees and membership fees

In the canonical model of Rochet and Tirole (2003), it is assumed that the average fees per interaction $p^B$ and $p^S$ are equal to the usage fees $a^B$ and $a^S$, that is, the platform does not charge any membership fees. But for some platforms, membership fees $A^B$ and $A^S$ are crucial. Some platforms only charge membership fees, some prefer a combination of usage and membership fees. One example are dating service sites, where interactions are not entirely observable for the platform and membership fees are therefore the better option for financing the service. Membership fees are described in the papers of Armstrong (2006), Rochet and Tirole (2006) and Vogelsang (2010).

In the utility functions of sellers and buyers, membership fees appear as costs. We assume that there are also corresponding benefits $B^B$ and $B^S$ from membership, which come in addition to the benefits from interactions $b^B$ and $b^S$.

Compared to the basic model, the key difference for the platform profit function is that besides profit from the interactions (determined by equation 1.3.3), two new components are introduced: Profit from the membership of buyers and profit from the membership of sellers. Profit from membership is represented by the number of members and membership fees minus membership costs, which is $(A^B - C^B)N^B$ for buyers and $(A^S - C^S)N^S$ for sellers.

\footnote{We assume that usage fees are denoted by $a^B$ and $a^S$, membership fees by $A^B$ and $A^S$, and average fees, which include usage fees and a proportional share of membership fees, by $p^B$ and $p^S$.}
1.4.2 Review process and quality of participants

As mentioned before, the utility of one market side depends on the number of participants on the other market side. Besides the amount of participants, their quality might also play a role. One of the most prominent examples in which the quality of participants is crucial are partner search agencies. Agencies such as Parship.com or Elitepartner.com charge high membership fees. These fees are not charged to cover costs, but serve primarily as a signal: An individual who is able to pay such a high membership fee is probably wealthy and serious about his search for a partner. Many partner search agencies check the potential participants and might exclude someone even though he is willing to pay the high membership fee. Another example of quality requirements on two-sided markets comes from the computer console and game industry. Game developers pay high royalties to game console producers. This is (at least partially) to ensure that low-quality games do not become profitable.12

To date, the development of the two-sided market theory has focused on pricing decision, as asserted by Hagiu:

“...The economics and strategy literature on two-sided markets to date has devoted most of its attention to two-sided pricing strategies (e.g., Armstrong (2006), Caillaud and Jullien (2003), Parker and Van Alstyne (2005), Rochet and Tirole (2003) and (2006)) and although some recent papers have started to tackle certain design issues (cf. Hagiu and Jullien (2009), Parker and Van Alstyne (2008)), there has been virtually no formal work on two-sided platform governance rules and the factors that drive two-sided platforms to restrict access beyond what they can achieve through pricing alone.”

Hence, the quality of participants is an important parameter that can play a crucial role for many platforms. Damiano and Li (2007, 2008) were among the first to discuss the quality of participants. They consider matchmakers who induce self-selection of participants through fee variations. Damiano and Li (2007) consider a duopoly in which two platforms offer different prices. Since this study considers a monopoly case and examines the quality impact within one platform, let us turn to the two most relevant models by Hagiu (2009) and Jeon and Rochet (2010).

---

12Hagiu (2009).
One possibility to restrict access to a platform is to introduce a lower bound for the quality of participants and to exclude all participants from the platform who lie beneath this boundary. This is how Hagiu (2009) and Jeon and Rochet (2010) proceed.

Hagiu (2009) focuses on partner search agencies when he considers quality requirements. He argues that quality sensitivity is not the same for both market sides. Usually, one market side is not as sensitive as the other, for example, men are said to be less “picky” about women than vice versa. Hagiu assumes that the benefits of one side ($W$) depend not only on the number of available participants on the other side ($M$), but also on their quality. Hagiu (2009) begins by modeling quality as a continuous distribution with a lower bound representing the minimum required quality.

This model is based on membership fees and does not include usage fees. But it considers both membership and usage benefits, assuming that for the side $W$ both types of fees depend on the average quality of participants on the side $M$. In the following Hagiu (2009) writes the profit function of the platform as a function of the minimum quality. Then he specifies quality distribution as a Bernoulli distribution and separates cases for usage and membership benefits. The main result of the analysis is that there is a trade-off between quality and quantity, and therefore, the effect on platform profit is ambiguous.

Jeon and Rochet (2010) interpret scientific journals as two-sided markets. They argue that journals are platforms which connect writers who want to publish their papers and readers who want to read them. The quality of papers is the crucial parameter that determines the price (and reputation) of the journal. The quality of articles is determined in a review process in which the quality of an article is compared with the minimum required quality. Jeon and Rochet (2010) assume that usage benefit alone depends on the quality on a linear basis. Apart from that, they proceed similarly to Hagiu (2009), assuming a Bernoulli distribution for the papers.

A Bernoulli distribution implies that all participants are divided into two groups, those with high quality $q_H$ and those with low quality $q_L$, e.g., high-quality men versus low-quality men. This can also be assumed for platforms like Apple’s App Store. Once developers submit their apps for review, Apple divides them into two groups: The first group’s apps are approved and can be distributed through the App Store, while the second group’s are rejected and the group thus does not
obtain access to the app platform. Sometimes quality is perceived as a subjective characteristic. Apple claims that it only rejects apps which contain malware, viruses, and errors, as well as apps that do not do what they promise in the description or replicate apps that are already available in the App Store.\footnote{For a detailed description of the review rules, compare \url{http://developer.apple.com/appstore/}.} Apple accepts most apps that pass these criteria and leaves it to their customers to decide on the usefulness of the apps, to rate them and provide evaluations for the apps.\footnote{Another possibility for ensuring high quality consists in reviewing sellers instead of (or in addition to) the products. This is how Nokia’s Ovi Store for app distribution proceeds. They license developers before their apps proceed to Nokia’s Quality Assurance process (compare Heath (2009)).}

We adopt the approach of Hagiu (2009) and Jeon and Rochet (2010) and integrate quality preference for one customer side. Furthermore, we assume a Bernoulli distribution for the quality of participants. All sellers $S$ are separated into two groups: There are $\nu N^S$ high quality ($q_H$) and $(1-\nu) N^S$ low quality ($q_L$) participants. The platform can decide which share of each group it wants to accept $(\beta_H, \beta_L) \in \{0,1\}$, whereby only two cases are to be considered: The platform can choose $\beta_H = 1$, $\beta_L = 1$ to accept all participants or $\beta_H = 1$, $\beta_L = 0$ to exclude low quality participants. The average quality is determined by the following equation:

$$q(\beta_H, \beta_L) = \frac{\nu \beta_H q_H + (1-\nu) \beta_L q_L}{\nu \beta_H + (1-\nu) \beta_L}. \quad (1.4.1)$$

This will be taken into account in Section 1.6.

### 1.4.3 Commission dependent on payments between market sides

Many Internet platforms like eBay, Amazon or App Store intermediate between two market sides where one side wants to sell products to the other. These platforms charge commissions depending on the success and price of products sold. Assume that the price of a given product equals $r$ and that the platform claims the $(1-\gamma)r$ share of the product’s price as commission. The seller side obtains the remaining $r \gamma$. In this case, payment from the buyer to the seller is a crucial part of the utility equation of buyers and sellers and will affect the amount and allocation of fees they are willing to pay.
Payment between customer groups can play an important role for all platforms where goods are sold from one market side to the other, not only for platforms which charge commission. It is also possible that the payment between customer groups is $r\gamma = \text{const}$ as assumed in Rochet and Tirole (2006). We consider the case where $r\gamma$ is not necessarily constant, but may depend on price $r$ of the good sold. Usually, the platform charges a commission percentage of $1 - \gamma$. The price of the good $r$ can be determined by the seller or through an auction (e.g., as on eBay). We assume that the price of goods offered on the platform follow a distribution $R$ with an average $\bar{r}$.

One possible impact of the introduction of payments between market sides is a (partial) neutralization of indirect network effects. If sellers determine the prices themselves, they can influence the allocation of fees. Imagine if eBay decided to charge 10% instead of 5% for successful sales. Sellers could then increase the price of the product they are offering by 5%, shifting all the fees to the buyers. Consequently, the number of buyers would go down in equilibrium. In a two-sided market where the intermediary controls prices, she could keep the prices constant, meaning that the sellers have to carry the extra costs.

The fact that the intermediary can determine the allocation of fees is central for a market to be two-sided. Payments between the two market sides can therefore potentially transform a two-sided market into a one-sided market. There are usually some additional factors that prevent sellers from the full neutralization of indirect network effects. These can, for instance, include membership fees that are difficult to compensate for or price steps requirements for the goods being sold.\textsuperscript{15}

1.4.4 Adjustments for the number of interactions

As mentioned in the previous section, the assumption that each participant on one market side interacts with each participant of the other market side exactly once is highly unrealistic for many platforms. That, for example, would mean that each of the 125,000,000 iPhone owners would buy or download each of the 300,000 available apps.\textsuperscript{16} This would result in 37,500,000,000,000 downloads instead of

\textsuperscript{15}Many app distribution platforms for mobile devices allow developers to determine app prices but require the prices to assume certain values like USD 0.99, 1.49, 1.99, etc.
\textsuperscript{16}All numbers as of November 2010, see 148apps.biz.
the registered 7,000,000,000 downloads. Similar examples are available for other platforms like Amazon or eBay.

In order to take into account that the number of interactions is much lower than the power set of the number of participants on both market sides, we introduce an adjustment. We assume that the interaction decision is a two-step process: The first step is scanning for possible interaction partners by the buyers, and the second step is the selection of partner(s) from the total scanned amount. The first step leads to reduction of the number of potential partners from $N^S$ to $f(N^S)$. $f$ is supposed to be differentiable and have an inverse function. The second step follows in which the buyer decides to either interact with the seller or not. This decision is reflected through the probability variable $X \equiv E[x(b,a)]$ with $x(b,a) \in [0, 1]$ being the probability of interaction. Rochet and Tirole (2006) suggest introducing $X$ to “prune” the power set. But if $X$ is introduced without $f$, then the number of interactions is still proportional to $N^B N^S$. Real world applications suggest that this is seldom the case. Following the law of diminishing marginal utility, the increase from 100 to 200 participants will have much more impact than the increase from 100,100 to 100,200 participants. Therefore, we propose adding $f$ which reflects this.

Introduction of the adjustments $X$ and $f$ can also help to take into account congestion effects on the sellers’ side and increasing searching costs for buyers. As the number of sellers growths, they can attract more buyers. But later on, it can happen, that number of sellers growths faster than the number of buyers. This leads to a situation, where an individual seller make less and less profit, albeit the number of users is still growing. In this case, congestion effect becomes visible. At the same time, growing number of sellers implies growing number of goods. This implies, on the one hand, more choice (which is positive from buyers point of view), but on the other hand, it increases search cost (which is negative from buyers point of view). Adjustment factors $X$ and $f$ can be set to reflect this, for instance, if a non-linear function such as logistic function is used for $f$.

\[ f(x) = \frac{1}{1+e^{x}} \] or an algebraic version \[ f(x) = \frac{x}{\sqrt{1+x^2}}. \] For some platforms, root functions might provide a suitable approximation.\[ ^{17} \]

\[ ^{17} \]It is possible to either consider the number of apps or the number of developers. In the case of app platforms, the number of downloads belongs to standard KPIs (key performance indicators) and is also the basis for utility and profit generation. Therefore, we consider the number of apps here.

\[ ^{18} \]For example, a function from the family of Sigmoids would be suitable, like the logistic function \[ f(x) = \frac{1}{1+e^{x}} \] or an algebraic version \[ f(x) = \frac{x}{\sqrt{1+x^2}}. \] For some platforms, root functions might provide a suitable approximation.
Hence, the total number of interactions for a participant from the side $B$ amounts to $X_f(N^S)$; the total number of interactions is $XN^B f(N^S)$ as shown in Figure 1.2. The number of interactions per seller is given by the total number of interactions divided by the number of sellers:

$$\frac{XN^B f(N^S)}{N^S}. \quad (1.4.2)$$

Figure 1.2: Sketch of the power set $N^B N^S$ and the reduction to $N^B f(N^S)$ and $XN^B f(N^S)$.

### 1.4.5 Segmentation of participants

On two-sided markets, two distinct groups of customers interact with each other. But the differences can occur not only between the two market sides, but also within them. Again using app platforms as an example, users can be differentiated according to the number of apps they download or according to the revenue they induce. App developers might be divided into private, enterprise and non-profit (e.g., universities). Such segmentations become relevant for the platform if it is possible to charge participants from different segments different prices. And this is precisely what Apple, for example, does: Apple distinguishes between different types of developers and charges different membership fees accordingly. On the
other hand, the users pay the same price for the apps and the same fees for the platform, regardless to which segment they belong. Hence, no segmentation occurs on the user side.

Following this example, we introduce the segmentation of participants for the sellers’ market side only. We assume that it is possible to divide all sellers into $L$ groups, so that $N^S = \sum_{k=1}^{L} N^S_k$. Furthermore, membership fees $A^S_k$, membership utility $B^S_k$, and the production cost $M_k$ are assumed to differ between the segments. Moreover, membership costs for the platform $C^S_k$ may vary, since different customer groups can require different customer service intensity, and so on. The remaining parameters are assumed to be the same.

1.5 Utility and profit functions for the integrated model

In this section, we introduce the key equations for the integrated model. We first consider sellers’, and then buyers’ utility function. The equation for the platform’s profit follows.

1.5.1 Sellers’ utility equation

To model developers, it suffices to construct their utility equation. Developers have two sources of benefit: One that depends on the number of interactions and one that does not. Benefit per interaction $b^S$ has already been mentioned. It corresponds to the cost per interaction $a^S$. Furthermore, payments are made between the two market sides $t = \gamma T$. These components have to be weighted with the number of interactions per seller. As was mentioned in the previous section, the number of interactions per seller equals $\frac{X_{N^B} N^S}{N^S}$, derived from the total number of interactions divided by the number of sellers. All these components are assumed to be equal across different segments.

Membership utility $B^S_k$ does not depend on the number of interactions, nor on membership fee $A^S_k$ and production costs $M^S_k$. Membership utility is a benefit that the market participant obtains, even if he does not interact with the other market side. It can stem, for example, from the respect and recognition of others (e.g., it might be considered trendy to be an “Apple developer” – even if one has never sold an app through the App Store). We also assume that the seller incurs
some form of costs $M_k^S$. These can, for example, comprise production costs or development costs.

Membership-related parameters are assumed to differ for different segments. Hence, the utility equations also depend on the segmentation:

$$U_k^S = (B_k^S - A_k^S - M_k) + (b^S - a^S + \gamma r) \frac{X f(N^S)}{N^S}. \quad (1.5.1)$$

Clearly, only sellers with a positive utility will participate in the platform. The key differences between the sellers’ utility function in the canonical model from that in the integrated model are: First, the integrated model takes membership fees $A_k^S$, membership benefits $B_k^S$, and production costs $M_k$ into account, which differ depending on the market segment; second, we introduce commission payments $\gamma r$ between the two market sides, and third, we implement adjustments $f$ and $X$ for the number of interactions per seller. The main structural differences that influence mathematical handling are the additive term $(B_k^S - A_k^S - M_k)$ and the more complex expression for the number of interactions per seller $\frac{X f(N^S)}{N^S}$.

### 1.5.2 Buyers’ utility equation

Similar to the sellers’ utility equation, the buyers’ utility equation also contains factors that are dependent on and factors that are independent of the number of interactions. The dependent factors include benefit per interaction $b^B$, fee per interaction $a^B$, and additional payment $r$, of which $\gamma r$ goes to the seller and the remaining $(1 - \gamma) r$ is the platform’s commission. Benefit $b^B$ is assumed to depend on the average quality of sellers: $b^B = \alpha q$. The number of interactions per buyer is calculated as the total number of interactions divided by the number of buyers, resulting in $X f(N^S)$.

There are also two membership-related components, $B^B$ and $A^B$. Membership benefit $B^B$ does not depend on the number of interactions and may arise from the potential ability to use the platform. Membership cost $A^B$ is the fee that buyers pay to the platform upfront.

Putting all these parameters together, we obtain the following equation:

$$U^B = (B^B - A^B) + (\alpha q - a^B - r) X f(N^S). \quad (1.5.2)$$

Again, the key differences compared with the canonical model are the membership benefit $B^B$, the membership fee $A^B$, the modeling of the usage benefit $b^B$.
to be proportional to the average quality $\bar{q}$ of participants on the sellers’ side, the
introduction of payment between the two market sides $\gamma \tau$, and the adjustment of
the number of interactions per buyer from $N^S$ to $Xf(N^S)$.

1.5.3 Platform profit function

With regard to the platform, we consider its profit function. The platform charges
both customer groups for usage and membership. The factor that does not depend
on the number of interactions includes membership fees minus costs on the buyers’
side $(A^B - C^B)N^B$, and the membership fees of the sellers’ side across all segments:
$\sum_k (A^S_k - C^S_k)N^S_k$. $C^B$ and $C^S_k$ are costs for the platform that do not depend
on the number of interactions. Here, we take into account that sellers are divided into
groups, for whom membership fees and costs may differ.

The part of the profit which depends on the number of interactions looks
similar to that of the canonical model which includes the sum of the usage fees $a^B$
and $a^S$, subtracted by the usage costs $c$ and multiplied by the number of interactions
$XN^B f(N^S)$. In addition to the usual usage fees $a^B$ and $a^S$, the platform receives a
commission fee $(1 - \gamma)\tau$. Taken together, this yields the following profit function:

$$\pi = (A^B - C^B)N^B + \sum_k (A^S_k - C^S_k)N^S_k +$$
$$+ \sum_k (a^B + a^S + (1 - \gamma)\tau - c)XN^B f(N^S) \frac{N^S_k}{N^S}$$
$$= (A^B - C^B)N^B + \sum_k (A^S_k - C^S_k)N^S_k +$$
$$+ (a^B + a^S + (1 - \gamma)\tau - c)XN^B f(N^S) \sum_k N^S_k$$
$$= (A^B - C^B)N^B + \sum_k (A^S_k - C^S_k)N^S_k +$$
$$+ (a^B + a^S + (1 - \gamma)\tau - c)XN^B f(N^S).$$

(1.5.3)

The major changes for the platform profit function are the altered expression
for the number of interactions and the integration of the membership fees, which
leads to the two additive terms $(A^B - C^B)N^B$ and $\sum_k (A^S_k - C^S_k)N^S_k$. Furthermore,
the usage fees $a^B$ and $a^S$ are supplemented by the commission fee $(1 - \gamma)\tau$ from
the payment $\tau$ between buyers and sellers.
1.6 Solution for the integrated model

This section is devoted to the platform’s profit optimization. We first discuss how to build the tariffs and to determine $a^B$, $a^S$, $A^B$, $A^S_k$ and $\gamma$. Subsequently, we address the decision on quality review from the platform’s point of view.

1.6.1 Optimal prices

The aim of the platform is to maximize its profit $\pi$ under the constraints $U^B \geq 0$ and $U^S \geq 0$. Hence, we have to determine the optimal $a^B$, $a^S$, $A^B$, and $A^S_k$. We apply the method used by Rochet and Tirole (2003) which was introduced in Section 1.3. To be able to do so, we have to bring $\pi$ into the following form:

$$
\pi = (p^B + p^S - c)D^B D^S. \tag{1.6.1}
$$

Before we proceed, note that $A^i$ and $a^i$ are not independent. That is, if one part of the tariff, for example, $A^i$, is fixed, the other part of the tariff $a^i$ cannot vary arbitrarily. This implies that the platform can choose between high $A^i$ combined with low $a^i$ or vice versa. It is possible to build so-called average prices $p^B(a^B, A^B)$ and $p^S_k(a^S, A^S_k)$ which include usage fees and a share of the membership fees. One important consequence is that a set of optimal combinations of $A^i$ and $a^i$ can exist. Mathematically, it follows from the fact that the usage of $p^B(a^B, A^B)$ and $p^S_k(a^S, A^S_k)$ instead of $a^B$, $a^S$, $A^B$, and $A^S_k$ reduces the number of equations from $L + 3$ being $\frac{\partial \pi}{\partial A^i} = 0$ and $\frac{\partial \pi}{\partial a^i} = 0$, $\frac{\partial \pi}{\partial A^B,k=1...L} = 0$, and $\frac{\partial \pi}{\partial A^S} = 0$ to $L + 1$. The ambiguity can be considered a problem, as Armstrong (2006) and Reisinger (2010) point out.\footnote{This problem was first mentioned by Armstrong (2006). In case of two-part tariffs, there is a continuum of equilibriums with the same profit for the platform achieved through various combinations of usage and membership fees. This is attributable to the fact that different combinations of usage and membership fees can be found, which leads to consumer indifference. That is, a low usage fee can compensate for a high membership fee and vice versa, resulting in the same total utility for consumers and, therefore, attracting the same number of consumers.}

As this approach is necessary from a mathematical point of view, we will follow it.\footnote{Reisinger (2010) suggests an approach to resolve this ambiguity by introducing heterogeneity in a duopoly market.} We will introduce average prices and adjust the equation 1.5.3 so that it
resembles the equation 1.6.1. We first complement all terms so that we can factor out \( N_B f(N^S) \):

\[
\pi = (A^B - C^B)N^B + \sum_k (A^S_k - C^S_k)N^S_k + \\
(a^B + a^S + (1 - \gamma)\pi - c)XN_B f(N^S) = \\
= (A^B - C^B)\frac{f(N^S)}{f(N^S)} + \sum_k (A^S_k - C^S_k)N^S_k \frac{N_B f(N^S)}{N^B f(N^S)} + \\
(a^B + a^S + (1 - \gamma)\pi - c)XN_B f(N^S) = \\
= \frac{(A^B - C^B)}{f(N^S)} + \sum_k (A^S_k - C^S_k)\frac{N^S_k}{N_B f(N^S)} + \\
+ a^B X + a^S X + (1 - \gamma)\pi X - cX)N_B f(N^S) = \\
= (a^B X + (1 - \gamma)\pi X + \frac{(A^B - C^B)}{f(N^S)} + \\
+ a^S X + \sum_k (A^S_k - C^S_k)\frac{N^S_k}{N_B f(N^S)} - cX)N_B f(N^S). \tag{1.6.2}
\]

Then, we define the average transaction prices \( p^B \) and \( p^S \) the platform charges per interaction, including the share of both the membership and usage fees:

\[
p^B \equiv a^B X + (1 - \gamma)\pi X + \frac{(A^B - C^B)}{f(N^S)}, \tag{1.6.3}
\]

\[
p^S_k \equiv a^S X + (A^S_k - C^S_k)\frac{N^S_k}{N_B f(N^S)}, \tag{1.6.4}
\]

We must, however, take into account that \( p^S_1, \ldots, p^S_L \) can differ for different segments.

Rochet and Tirole (2006, p. 661) provide a different definition for \( p^B \) and \( p^S_k \), since they add the component \( E[b^i x(b, a^B) + t^i(b, a^B)] \). This leads to the introduction of \( v(a^B) = E[(b^B + b^S - c)x(b, a^B)] \) to compensate for this aspect. From my point of view, it is possible to avoid this, constructing average transaction prices as shown in equations 1.6.3 and 1.6.4.

Subsequently, we insert the average prices into the equation 1.6.2:

\[
\pi = (p^B + \sum_k p^S_k - cX)N_B f(N^S). \tag{1.6.5}
\]
or with $D^B(p^B, N^S) \equiv N^B$ and $D^S(p^S, N^B) \equiv f(N^S)$

$$\pi = (p^B + \sum_k p^S_k - cX)D^B D^S.$$

(1.6.6)

Since we have managed to bring the platform profit equation into the same form as in the canonical model, we can set out to solve it with the help of the same methods. Similar to the canonical model, we transform the function with the help of a logarithm, then differentiate and set the result to zero:

$$\log \pi = \log(p^B + \sum_k p^S_k - cX) + \log N^B(p^B) + \log f(N^S(p^S)),$$

(1.6.7)

$$\frac{\partial (\log \pi)}{\partial p^B} = \frac{1}{p^B + \sum_k p^S_k - cX} + \frac{\partial N^B}{\partial p^B} \frac{1}{N^B} \equiv 0,$$

(1.6.8)

$$\frac{\partial (\log \pi)}{\partial p^S_k} = \frac{1}{p^B + \sum_k p^S_k - cX} + \frac{\partial f(N^S)}{\partial N^S_k} \frac{\partial N^S_k}{\partial p^S_k} \frac{1}{f(N^S)} \equiv 0.$$

(1.6.9)

Since sellers are divided into $L$ segments, we obtain a system with $L + 1$ equations. The first summands are identical, so the following can be set as equal:

$$\frac{\partial N^B}{\partial p^B} \frac{1}{N^B} = \frac{\partial f(N^S)}{\partial N^S_k} \frac{\partial N^S_k}{\partial p^S_k} \frac{1}{f(N^S)}.$$

(1.6.10)

The price elasticities are defined as follows:

$$\eta^B = -\frac{\partial N^B}{\partial p^B} \frac{p^B}{N^B},$$

(1.6.11)

$$\eta^S_k = -\frac{\partial N^S_k}{\partial p^S_k} \frac{p^S_k}{N^S_k}, \text{ with } k \in [1, ..., L].$$

(1.6.12)

From that we obtain:

$$\frac{\partial N^B}{\partial p^B} \frac{1}{N^B} = -\frac{\eta^B}{p^B},$$

(1.6.13)

$$\frac{\partial N^S_k}{\partial p^S_k} = -\frac{\eta^S_k}{p^S_k}, \text{ with } k \in [1, ..., L].$$

(1.6.14)

Now we insert the equations 1.6.13 and 1.6.14 into the equation 1.6.10 and obtain a system with $L$ equations:
\[ \frac{\eta^S_1 \partial f(N^S)}{p^S_1 \partial N^S_1} \frac{N^S_1}{f(N^S)} = \frac{\eta^B}{p^B}, \]
\[ \vdots \]
\[ \frac{\eta^S_k \partial f(N^S)}{p^S_k \partial N^S_k} \frac{N^S_k}{f(N^S)} = \frac{\eta^B}{p^B}, \]
\[ \vdots \]
\[ \frac{\eta^S_L \partial f(N^S)}{p^S_L \partial N^S_L} \frac{N^S_L}{f(N^S)} = \frac{\eta^B}{p^B}. \]

One more equation follows from equation 1.6.8 together with equation 1.6.11:

\[ p^B + \sum_k p^S_k - cX = \frac{p^B}{\eta^B}. \quad (1.6.15) \]

We obtain a system with \( L + 1 \) equations and \( L + 1 \) unknown variables. This system is a generalization of the solution Rochet and Tirole (2003) provide for the canonical model (cf. proposition 1 in Section 1.3). There are two crucial differences: First, due to the segmentation of sellers into \( L \) groups, we obtain \( L + 1 \) equations instead of 2; second, the ratio of the average prices is no longer simply equal to the price elasticities, but there are correction factors. These differences occur due to the introduction of the two new parameters, namely, the segmentation of sellers and the adjustment of the number of interactions. If we set \( L = 1 \) and \( f = 1 \), we would obtain the same solution as that developed for the canonical model in Section 1.3.

Further differences between the canonical model and the integrated model would be observable if we solved the system of equations. At this point, membership fees \( A^B \) and \( A^S \), the payment between customer groups \( \gamma \), and the average quality of sellers would emerge.

The solution we have developed so far can be recorded as a proposition:

**Proposition 1.2.** The average prices for a two-sided market with a segmentation of one market side, with tariffs consisting of both usage and membership fees and the adjusted amount of interactions written as \( XN^B f(N^S) \) are given in the following system of equations:
\[
\frac{\eta_1^S \partial f(N^S)}{p_1^S \partial N_1^S} \frac{N_1^S}{f(N^S)} = \frac{\eta^B}{p^B},
\]
\[
\vdots
\]
\[
\frac{\eta_k^S \partial f(N^S)}{p_k^S \partial N_k^S} \frac{N_k^S}{f(N^S)} = \frac{\eta^B}{p^B},
\]
\[
\vdots
\]
\[
\frac{\eta_L^S \partial f(N^S)}{p_L^S \partial N_L^S} \frac{N_L^S}{f(N^S)} = \frac{\eta^B}{p^B}.
\]

and

\[
p^B + \sum_k^S p_k^S - cX = \frac{p^B}{\eta^B}. \tag{1.6.16}
\]

It is easy to see that the result of this equation system yields the average prices \(p^B, p_1^S, \ldots, p_L^S\). But what the platform is looking for are the tariffs, that is, \(a^B, a^S, \ldots, A^B, A_1^S, \ldots, A_L^S\). This is the standard approach in the literature to provide the equation system for \(p^B, p_1^S, \ldots, p_L^S\) (cf. Armstrong (2006), Rochet und Tirole (2006)). To determine \(a^B, a^S, A^B, A_1^S, \ldots, A_L^S\), the values for \(p^B, p_1^S, \ldots, p_L^S\) must be plugged into the equations 1.6.3 and 1.6.4. It also requires the definition and incorporation of the demand functions \(D^B(p^B)\) and \(D^S(p^S)\) from the utility functions that we have discussed above.

### 1.6.2 Profitability of the quality review of participants

Besides optimal price setting and allocation, we have to determine the optimal quality of participants. As mentioned in Section 1.4, there are two possibilities: The platform either restricts access to the market place, allowing only high quality sellers to participate or it permits all sellers to participate, regardless of their quality. In the first case, a review process should be in place. We assume that the launch of the review process costs \(\kappa\) and that no variable cost is incurred. We also assume that during the course of the review process, the quality of the participants is perfectly observable, that is, there are no inaccuracies in the quality estimation. For now, let us assume that optimal prices are already determined. We will suspend this assumption later on. If a quality review process is installed,
the average quality of participants $\overline{q}$ equals $q_H$, since only high quality sellers are allowed to participate:

$$\overline{q}(\beta_H = 1, \beta_L = 0) = \frac{\nu \beta_H q_H + (1 - \nu) \beta_L q_L}{\nu \beta_H + (1 - \nu) \beta_L} = \frac{\nu \beta_H q_H}{\nu \beta_H} = q_H. \quad (1.6.17)$$

If no quality review process is installed, no investment is necessary. But then all sellers who are willing to pay the fees gain access to the platform. The average quality of participants is then given by the average of the Bernoulli distribution with $\beta_H = \beta_L = 1$:

$$\overline{q}(\beta_H = 1, \beta_L = 1) = \frac{\nu \beta_H q_H + (1 - \nu) \beta_L q_L}{\nu \beta_H + (1 - \nu) \beta_L} = \nu q_H + (1 - \nu) q_L. \quad (1.6.18)$$

The platform profit function is as follows:

$$\pi(\nu q_H + (1 - \nu) q_L) = (A^B - C^B)N^B + \sum_k (A^S_k - C^S_k)N^S_k + (a^B + a^S + (1 - \gamma)\tau - c) X N^B f(N^S), \quad (1.6.19)$$

and the utility functions of the platform yield:

$$U^B(\nu q_H + (1 - \nu) q_L) = (\alpha(\nu q_H + (1 - \nu) q_L) - a^B - \tau) X f(N^S) + (B^B - A^B), \quad (1.6.20)$$

$$U^S_k(\nu q_H + (1 - \nu) q_L) = (b^S - a^S + \gamma \tau) X \frac{N^B f(N^S)}{N^S} + (B^S_k - A^S_k - M_k). \quad (1.6.21)$$

In order for the quality review process to be installed, it must yield a higher profit compared to the base case which does not involve a quality review. Hence, these equations build a reference point for the quality review.

To determine the profit in the quality review case, we have to consider what actually changes if it is introduced – apart from the average quality. First, the buyers’ benefit per interaction $b^B$ increases due to the proportionality between benefit per interaction and quality $b^B = \alpha \overline{q}$. Secondly, the number of available sellers declines from $N^S$ to $\nu N^S$. If we assume that the membership fees do not change for neither market side, then the platform has to compensate for the loss of profit by increasing the usage fees from $a^B$ to $a^B_H$ or by increasing the number
of buyers from $N^B_k$ to $N^B_H$. If a quality review process is installed, then the profit equation is as follows:

$$
\pi(q_H) = (A^B - C^B)N^B_H + \sum_k (A^S_k - C^S_k)\nu_k N^S_k + (a^B_H + a^S + (1 - \gamma)r - c)XN^B_H f(\nu N^S) - \kappa,
$$

(1.6.22)

with $\nu_k$ being the share of high quality participants among the segment $N^S_k$ and $\nu = \sum_k \nu_k$. This allows us to take into account the case when there is a correlation between the segmentation and the quality of participants. The utility functions for buyers and sellers can be written as described below:

$$
U^B(q_H) = (B^B - A^B) + (\alpha q_H - a^B_H - r)X f(\nu N^S),
$$

(1.6.23)

$$
U^S(q_H) = (B^S_k - A^S_k - M_k) + (b^S - a^S + \gamma r)XN^B f(\nu N^S) - \kappa.
$$

(1.6.24)

After we have derived the equations for the platform’s profit with and without the installment of a quality review process, we can compare them. If $\pi(q_H) - \pi(\nu q_H + (1 - \nu)q_L) \geq 0$, then it is profitable to introduce a quality review process:

$$
\begin{align*}
\pi(q_H) - \pi(\nu q_H + (1 - \nu)q_L) &= \\
= (A^B - C^B)N^B_H + \sum_k (A^S_k - C^S_k)\nu_k N^S_k + (a^B_H + a^S + (1 - \gamma)r - c)XN^B_H f(\nu N^S) \\
- ((A^B - C^B)N^B_H + \sum_k (A^S_k - C^S_k)N^S_k + (a^B + a^S + (1 - \gamma)r - c)XN^B_H f(N^S)) - \kappa \\
= (A^B - C^B)(N^B_H - N^B) + \sum_k (A^S_k - C^S_k)(\nu_k - 1)N^S_k + a^B_H XN^B_H f(\nu N^S) \\
+ (a^S + (1 - \gamma)r - c)XN^B_H f(\nu N^S) - \kappa - (a^B + a^S + (1 - \gamma)r - c)XN^B_H f(N^S).
\end{align*}
$$

(1.6.25)

Using this equation, we can obtain the value for $a^B_H$ which suits the condition $\pi(q_H) - \pi(\nu q_H + (1 - \nu)q_L) \geq 0$:

$$
a^B_H \geq \frac{(A^B - C^B)(N^B - N^B_H) + \sum_k (A^S_k - C^S_k)(1 - \nu_k)N^S_k + \kappa}{XN^B_H f(\nu N^S)} + \\
- (a^S + (1 - \gamma)r - c) + \frac{(a^B + a^S + (1 - \gamma)r - c)N^B_H f(N^S)}{N^B_H f(\nu N^S)}.
$$

(1.6.26)
At the same time, $a^B_H$ must suit the utility condition $U^B(q_H) \geq 0$. Hence,

$$a^B_H \leq \frac{(B^B - A^B)}{X_f(\nu N^S)} + \alpha q_H - \tau.$$  

(1.6.27)

The two inequalities 1.6.26 and 1.6.27 yield the conditions for the appropriate $a^B_H$. Three cases are possible:

1. The upper bound equals the lower bound, then only one solution exists for $a^B_H$;

2. The upper bound lies above the lower bound, then a set of feasible values exists for $a^B_H$, and the highest should be taken to maximize profit;

3. The upper bound lies below the lower bound, then no solution exists.

Based on the outcome of these comparisons, the platform can decide whether it should introduce a quality review process or not. Once quality optimization procedure is understood, the platform owner can conduct price and quality optimization simultaneously. She would need to consider two cases: The first one with a review process installed and the second, where no quality review is conducted. For these two cases, the platform owner will have to determine the optimal prices and corresponding profits. Then, by comparing the profits, she will be able to see, which case is preferable – the one with quality review process or without.

1.7 Case example: App platforms

In this section, we provide an example of how the integrated two-sided model can be used to model app platforms. “App platforms” are software distribution platforms for mobile devices like smartphones or tablets. They gained popularity after Apple launched its App Store in 2008. Hence, our monopoly model can be applied to the time period during which the App Store was the only strong platform on the market. Although the advantage of the App Store seemed incontestable, other app platforms like Google Play for Android OS managed to enter the market and achieve high popularity. Other platforms have tried to emulate Apple and Google, forming coalitions and trying to create niche markets. These developments provide interesting avenues for a further development of the integrated two-sided market model and its applications.

\[ ^{21} \text{Cf. comScore Reports (2011).} \]
1.7.1 Introduction to app platforms

App platforms are a special form of electronic markets. Software developers can distribute their software applications (apps) via app platforms to users of mobile devices like smartphones or tablets. App platforms can act as an intermediary connecting the two market sides, as an infomediary providing information about the market participants or as a certifier verifying identity or controlling the quality of the market participants.\(^\text{22}\)

Apple’s App Store and Google Play for Android OS are probably the best known app platforms. Actually, many more app platforms aside from these two exist – and some of them were founded as early as 1999.\(^\text{23}\) The launch of the App Store has changed the mobile phone industry in practically all dimensions.\(^\text{24}\) After 3 years in the market, there were 425,000 apps available in the App Store. The number of downloads exceeded 14,000,000,000.\(^\text{25}\)

A lot of companies are trying to replicate the App Store’s success. Among them are native (to the operating system) platforms like Google Play (Android), RIM’s App World and Nokia’s Ovi Store, smartphone manufacturers like Samsung, LG or SonyEricsson, mobile network operators like Verizon, Vodafone or Telekom. Native platforms have had the highest impact on the industry so far, and they also tend to be larger (in terms of available apps and downloads). Figure 3.3 in the appendix provides an overview of the key native app platforms.

Since other app platforms were very small compared to the App Store, the integrated two-sided market model for monopoly platforms is particularly suitable for the time period between the launch of the App Store in July 2008 and the launch of the Android market (the second biggest app platform, now Google Play).


\(^{23}\)For example, Handango has been providing apps for mobile phones since 1999. But it was not until the App Store appeared that app platforms have gained momentum. Several hypotheses may explain why it took until 2008 for app platforms to gain popularity, for example, usability (size of screen), connectivity (3G and 4G coverage) or the hardware price may have contributed to the app platform development.

\(^{24}\)Cf., for example, the remark in the Financial Times (13 March 2009): “The runaway success of Apple’s iPhone App Store, the online site where iPhone and iPod Touch owners can download free or cheap software for their devices, has transformed the mobile software marketplace.” or the remark by Steve Jobs, CEO of Apple (October 2009): “The App Store is like nothing the industry has ever seen before in both scale and quality.”

at the end of 2008. In the following, we will discuss how the integrated two-sided market model can be applied to model app platforms.

### 1.7.2 Structure and operations of an app platform

Before we can turn to modeling, we have to discuss how an app platform operates and which parameters must be included in the mathematical analysis. Figure 1.3 exemplifies the key participants of app platforms and the interactions between them. They are developers, an app platform and users. Before a developer can start to program an app, she has to sign up with the platform. Some platforms charge membership fees for that, which can vary for private developers, enterprises and non-profit organizations. In return, the developer gains access to the Software Development Kit and other tools.

![App Store Diagram](image)

Figure 1.3: Sketch of the key participants of an app platform and interactions between them (exemplified here by the App Store).

Developers write apps which they submit to the app platform. In general, they are entitled to choose app prices themselves.\(^{26}\) Some platforms conduct quality

---

\(^{26}\)Some platforms restrict prices to certain values like USD 0.99, 1.49, 1.99, and so on. There is also a new development regarding app prices: Since March 2011, Amazon has been offering another model for which it determines app prices itself (cf. [http://business.chip.de/news/Amazon-Android-App-Store-oeffnet-fuer-Entwickler_46573233.html](http://business.chip.de/news/Amazon-Android-App-Store-oeffnet-fuer-Entwickler_46573233.html)).
reviews before they make apps available to users (e.g., App Store), some do not (e.g., Google Play market). Once apps are accepted, the platform “publishes” them, that is, the apps become available to the users. Users may search and download the apps. Depending on the platform, 20-60% of submitted apps are free of charge.\footnote{Cf. report by Distimo (Juli 2010).} The share of free apps among the downloaded apps amounts to 80%-90%.\footnote{Cf. report by Gartner (December 2009).} The payment process in the case of apps that can be purchased occurs through the platform. Users may also rate the downloaded apps and submit reviews for them.

Developers obtain their share of revenues from the platforms (usually around 70%). Payments thus take place between users and developers. The remaining 30% represents the platform’s commission. In addition, users pay for the mobile phones and it is likely that part of this payment represents the app platform usage. This completes the circuit of interactions.

1.7.3 Application of the integrated two-sided market model

We begin by explaining how the operations of an app platform can be reflected in two-sided model parameters. Then, we show how utility and profit equations can be adjusted. The parameters of the integrated two-sided market model can be interpreted as follows:

- \( a^B, a^S \) – usage fees per download for both users and developers. \( a = a^B + a^S \) is the total usage fee the platform receives.

- \( A^B, A^S_k \) – membership fees for both users and developers. For the users, it can be interpreted as part of the mobile device cost. For developers, it is the fee they pay for access to the tools and participation in the platform. It does not depend on the number of downloads. We take into account that developers from different groups (private, enterprise or non-profit organization) pay different membership fees.

- \( b^B, b^S \) – benefit per download. For users, we assume that usage benefit depends on the average quality of apps \( b^B = a\bar{q} \) with \( a = \text{const}, a > 0 \) and \( \bar{q} = E(Q) = \sum_{i \in I} q_i w_i \). Usage benefit for developers may stem from other
revenues, such as payment from users (e.g., advertising) or from non-monetary sources (e.g., recognition from peers). The last source is probably zero for the majority of developers, especially for enterprise developers.

- $B^B, B^S_k$ – benefit from participation in the platform, which does not depend on the number of downloads.
- $c$ – costs per download for the platform.
- $C^B, C^S_k$ – cost of membership for the platform, which may derive from service requirements. We assume that membership costs can vary among developer segments.
- $M_k$ – production costs for developers.
- $p^B, p^S$ – average prices consisting of usage fees and a proportional share of membership fees.
- $p = p^B + p^S$ – total average price the platform charges per interaction.
- $r$ – app price with distribution $R$ and average $\bar{r}$.
- $\gamma$ – share of app price that developers receive. The remaining $(1 - \gamma)\bar{r}$ is allocated to the platform.
- $\gamma r$ – payment from users to developers.
- $q$ – quality of an app with distribution $Q$. We assume a Bernoulli distribution for app quality. The average quality is then given by $\bar{q}(\beta_H, \beta_L) = \nu\beta_H q_H + (1 - \nu)\beta_L q_L / \nu\beta_H + (1 - \nu)\beta_L$.
- $\eta = \eta^B + \eta^S$ – price elasticity of demand.
- $N^B = D^B(p^B)$ – number of users.
- $N^S = D^S(p^S)$ – number of developers.
- $XN^Bf(N^S)$ – adjustments of the number of interactions.
- $x(b^B, b^S, a^B) \in [0, 1]$ with $X \equiv E[x(b, a^B)]$ – the probability of download of scanned apps.
- $f$ – correction function for the number of downloads (differentiable, invertible).
• Segmentation of developers: \( A_k^S, B_k^S, C_k^S \) and \( N_k^S \), with \( k = 1, ..., L \).

Using these parameters, we can now construct the following equations for developers, users, and platform profit:

\[
U_k^S = (B_k^S - A_k^S - M_k) + (b^S + \gamma \bar{r}) \frac{X N_k^B f(N_k^S)}{N_k^S}, \quad (1.7.1)
\]
\[
U^B = (B^B - A^B) + (\alpha \bar{q} - \bar{r})X f(N^S), \quad (1.7.2)
\]
\[
\pi = (A^B - C^B)N^B + \sum_k (A_k^S - C_k^S)N_k^S + ((1 - \gamma) \bar{r} - c)X N_k^B f(N_k^S). \quad (1.7.3)
\]

The solution of this system is basically the same as in Section 1.6. For a given demand function and benefit values, we can determine the prices, that is, fee allocation to the two market sides. Using our methodology from Section 1.6.2, we can also determine whether a quality review system would be profitable for the app platform.

It would be interesting to test this model empirically and to compare the results with the App Store performance and strategy in the past. Another research area that would be particularly interesting from an applied point of view is the modeling of competition over time and an analysis of the competition between the App Store and the Google Play. Yet another interesting research focus would be on competition and coalitions between less dominant app platforms, like the agreement between Nokia and Windows.\(^{29}\) Modeling of these phenomena provides promising avenues for future research in two-sided market theory and applications.

Some limitations exist for the application of the two-sided market model. For example, it is possible to identify further parameters, like branding or interdependence between software and hardware, which might influence the app platform’s strategy and performance. It might be interesting to explicitly model such parameters. We must also mention that in the real world, it could be difficult to determine demand functions or to provide values for price elasticities. In that case, assumptions and estimations have to be made. They can be revised later and the fees can be adjusted accordingly.

1.8 Discussion and conclusion

This study contributes to the theory of two-sided market models. Departing from the canonical two-sided market model of Rochet and Tirole (2003) for a monopoly platform with usage fees, we have considered possible extensions of this model. Some of them were new and others have already been discussed in the literature. The prevalent parameters include membership fees (cf. Armstrong, 2006, Rochet and Tirole, 2006), payments between customer groups (cf. Rochet and Tirole, 2006), and quality review of participants (Hagiu, 2009, Jeon and Rochet, 2010). The new extensions are commission fee, segmentation of participants, introduction of commission fee and adjustments for the number of interactions between customer groups.

Subsequently, we integrated all these parameters into one model. The main contribution of the integrated model is that it allows consideration of all parameters simultaneously. Using the methodology of Rochet and Tirole (2003, 2006) and Armstrong (2006), we have derived a solution for the new model. The solution is a general case of the underlying models, so the price level equation resembles Lerner’s index and the allocation of fees is proportional to the price elasticities up to a certain factor. The key differences compared to Rochet and Tirole (2003) include an increased number of equations due to segmentation and correction terms for the proportionality of fees to price elasticities.

The resulting model with a new combination of parameters allows us to improve the modeling of two-sided market platforms with the following features: There are usage and membership fees as well as payments between market sides, the quality of participants is crucial, segmentation is present and the number of interactions cannot be approximated as the power set of the participants’ number. Amazon, eBay or Apple’s App Store are prominent examples of this type of market.

Finally, we have discussed an example of how the integrated two-sided market model can be used to model app platforms – software distribution platforms for mobile devices like smartphones or tablets. Following a brief description of app platform operations, we show how the parameters of the integrated two-sided market model can be interpreted to reflect the structure of app platforms.

The limitations of the model at hand are that while many important parameters have been integrated into it, there are many more parameters that might be useful for the description of real-world two-sided markets. For example, if
we included such parameters as non-monetary incentives, overall strategy of the platform, or path dependence, the model would probably reflect the real-world two-sided markets even better. The integration of these parameters represents an interesting future research opportunity. Further development opportunities for this model include the introduction of competition, the integration of market development over time and empirical tests of the model.
Bibliography


platforms drive innovation and transform industries. The MIT Press.


Working paper #12-024.


pp. 222–255.


822–841.


Paper II: Toward Understanding Dynamics and Disruptions in Two-sided Markets: A Dynamic Two-sided Market Model

Abstract

Over the last decade, a large body of literature on theoretical, as well as applied aspects of two-sided markets has emerged. Most of it concentrates on developing static models. The real-world two-sided markets like app platforms (the App Store for iOS, Google Play for Android OS, etc.), evolve strongly over time. Also, they are prone to highly disruptive changes causing fast rise and fall (e.g., Android OS is up from 0% to more than 60% market share for smartphone shipments, Nokia OS is down from 70% to 10% in the last 5 years. This implies that static models and not sufficient to describe such industries. In this research paper, we propose a dynamic model that explicitly includes evolving number of participants and can help to analyze disruptive changes.

Our model is based on dynamic systems theory, examples from life sciences and differential game theory. The centerpiece of the model is a mathematical representation of the population development over time. These equations serve as constraints for the optimal pricing policy. Since the model is too complex to be solved analytically, we use Matlab simulation to analyze model behavior. We derive strategies for different situations and development phases of app platforms. One
important result concerns the problem that a platform must get both sides on board (the so-called “chicken-and-egg” problem). The dynamic model suggests that this problem can be avoided if membership benefits are high enough to compensate for the low network effects. Furthermore, we show how the number of agents necessary to start off the platform can be calculated.

The next series of results show how platform owner should adjust prices in case there is a chance to do so once the app platform is up and running. Our findings show that in general, it is optimal to increase fees for users as well as developers. Furthermore, we analyze disruptions like entrance of new competitors. We show that competitive entry not necessarily leads to noticeable price reduction. This can help to explain some real-world observations, for instance, Apple Inc. did not reduce their fees after other competitors like Android have entered the market. Our model also helps to evaluate the difference between short-term and long-term decisions, pointing out how far away the results of optimization can be depending on the time horizon under consideration. Overall, the dynamic model proves to be a powerful instrument for analyzing two-sided markets. We hope that future research will build on this model adding further aspects and conducting empirical research to better understand Internet-based platforms like App Store, Amazon and eBay.

Keywords: Two-sided market, multi-sided market, platform, e-business, dynamic model, “chicken & egg” problem.

JEL classification numbers: L8, L81, L82, L86, L96.
2.1 Introduction

Over the last decade, a large body of literature on two-sided markets has emerged. Two-sided markets are platforms that connect two groups of customers who value each others’ presence. Examples of these markets are abound: Amazon, eBay and Google have advanced to top brands worldwide (cf. www.interbrand.com) and have become the “invisible engines” (cf. Evans et al. 2006) of our economies.

To be able to analyze such Internet-based platforms, a model is needed that incorporates key parameters of these platforms. The parameters include usage and membership fees, payments between customer groups, role of quality differences, segmentation and appropriate number of interactions depending on the number of participants. This was the main topic of Kouris (2011), where several extensions were introduced and prevalent parameters were integrated into a single unified model. The focus of this article is on development of a dynamic two-sided market model based on the integrated model. This leads to a platform strategy that will remain valid over a longer time period, while price elasticities might change. In this research paper, we begin with the monopoly case, and proceed with consideration of external shocks, which represent, for example, competitive entry or introduction of new technology.

We develop a mathematical representation for the platform dynamics based on dynamic systems theory, examples from life sciences and differential game theory. Profit calculation and optimization is implemented in Matlab in form of computer simulation, since the mathematical problem at hand is too complex to be solved analytically.

Most two-sided market models focus on pricing strategies in a static setting, for instance, Rochet and Tirole (2003, 2006), Armstrong (2006). We will extend this to the dynamic setting. The research questions that were central for static models, i.e., “Which side to charge and how much?”, “How to divide fees into usage/commission and membership fees?”, “Is the solution unique?” will be addressed for the dynamic setting. The dynamic model at hand provides recommendations on how fees should be optimally allocated between the market sides, so that the solution remains optimal in the future. In terms of division of fees in usage/commission and membership fees, the dynamic model provides a unique solution. In the static case, the solution was not unique, which was considered a problem (cf. Armstrong, 2006; Reisinger, 2010). The dynamic models helps to resolve this issue.
Further research questions pertain to the “chicken-and-egg” problem, which was introduced by Caillaud and Jullien (2003) and refers to the problem of launching a platform: in order to attract users, developers should have joined the platform and have offered apps, but developers would only join, if potential users already have joined. We will discuss the minimal number of participants on both sides necessary to kick-off the platform and show that this combination is not unique. These insights are particularly important for the launch of new platforms, where one needs to know how many participants (and, consequently, resources) are required to get the platform going.

Furthermore, we compare short-term and long-term optimization strategies showing how they might differ. Then we analyze the possibility to adjust prices after a certain period of time. We describe which price component should be adjusted and how. The next step represents introduction of external shocks, representing for instance a competitor's entry, regulations adjustments or introduction of new technologies. The key threat behind such disruptions is basically the same, namely reduction of the potential number of participants. Therefore, such external shocks can be modeled applying the same approach. With help of Matlab simulations we show that price adjustments in case of disruptions may remain pretty small. This is in line with real-world observations.

The research paper is organized as follows. The next section focuses on literature review and background information on the two-sided markets and dynamic systems modeling theory. In Section 2.3 we develop a dynamic model. The model includes the goal function represented through the platform profit equation (Section 2.3.4), and constraints equations which describe population dynamics (Sections 2.3.1 and 2.3.2). For the overall model formulation see Sections 2.3.5. Section 2.4 describes Matlab simulation approach and simulation results. Section 2.5 concludes.

2.2 Literature and background review

In this section, we provide literature review and background information for the model. The starting point of the dynamic framework are two-sided market models originated by Rochet and Tirole (2003). We show how such models evolved since Rochet and Tirole (2003) in the next section. Furthermore, we provide some background information on dynamic models. We discuss briefly the most relevant
aspects of dynamic systems theory, examples from life sciences and differential
game theory.

2.2.1 Two-sided market theory

Two-sided markets are platforms that enable interaction between two groups of
customers who value each other’s presence (cf. Rochet and Tirole, 2003 p. 990,
Evans, 2003 p. 191, Tag, 2008 p. 5.). Research on two-sided markets stems from
network economics and complementary product pricing (cf. Rochet and Tirole,
2003 p. 646). For the early works see Katz and Shapiro (1985, 1986), Farell
and Saloner (1985, 1986). One of the key concepts for two-sided markets is that
of “indirect network effects”: The utility on the one side of the market increases
with the number (and/or quality) of participants on the other side.1 Examples
of platforms that can be interpreted as two-sided markets range from credit card
systems and software platforms to night clubs and shopping malls. Due to the
diversity of two-sided market examples various extensions are needed to describe
different kinds of platforms.

Although two-sided market theory emerged only a decade ago2, there is
already a considerable amount of research papers on two-sided markets. The first
published studies include: Rochet and Tirole (2003), Caillaud and Jullien (2003)
and Evans (2003). Since then, two-sided markets research concentrates on four key
directions:

• Introduction of new extensions for a static monopoly model (see Armstrong
(2006) and Rochet and Tirole (2006) on membership fees, Hagiu (2009), Jeon
and Rochet (2010) on quality preference of participants);

• Analysis of duopoly setting and development of extensions for it (see Arm-
strong (2006) on “competitive bottlenecks”, Choi (2010) on tying and multi-
homing, Tag (2008) on comparison of open and closed platforms);

---

1For exact definition of two-sided markets see Rochet and Tirole, (2006 pp. 657-658). Many
attempts were undertaken to provide a definition for the two-sided markets. One of the latest
was presented by Hagiu and Wright (2011 p. 2): “We define MSP [MPS stands for multi-sided
platforms] to be an organization that creates value primarily by enabling direct interactions
between two (or more) distinct types of affiliated customers.” It remains to be seen whether this
definition will be widely adopted.

2The first research papers on two-sided markets were circulated around 2001 by Rochet and
Tirole, Caillaud and Jullien.


The emphasis was clearly on the first two research directions — development of extensions for monopoly and duopoly cases. The dynamic view was not getting much attention before but belongs to the most promising directions for future research. This research paper should help to fill this gap by developing a dynamic framework for two-sided markets. Thereby we build on the integrated two-sided market model introduced in Kouris (2011), which includes extensions such as usage and membership fees, commission fee, correction of the number of participants, product quality and participants segmentation.

The need for a dynamic model arises from the observation that in the real-world platforms the number of participants changes considerably over time in a non-linear way. Also price elasticities do not remain constant. Take for instance the attitude change towards paid content from the Internet: in 2000–2001, the willingness to pay for content downloaded from the Internet was very low compared to 2010–2011, where eBooks passed paper books on Amazon (cf. Miller and Bosman, 2011) and mobile application platforms’ revenue reaches about USD 4 billion in 2011 as was reported by iSuppli (cf. Kent, 2011).

Hence, the questions arises how to set prices that take these changes and disruptions into account. Static models consider only current situation and cannot include anticipated future changes. To overcome this limitation of static models, we develop a dynamic model that includes the over time evolving number of participants and calculates the appropriate prices to maximize platform profit. In the following section, we describe the dynamic theories the model relies on.

3For example, the key note speech by Luiz Cabral delivered on the ICT conference 2011 at Telecom ParisTech was devoted to dynamic models for two-sided markets.

4For more details on the integration of the prevalent parameters into one integrated model and analytic solution for this model in the static setting cf. Kouris (2011).
2.2.2 Background on dynamic modeling

Dynamical systems theories provide methodologies to handle complex problems with a dynamic component, that is, systems that evolve over time (cf. Bender, 2000; Fabien, 2009). Dynamic systems modeling and optimization is a vast area. It includes dynamic programming, differential game theory, system dynamics, optimal control theory, mathematical biology and many more. Since most processes evolve over time, dynamic modeling has applications in many sciences pertaining to subjects such as: population of species, weather forecasting, information diffusion, management of product cycle, number of people participating in a demo.

Optimal control theory is one branch of dynamic systems theories, that deals with optimization questions around dynamic processes. It is mainly applied in Mathematics and Engineering. Optimal control theory helps to determine a control law for a system consisting of a goal functional and a set of dynamic constraints (cf. Liberzon, 2012; Kirk, 2004). Goal functional depends on state and control variables. Constraints are represented by a set of differential equations. For instance, the aim of a platform owner is to maximize her profit. Hence, profit represents goal functional in this case. Platform profit depends on control variables set by the platform (e.g., usage fees) and on development of the number of participants over time. In order to maximize her profit, the platform owner has to find a balance between choosing high prices and attracting many participants. In optimal control theory it is assumed that prices can be adjusted at any point of time. Solutions of such optimal control problems can be found by applying Pontryagin’s maximum principle, or by solving the Hamilton-Jacobi-Bellman equation (cf. Dockner, 2000, Pontryagin, 1962).

Application of optimal control theory in economics, especially in strategic environments, is known as differential game theory (cf. Dockner, 2000). In case where recursive difference equations replace differential equations, differences game theory applies. In difference equations population dynamics evolves in discrete time, with deltas per time period instead of derivatives (cf. Huckfeldt, 1982). Current state of variables depend on the previous state(s). For instance, the number of customers at a certain time point $t + 1$ is given by the number of customers in the previous time point $t$ plus change in the number of customers during the period between $t$ and $t + 1$. Platform dynamics is then given by a recursively defined sequence.
Optimization methods, as opposed to optimal control methods, assume that control variables remain constant over time. Applied to the platform profit optimization it means that prices are chosen once with no adjustment possibilities. Which theory – optimal control or optimization – is more suitable, depends on the problem at hand.

Over the last five years, efforts were started by Sun and Tse (2007), Markovich (2008) and Cabral (2011) to provide dedicated dynamic models for the two-sided markets. Generally, many of these models make simplifying assumptions regarding consumer behavior. For instance, Markovich (2008) assumes that consumers live for two periods, therefore, this model cannot provide insights on how platforms evolve over time or compare short-term and long-term perspective. Earlier research papers use even stricter and less realistic assumptions, e.g., Fundberg and Tirole (2000), consider a population consisting of only two consumers. This poses limits to the degree of comparability with the real two-sided markets. Cabral (20011) develops a stochastic model with forward-looking consumers. Consumers are assumed to have idiosyncratic preferences, which lead to stochastic dynamics. Compared to that, we assume that consumer preferences are determined by their expected utility.

Sun and Tse, (2007) employ differential game theory to study two-sided markets, considering long-term market development and concentrating on the steady-state market share. Differential game approach is used, for instance, to define optimal pricing decisions in other areas like monopolistic network with positive network effects (e.g., Dhebar and Oren, 1985, 1986). Sun and Tse (2007) assume that consumer behavior is determined by the current observations and not their expectations. The major contribution of Sun and Tse (2007) is to show how two-sided markets can be modeled with help of differential equations as a two-point boundary value problem. Furthermore, they show how single-homing vs. multi-homing decision affects long-term equilibrium. We begin by building a model which is based on Sun and Tse (2007) approach. But since we are rather interested in the dynamic than in the final state, we then switch to a model that does not require to adjust prices constantly.

The model presented in this research paper is based on differential and difference games theory (cf. Dockner et al., 2000). As Huckefeldt et al. (1982) asserts, “The goal of dynamic modeling is to specify the structure of such processes and to deduce the manner in which they generate [...] change”. We begin by
developing a continuous-time differential game model. Then we transform it into a discrete-time optimization model. We will elucidate this in the following sections.

### 2.3 Model formulation

We begin this section with construction of population dynamic in continuous time based on dynamic systems theory, examples from life sciences and differential game theory. Then we show how to adjust this for the discrete-time optimization. Subsequently, we determine expected utility and NPV expressions which are needed for the system dynamic equations. Finally, we derive goal function and formulate the optimization problem.

#### 2.3.1 Population dynamics in continuous time

The number of platform participants usually changes over time. The platform owner should take that into account when determining profit maximizing prices. In reality we observe different types of platform dynamics. Consider, for instance, sales development of smartphones by operating system (OS). This is, in fact, a good representation of the number of app platform users. Figure 2.1 displays development of the four major operating systems over the last 5 years. Cumulated smartphone sales show how customer populations for different smartphones evolved over time. Some display an exponential kind of growth like Android, others grow slowly like Nokia’ Symbian during the last 5 years.

Generally, Sterman (2000), suggests that despite of the vast variety of dynamic processes, all of them can be represented through a very small number of fundamental patterns, which are shown on Figure 2.2. Three most important models of dynamic system behavior are (exponential) growth, goal seeking and oscillation. Three more common patterns are a combination of the previous two and include S-shaped growth, growth with overshoot and overshoot and collapse. The first three patterns result from a simple feedback structure: growth occurs when there is positive feedback, goal seeking from negative feedback and oscillation

---

5Apple iOS includes only iPhones. To take the full impact of the operating system into account, iPads and iPods ought to be considered as well.

6Actually, considering Nokia, we have to take into account that this is just a part of a larger picture. They were on the smartphone market since 1999, hence, in 2007–2012 their smartphones were in a different phase of the product life cycle compared to Android smartphones.
Figure 2.1: Cumulated world-wide smartphone sales 2007 Q1–2012 Q1, millions of units. Source: Gartner.

results from negative feedback with time lag (cf. Sterman, 2000). Further structures arise from combinations of the fundamental feedback patterns.

The case of linear growth presupposes that there is no feedback. This occurs rarely. As Sterman (2000) points out, “what appears to be linear growth, is often actually exponential, but viewed over a time horizon too short to observe acceleration”. We can observe this effect on Figure 2.1 with the Nokia’s Symbian case.

Platform dynamics could potentially show all these patterns at different times. The most widespread dynamics for app platforms until now can be described best as exponential growth. Since potential number of customers is restricted by the total population of the Earth with income high enough to buy a mobile device, there will be an inflection point which leads to an S-curve. On the long run, we would expect to see a growth rate decline as observed for product life cycles.\footnote{Clearly, population limitation is not the only reason for the decline. For instance, appearance of a substitution product can lead to sales decline.}
A lot of work on population dynamics was done in life sciences. Different types of population dynamics were proposed and analyzed. Key factors that determine population growth in life sciences are birth and death rates, immigration and emigration, environmental influences, competitive or mutual relationships with other species, etc. (cf. Schoen, 2006). In other areas like IT there are also processes that require application of the optimal control theory. For instance, information diffusion can be described as a system of differential equations (e.g., Wang et al., 2011).

In life sciences, birth and death rates are usually used. The meaning of birth rate is that the future population size depends on the current number of participants in a direct way. Every participant “produces” future participants with a certain probability at a certain point of time. For platforms under consideration it is rather not the current platform participants on the same market side, but the number of participants on the other market side which is crucial. This is the manifestation of the indirect network effects. More precise, the dynamics of the number of participants on the one side depends on the expected utility based on the number or participants on the other market side.\footnote{Sure enough, there might also be same-side effects involved, positive and well as negative. But they are assumed to be not central and, hence, not to be modeled explicitly in this research paper.}
One more factor that influences participants’ behavior is the maximum size of population that could potentially join the platform. In case of app platforms, this population consists of all people in the world who could afford a mobile device. This population is called carrying capacity in the life sciences (cf. Sterman, 2000, de Vries, 2006). Carrying capacity \( K^i \) limits possible growth of a platform. Its influence can be modeled by multiplying potential change in participant number by the factor \( 1 - \frac{N^i}{K^i} \). It is easy to see that this factor is close to 1 as long as the population is small

\[
\lim_{N^i \to 0} \left( 1 - \frac{N^i}{K^i} \right) = 1. \tag{2.3.1}
\]

When population growth is approaching carrying capacity, that is, \( N^i \to K^i \), we have

\[
\lim_{N^i \to K^i} \left( 1 - \frac{N^i}{K^i} \right) = 0. \tag{2.3.2}
\]

Hence, this factor does not allow population to grow higher than carrying capacity. Altogether, we obtain the following equation for the population dynamics:

\[
\frac{dN^i(t)}{dt} = \lambda^i \mu U^i \cdot \left( 1 - \frac{N^i(t)}{K^i} \right), \quad i \in \{B, S\}, \tag{2.3.3}
\]

The usual assumption for agents’ decision regarding joining the platform is “fulfilled expectations” (Katz and Shapiro, 1985, 1986) or “perfect foresight” (Shy, 2001). It is assumed that platform participants can predict the future network size correctly at any point of time. Sun and Tse (2007) suggest another approach. They assume that potential participants make their decision based on what they currently observe, rather than trying to predict future population development. In this research paper, we propose to use a mixed approach: The population diffusion is assumed to be proportional to the expected utility or NPV (net present value), at the same time, for the future network size agents take current network size as a proxy. Therefore, potential participants are forward looking, but are not supposed to be able to predict the future. We will discuss the exact expressions for the expected utility and NPV in detail in Section 2.3.3.

Population diffusion is proportional to the expected utility or NPV (net present value), as opposed to current utility. The reason for that is that current utility takes into account only current losses and gains and does not take into account future cash flows. But many businesses require an upfront investment, delivering profits and benefits only in the future. For instance, app developers have
to invest money in hardware, software and membership fee and their time into programming of an app before they can start selling it. The same is true for users: they have to buy a mobile device to obtain access to the apps on an app platform, hoping that the package will provide enough benefits in the future. In order to take future cash flows in account, we operate with expected utility.

### 2.3.2 Population dynamic in discrete time

Dynamic pricing (as discussed in the previous section) would mean for eBay or App Store, that they would have to adjust their membership and/or usage fees constantly. For instance, App Store would have to charge on one day 30% commission and on the next day 50% commission. This would create high instability and insecurity for developers, who now rely on the constant commission. This could cause many developers to leave the platform.

In case of discrete dynamic the number of participants in the next period $N^i(t+1)$ can be obtained recursively from the number of participants in the current moment $t$ and change in the number of participants between $t+1$ and $t$:

$$N^i(t + 1) = N^i(t) + \Delta N^i(t+1), i \in \{B, S\},$$

(2.3.4)

with $\Delta N^i(t)$ being change in the number of customers as shown in Figure 2.3. For $\Delta t \to 0$ we obtain the differential equations used in the previous sections.

**Figure 2.3: Discrete-time structure of the model dynamics.**
We obtain the following recursive difference equations:

\[ \Delta N^i(t + 1) = \lambda^i \mathbb{E}U^i(t) \left( 1 - \frac{N^i(t)}{K^i} \right), \quad i \in \{B, S\}. \tag{2.3.5} \]

The next step consists in making assumptions regarding \( \mathbb{E}U^i(t) \). As in the continuous problem formulation, we assume that the willingness of customers to join the platform depends on the expected utility (or the net present value of the future utility) they would obtain. If the NPV of future utility in the current period is positive, new customers will join the platform in the next period, if the utility is negative, customers will leave the platform. Hence, we can use similar equations as in the continuous case.

### 2.3.3 Expected utility and NPV

For users, we can consider expected utility, for developers, it can be expected utility or NPV, if they follow strictly monetaristic incentives. Expected utility can contain two components, namely usage and membership (dis-)utilities. The membership component stems from the participation in the platform alone and does not depend on platform usage (it can be periodical as well). For instance, developers incur costs \( M^S \) to produce their apps. They have to buy hardware and software, learn programming language, pay membership fees (denoted \( A^S \)) to the platform and spend time programming the apps. Similar aspects apply to users. They also have to buy a mobile device and invest time in getting used to the new mobile device.

Platform participants might experience not only membership costs, but also membership benefits from joining the platform. Users might obtain benefit from belonging to the platform, that is, having an iPhone, without using it much. They obtain then membership benefit \( B^B \). Similarly, some developers might be proud to be an iOS or Android developer, even if they do not sell many copies of their apps. \( B^S \) denotes developers’ benefit. We assume that membership costs \( A^B \) and \( A^S \) are paid only once. This can be easily extended to the case with yearly/monthly payments.

Usage benefits \( b^B \) and \( b^S \) stem from interactions with participants from the other market side accordingly. In case of app platforms these are app downloads. Developers obtain revenues each time their app is downloaded (if the app in not offered for free). They obtain a percentage \( \gamma \) of the app price \( r \). App prices are
assumed to follow a distribution $R$ with average $\tau$. The remaining part is obtained by the platform as a commission. In addition, platforms might charge a certain amount $a^i$ which does not depend on the price of goods sold over the platform (e.g., some mobile tariffs charge for each domestic call a certain amount independent on the actual usage, namely on the call length). There are also other sources of usage benefit/cost. For instance, developers might obtain revenue from in-app-purchases or from advertisement\footnote{Cf. Gans (2011), in-app ads are a growing segment. This factor might provide an interesting model extension in future research.}. Also users obtain benefits not only from downloading apps alone, but also by app usage later on. For the time being we assume that these benefits are included in the usage benefits $b^B$ and $b^S$.

The number of downloads per user depends on the amount of available apps. As opposed to the current literature on two-sided markets (e.g., Rochet and Tirole, 2006, Armstrong, 2006), which assumes that each participant on the one market side interacts with each participant on the other market side, we suggest a correction in form of a two-step process (cf. Kouris, 2011). The first step of an app download is sifting through available apps (scanning process), of which some get downloaded in the second step. We assume that each user considers certain number of apps $f(N^S)$, with $N^S$ being the number of apps and $f(N^S) << N^S$. The correction function $f$ is chosen to be differentiable and invertible for $N^S > 0$. $f$ should insure that the number of scanned apps does not explode with the number of available apps. For instance, if 1000 apps are available, a user might check 100 of them. If 500,000 apps are available on an app-platform, user might scan 500 apps, but probably not 50,000, as proportionality would imply. In addition, we assume that of $f(N^S)$ apps under consideration users download only a certain fraction $X^S \cdot f(N^S)$ with $0 \leq X^S \leq 1$.\footnote{Generally, it is possible to subsume $X^S$ and $f(N^S)$ into one function. The reason why we suggest to consider them separately is because it reflects the actual process of buying goods on Internet platform – first check several, then buy some.} Hence, total number of download per user amounts to $X^S \cdot f(N^S)$. It follows that the total number of downloads is the total number of users $N^B$ multiplied with the number of downloads per user resulting in $X^S N^B f(N^S)$. The number of downloads per seller amounts then to $\frac{X^S N^B f(N^S)}{N^S}$, derived from the total number of interactions divided by the number of sellers.

For the expected utility and NPV calculations timing of payments is crucial. We assume that membership fees and benefits accrue as soon as a member joins
the platform. Usage fees and benefits are distributed over the next \( t \) time periods and should therefore be discounted by \( \frac{1}{(1+\sigma)t} \) with a discounting rate \( \sigma \). Platform participants consider current number of users and developers and assume that they will stay stable in the future. Altogether, we obtain the following equations for the expected utility of users \( B \) and developers \( S \):

\[
\mathbb{E}U^B(t) = B^B - A^B + \sum_t \frac{1}{(1+\sigma)t}(b^B - a^B - \bar{r})X^S f(N^S(t)) \\
\mathbb{E}U^S(t) = B^S - A^S - M + \sum_t \frac{1}{(1+\sigma)t}(b^S - a^S + \gamma\bar{r})\frac{X^SN^B(t)f(N^S(t))}{N^S(t)}
\] (2.3.6) (2.3.7)

### 2.3.4 Goal function: platform profit

Besides constraint equations, a goal function is needed to complete the optimization problem. The goal function is in this case cumulative platform profit. Similar as for customer groups, platform profit has a membership component and a usage component. Both components include profit from developers’ market side and from the users’ side.

Usage profit component includes possible usage fees for users and developers \( a^B \) and \( a^S \). Furthermore, there is the commission \((1 - \gamma)\bar{r}\) and cost per download from the platform point of view \( c \). The sum of all these components, multiplied with the number of interactions \( X^SN^Bf(N^S) \), yield the platform profit share that stems from the usage:

\[
\pi_{use}(a^B, a^S, \gamma) \equiv (a^B + a^S + (1 - \gamma)\bar{r} - c)XN^B(t)f(N^S(t)).
\] (2.3.8)

Profit the platform owner obtains from users’ membership at a certain period of time amounts to \((A^B - C^B)\Delta N^B\) with \( A^B \) being membership fee (e.g., price of mobile device or cost of mobile tariff) and \( C^B \) cost for platform per user (e.g., cost of mobile device production). The analogous formula applies for the developers: \((A^S - C^S)\Delta N^S\). We have to consider the case where \( \Delta N^i < 0 \), that is, if agents leave the platform, separately. In this case, profit from membership is 0, but not negative. This is due to the fact that the membership profit is realized as soon as participants join the platform. Therefore, from the membership profit perspective,
The membership calculation we have to consider four cases:

\[ \pi_{\text{mem}}(A^B, A^S) = \begin{cases} 
(A^B - C^B)\Delta N^B(t) + (A^S - C^S)\Delta N^S(t), & \text{if } \Delta N^B > 0, \Delta N^S > 0; \\
(A^S - C^S)\Delta N^S(t), & \text{if } \Delta N^B \leq 0, \Delta N^S > 0; \\
(A^B - C^B)\Delta N^B(t), & \text{if } \Delta N^B > 0, \Delta N^S \leq 0; \\
0, & \text{if } \Delta N^B \leq 0, \Delta N^S \leq 0.
\] (2.3.9)

To obtain the final goal function equation we take into account a discounting rate \( \frac{1}{(1 + \sigma)^T} \), with discounting factor \( \sigma \). We choose \( \sigma \) based on the usual assumptions, depending on the period length \( \Delta t \).\(^{11}\) Altogether, we consider \( T \) periods, it can be assumed that \( T \to \infty \) if long-term strategy is required. Total platform profit includes the usage and the membership components, and amounts to:

\[ \max \pi (a^i, A^i, \gamma) = \max \sum_{t=0}^{T} \frac{1}{(1 + \sigma)^t} (\pi_{\text{mem}} + \pi_{\text{use}}), i \in B, S \] (2.3.10)

whereby \( \pi_{\text{mem}}(A^B, A^S) \) varies between 0 and \((A^B - C^B)\Delta N^B(t) + (A^S - C^S)\Delta N^S(t)\). With the goal function our optimization problem is complete. Its formulation follows in the next section.

### 2.3.5 Optimization problem formulation

In this section we will formulation the optimization problem. It includes the goal function and constraint equations as defined in the the previous sections:

The goal function:

\[ \max \pi (a^i, A^i) = \max \sum_{t=0}^{T} \frac{1}{(1 + \sigma)^t} (\pi_{\text{mem}} + \pi_{\text{use}}), i \in B, S \] (2.3.11)

Constraint equations with a discrete variant of the expected utility equations:

---

\(^{11}\)Clearly, if we choose \( \Delta t = 1 \) day its value differs from the situation where \( \Delta t = 1 \) month.
\[ N^B(t + 1) = N^B(t) + \Delta N^B(t + 1) = N^B(t) + \lambda^B E U^B(t) \left( 1 - \frac{N^B(t)}{K^B} \right) = \\
= N^B(t) + \lambda^B (B^B - A^B) + \\
+ \sum_t \frac{1}{(1 + \sigma)^t} (b^B - a^B - \tau) X^S f(N^S(t)) \left( 1 - \frac{N^B(t)}{K^B} \right) \quad (2.3.12) \]

\[ N^S(t + 1) = N^S(t) + \Delta N^S(t + 1) = N^S(t) + \lambda^S E U^S(t) \left( 1 - \frac{N^S(t)}{K^S} \right) = \\
= N^S(t) + \lambda^S (B^S - A^S - M) + \\
+ \sum_t \frac{1}{(1 + \sigma)^t} (b^S - a^S + \gamma^\tau) X^S N^B(t) f(N^S(t)) \left( 1 - \frac{N^S(t)}{K^S} \right) \quad (2.3.13) \]

Furthermore, we require that the number of participants must be non-negative:

\[ N^B(t) \geq 0 \]
\[ N^S(t) \geq 0 \]

With this dynamic model we take into account development of the platform participants’ number and determine optimal pricing which would remain constant during the whole time. For instance, if the platform owner assumes certain prices \( a^i, A^i \) and \( (1 - \gamma) \), she can calculate expected utility for platform participants and from that determine population dynamics. Then the platform owner can calculate her cumulated profit. This procedure can be repeated for the whole range of suitable prices. At the end, the platform owner can compare cumulated profits resulting from different price setting options and chose the one with the highest cumulated profit.

Equations 2.3.12 and 2.3.13 are first level recursive equations with two state interdependent variables \( N^B \) and \( N^S \). Some difference equations can be rewritten in the analytic form, that is, not dependent on the previous period, initial values only. Whether this is possible or not, depends on the order and the linearity of the underlying recurrence equations. Since we have two implicitly interdependent variables \( N^B \) and \( N^S \) which are connected through indirect network effects, their combination would lead to an increase in the order of the lag (Huckfeldt et al., 1982). This would also transform the system of linear equations into one nonlinear equations. For the nonlinear dynamic systems, there are no general solution
techniques. As Huckfeldt et al. (1982) asserts, “solutions to such systems are rarely known”. Due to this fact, we propose to model the system period by period. We use Matlab to implement the dynamic framework and analyze the results. Details will follow in the next section.

2.4 Matlab solution and simulation results

After a brief comment on the implementation in Matlab, we explain the results of dynamic modeling with respect to the research questions that were formulated in the introduction section. The first step includes analysis of the model behavior, which is driven by the customers’ population diffusion. In this section, we consider the research questions suggested in the introduction and discuss simulation results.

2.4.1 Implementation in Matlab

According to the research questions suggested in the introduction, our goals include profit maximum calculation and analysis of the model behavior depending on usage and membership fee and other parameters. The platform owner can vary all decision parameters, that is, usage and membership fees, etc. to maximize her profit. Parameter values are to be set only once, in the first period. Also, initial conditions for other parameters like initial number of platform participants are to be chosen. Together with the dynamics defined in the previous section and the initial conditions for the number of participants, the model is completely determined.

We implement variation of parameters with the help of for-loops. All prices are varied in certain ranges, e.g., membership fee $A^i$ is increasing from 0 to a certain value comparable to the benefits that a platform participant obtains. Generally, $A^i$ should not be much higher than membership benefit $B^i$ except in cases where low membership benefits can be compensated through high usage benefits.

The structure of the Matlab program consists of three major blocks: The first is parameters and variables declaration, the second includes the main body with loops that go over fees ranges and time, the third part includes analyses, visualization of results and various cross-checks. The main body requires some more explanations.

Beginning with the initial conditions at $t = 0$, we calculate expected utilities $\mathbb{E}U^i(t), i \in \{B, S\}$. Using those we determine $\Delta N^i(t+1)$ and $N^i(t+1)$ accordingly.
Then we calculate platform profit $\pi(t + 1)$. Two checks are conducted before platform profit is calculated: the first one tests whether $N^i > 0$, the second takes care of different formulations of $\pi$ depending on the valued assumed by $\Delta N^i$. For instance, if $\Delta N^i < 0$ it does not mean that platform loses membership profit as was discussed in Section 2.3.4.

This part of the algorithm is to be repeated $T$ times to calculate cumulated total profit. Further outputs of the time loop are trajectory of the number of participants and their utilities over time. These calculations must be repeated for every combination of usage and membership fees for both sides yielding five more loops including $a^B, A^B, a^S, A^S, \gamma$.

Platform owners’ task is to set prices. Hence, in general, the fees $a^B, A^B, a^S, A^S, \gamma$ are varied. Other parameters, like the benefits $b^B, B^B, b^S, B^S$, costs $M$ for the developers and costs $C^B, C^S, c$ for the platform, app prices $r$, etc., are assumed to be constant. We usually consider $T = 50$ periods. For the calibration purposes we considered the following ranges for these parameters: $B^B \in [0; 300], b^B \in [0; 5], \lambda^B \in [0.5; 10], B^S \in [0; 100], M \in [30; 300], b^S \in [0; 5], X \in [0.01; 0.1], \lambda^S \in [0.5; 10], C^B = 50, C^S = 50, c = 0.5, \tau = 1$. Apart from model calibration, we used variation of parameter values to prove robustness. We will comment on this in the following sections. The adjustment function $f(N^S)$ is assumed to be a square root, reflecting the fact that number of interactions grows under-proportionally with the number of sellers $N^S$.

### 2.4.2 Analysis of population dynamics

There are different possibilities to model population development. In this model, the number of new participants is assumed to be proportional to the expected utility and limited by carrying capacity. There are four cases that describe the relationship between expected utility and population dynamics:

As long as the impact of carrying capacity is low, four cases are possible depending on expected utility:

- If expected utility is positive and growing, the number of participants should be growing with an increasing rate
- If expected utility is positive but sinking, the number of participants should still be growing but with a decreasing rate
• If expected utility is negative and rising, the number of participants should go down with a decreasing rate

• If expected utility is negative and sinking, the number of participants should go down with an increasing rate.

Figure 2.4 illustrates the case where utility is positive and growing in the beginning. We have assumed the following parameter values after calibration: For the users’ side $B^B = 30, b^B = 2, \lambda^B = 2$; For the developers’ side $B^S = 0, M^S = 50, b^S = 0, X = 0.1, \lambda^S = 0.5$; For the platform owner $C^B = 50, C^S = 50, c = 0$. The initial numbers of participants are $N^B(t = 0) = 5000, N^S(t = 0) = 1000$. The carrying capacities are $K^B = 100000, K^S = 5000$. We assume that $f(N^S)$ is a root function, which reflects the idea, that in the beginning the function should be similar to linear and later on, when more agents join the platform, it should restrict the number of interactions considerably.

After the 30th time period, population of developers approaches its carrying capacity $K^S$. This is reflected through slower growth towards the end of the time interval under consideration. Since the number of developers (and apps) stops growing, the utility of users decelerates and converges against a certain level. This leads to an almost constant growth rate and, hence, to an almost linear population increase. This state will last until carrying capacity of users $K^B$ is approached.

![Figure 2.4: Rising population and utility.](image-url)
In the beginning of the simulation runs, we observe that platform needs a certain mass to start off, otherwise network effects are not strong enough. This aspect is called “chicken & egg”-problem, we will discuss it in detail in the next section. In addition, initial values chosen for $N^t(t=0)$ must agree with other parameters like the carrying population $K^t$ and $\lambda$, otherwise instabilities and “artificial” oscillations might occur in the first periods.

If the expected utility of at least one side is negative, the participants on this side will leave the platform. This can happen if the fees for this market side are set too high. Figure 2.5 illustrates this case. Utility of users (top left graph) is negative (but increasing). Therefore, the number of users decreases (bottom left graph), leading to a decrease of the developers’ utility (top right graph). Since developers utility remains positive, their number is rising but growth is slowing down (bottom right graph). To prevent number of participants from decreasing, it is necessary to ensure that their utility is positive.

![Figure 2.5: Decreasing population and utility.](image)

**2.4.3 Platform profit maximization**

One of the key questions in two-sided market theory concerns profit maximizing pricing strategy. In our case, platform owner can vary five pricing components to optimize her profit: usage fees $a^B, a^S$, membership fees $A^B, A^S$ and commission fee $(1 - \gamma)$. She can choose, for instance, to compensate high membership fees with low usage fees (or the other way around).
Analysis and visualization are challenging, since we have five pricing parameters to vary (i.e., usage fees \( a^B \), \( a^S \), membership fees \( A^B \), \( A^S \) for the both market sides and commission payment \((1 - \gamma)\)). To address this challenge, we begin with varying two pricing components first. Then we build up on this and increase complexity by introducing commission fee next, and finally, usage fees. In the first case, we optimize platform profit with respect to \( A^B \) and \( A^S \), assuming following values for the remaining pricing parameters: \( a^B = a^S = 0, \gamma = 50\% \). We will relax these assumptions later on.

Profit projection depending on both membership fees \( A^B \), \( A^S \) is a cone-shaped structure with a unique maximum (cf. Figure 2.6). Maximum profit equals 2.79 million, corresponding membership fees amount to \( A^B = 110, A^S = 151 \). Hence, in terms of membership fees there is a unique maximum.
Next, we want to find out what happens if commission fee can be chosen also. It can vary from 0 to 100%, hence it represents the profit share which developers are getting per sold app. Altogether, we now have three decision parameters and vary them to maximize profit. In this case, we obtain maximal profit of 2.84 million for the following combination of pricing parameters: $A^B = 103, A^S = 1$ and $(1 - \gamma) = 30\%$ (see Figures 2.7 and 2.8). That means, when flexibility is given, platform owner chooses to reduce membership fee, but to take higher commission. Compared to the previous case with higher membership fees, but lower commission, this leads to a steeper growth of platform participants amounts (number of users equals 18,000 after 50 periods, instead of 12,000, number of developers equals 4,400 instead of 2,400). That is, due to lower membership costs, more participants join the platform. And more participants lead to more interactions and therefore higher profit from usage. Hence, the platform owner can increase her profit altogether capitalizing on increased transactions even more by increasing commission fee from 50% to 70%. On the long run, the effect is even larger, since growth of participants number slows down as it reaches carrying capacity. Then, less and less profit comes from membership fees. In this case, high number of interactions is crucial.

One more advantage of fast platform growth is that participants get into a lock-in situation. This reduces the threat from competitors, since they have to overcome this lock-in effect first. In many cases, it was crucial for platforms to build up customer base before competitors join the business. For instance, currently Nokia has tremendous difficulties to increase its smartphone customer base, although device quality is quite high (cf., for instance, Cando, 2012), since most potential customers already own an iPhone, Samsung, HTC or some other smartphone. Therefore, the possibility to drive down membership fees by introducing higher commission fee, provides an important degree of freedom.

Figures 2.7 and 2.8 illustrate that there is a unique maximum, both in terms of membership and commission fees. Several research papers on two-sided markets, e.g., Rochet and Tirole (2006), Armstrong (2006) and Reisinger (2010), suggest that in the static setting, it is possible to find more than one combination of usage and membership fees leading to the same maximum profit. This was considered a problem, since it made specific recommendations for platform owners impossible, as Reisinger (2010, p. 1) states:
Figure 2.7: Platform profit depending on membership fee $A^B$ and commission payment $(1 - \gamma)$. Usage fees are assumed to be 0.

“He [Armstrong (2006)] shows that when platforms compete in two-part tariffs, a continuum of equilibria exists, each one with a different profit and surplus for both sides. This causes major problems on the predictive power of such models. The reason for this multiplicity is that, given the prices of the rival, a platform receives the same profit via different combinations of the fixed and the per-transaction fee. In particular, an agent is indifferent between paying a high fixed fee but a small per-transaction fee and a low fixed fee but a high per-transaction fee. Therefore, these combinations attract the same number of agents and a platform obtains the same profit. Since this holds for both platforms, a tremendous multiplicity of equilibria emerges.”

In the dynamic case, however, different combinations of fees lead to different population dynamics. This results in a unique solution achieved through a unique
combination of usage, membership fees and commission. This is an important difference between static and dynamic models.

The next step consists in considering all fees simultaneously. So we optimize platform profit with respect to all five pricing parameters. Interestingly, Matlab simulation suggest that usage fees $a^B$ and $a^S$ should be set zero to obtain maximum profit. Therefore, this yields the same result, as in the previous situation: $A^B =$
The meaning of this result is that it appears preferable to charge a commission \((1 - \gamma)\) depending on the app price, rather than a constant per transaction usage fee for users and developers.\(^\text{12}\)

Simulations show that usage fees for the users are supposed to be zero in the optimal case. This is compensated through comparatively high membership fees for users.

Extensive testing shows that commission fee proves to be the preferred pricing instrument in our setting, resulting in \(a^B = a^S = 0\). Hence, we assume \(a^B = a^S = 0\) going forward. Since other research papers do not use the whole set of fees including usage, membership and commission fees, as we do, they also do not deliver any comparable result. The result that platforms rather use commission fees than constant usage fees, is remarkable. The reasoning behind this is that a commission fee allows developers (or, in general, sellers) to offer inexpensive or even free apps (or goods), what leads to high trading volumes. But it also allows platforms to capitalize on expensive goods obtaining a share of sales prices. This pricing mechanism is employed widely by such platforms as the App Store, Amazon and eBay.

### 2.4.4 Platform kick-off and minimal number of participants

One of the key challenges on two-sided markets is that a platform must get both customer sides on board to do business. But as long as there are no users, no developers would join and vice versa. Caillaud and Jullien (2003) have called this phenomenon “chicken & egg” problem. Which number of participants would be sufficient to kick-off the platform, depends on several parameters. First, looking at the expected utility equations, we recognize that due to the low number of participants the usage part will be quite small in the beginning. This must be compensated with very high membership benefits. For developers the initial investment is quite high, since they do not only pay fees and buy hardware, but also

\(^\text{12}\)Clearly, it is possible to choose usage fee equivalently to the commission fee for developers. But in general, commission fee can vary depending on the app prices.
invest time in programming and designing the apps. Platforms will be forced to ask for extremely low membership payments in order to attract more participants.\textsuperscript{13}

This is an interesting result that also provides an explanation for the phenomenal success of Apple’s App Store or Amazon’s marketplace. Due to high membership benefits, they managed to attract users first, then app developers or sellers followed very fast.

In the beginning, membership fees are the key platform engine. Later in the lifecycle, usage fees become more and more important due to two effects. The number of participants on both sides is high enough to enable many interactions, leading to a higher profit from platform usage. At the same time, the number of new customers per period will finally decrease, so that the contribution of the membership component for the platform will decrease. Altogether, this suggests that on many platforms, a shift should occur from the membership fees in the beginning of the life cycle, to the usage fees later on. We will discuss this in more detail in Section 2.4.6.

Once platform owner recognizes that she needs a certain number of participants on both sides to start-off the platform, she might ask herself, how many participants exactly are necessary. In the following, we show how the initial number of participants necessary to ensure that the platform can kick-off can be determined.

Compare Figures 2.9 and 2.10. On Figure 2.9 expected utility drops to 0, also population of B’s decreases to 0 in the second period (in the first period population is determined by initial conditions). On Figure 2.10 utilities are slightly positive, and also number of participants starts to grow. In the first case we used 1137 as the initial number of users (buyers), in the second case, 1138. We assume that we have only one developer (seller) in the beginning and calculate, how many users are at least necessary to kick-off the platform nonetheless. We have assumed $\lambda^B = 10$ to speed up population growth\textsuperscript{14}, all other parameters remain the same.

It is easy to imagine that this combination of values is not unique. Clearly, lower initial number of users can be compensated by higher number of developers

\textsuperscript{13}As some key developers (Cheezburger Network, Foursquare) considered Microsoft’s market share too small to justify development of a new app for the Windows Phone, Microsoft reacted by incentivizing developers. Not only did Microsoft provide developers with free phones and prime spots in its app platform, in some cases Microsoft even financed the app development (cf. Wortham and Wingfield, 2012).

\textsuperscript{14}This allows us to operate with lower initial numbers, which requires less resources, and therefore makes Matlab simulation faster.
Figure 2.9: There are infinitely many combinations of developers and users numbers that are not sufficient to get the platform going.

Figure 2.10: Adding a small number of agents (in this case one) to at least one of the sides might be sufficient to kick-off the platform.

and vice versa. Hence, the question arises, how to find the optimal combination of initial number of users and developers that would allow to kick-off the platform. Table 2.1 shows profit assigned to different combinations of initial numbers of users
and developers varied by 100 for a given pricing decision.\textsuperscript{15} Profit is assumed to be 0 if platform fails to kick-off. Shaded areas highlight combinations of users and developers numbers, where profit switches from 0 to a positive number, hence, where the platform kicks off.

Information regarding minimal number of participants necessary to kick off the platform can be very useful for a platform owner who wants to launch a new platform. In this case, she can determine, how many participants are needed on both sides. For instance, the platform would start off if 500 developers and 800 users are on board. If there are only 400 developers, 800 users would not be sufficient. But the solution is not unique, that is, there are infinitely many combinations of user and developer numbers that allow to just kick off the platform.\textsuperscript{16} This is an important insight, leading to the conclusion that if a platform possesses many customers on the one market side, that can compensate for the lack of customers on the other market side, attracting missing customers due to high potential indirect network effects. Still, not all these combinations lead to the same platform profit. Hence, from the platform’s point of view, an additional profit optimization is necessary.

One more important insight is that the result (that is, platform profit), reacts to the absolute change in the number of agents on the both market sides not in the same way. In this case, profit responds more strongly to the absolute change in the number of developers. This is due to the fact, that we assumed that much less developers (or apps) are available (and needed) to start of the platform. It is easy to imagine that if there are 10,000 users and 100 developers\textsuperscript{17}, each user has a choice between 100 apps. This would result in many interactions. Ideally, each of the 10,000 users would download each app, resulting in 1,000,000 total downloads. Moreover, if there are 100 users and 10,000 apps, it is not probable that we would obtain the same number of interactions, because there are limits to the sensible number of apps per mobile device. So even if every of the 100 users would download the same 100 apps, we would obtain only 10,000 downloads instead of 1,000,000. From the mathematical point of view, this fact is expressed through

\textsuperscript{15}Clearly, the initial numbers of users and developers can be varied by 10s or 1s, we consider the variation by 100s to speed up Matlab simulations.
\textsuperscript{16}There are infinitely many solutions if we assume that the number of participants need not be an integer.
\textsuperscript{17}We assume that each developer produces one app.
Table 2.1: Profit depending on the combinations of initial numbers of developers and users.

<table>
<thead>
<tr>
<th>S</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>70.719</td>
<td>203.463</td>
<td>316.405</td>
<td>417.066</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>92.434</td>
<td>219.883</td>
<td>329.906</td>
<td>428.560</td>
</tr>
<tr>
<td>300</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>112.827</td>
<td>235.766</td>
<td>343.041</td>
<td>439.850</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7.408</td>
<td>132.161</td>
<td>251.083</td>
<td>355.891</td>
</tr>
<tr>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14.265</td>
<td>150.582</td>
<td>265.942</td>
<td>368.376</td>
</tr>
<tr>
<td>600</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>37.810</td>
<td>168.194</td>
<td>280.306</td>
<td>380.571</td>
</tr>
<tr>
<td>700</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59.487</td>
<td>185.074</td>
<td>294.284</td>
<td>392.526</td>
</tr>
<tr>
<td>800</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.641</td>
<td>80.125</td>
<td>201.345</td>
<td>307.805</td>
</tr>
<tr>
<td>900</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.951</td>
<td>99.851</td>
<td>217.116</td>
<td>321.010</td>
</tr>
<tr>
<td>1000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10.480</td>
<td>118.772</td>
<td>232.428</td>
<td>333.921</td>
</tr>
<tr>
<td>1100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>28.855</td>
<td>136.972</td>
<td>247.315</td>
<td>346.553</td>
</tr>
<tr>
<td>1200</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.385</td>
<td>48.423</td>
<td>154.523</td>
<td>261.809</td>
<td>358.924</td>
<td>448.481</td>
<td>532.128</td>
</tr>
<tr>
<td>1300</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.350</td>
<td>68.264</td>
<td>171.485</td>
<td>275.936</td>
<td>371.047</td>
<td>459.099</td>
<td>541.568</td>
</tr>
<tr>
<td>1400</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.788</td>
<td>87.168</td>
<td>187.910</td>
<td>289.722</td>
<td>382.936</td>
<td>469.548</td>
<td>550.881</td>
</tr>
<tr>
<td>1500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18.682</td>
<td>105.889</td>
<td>203.841</td>
<td>303.187</td>
<td>394.602</td>
<td>479.835</td>
<td>560.073</td>
</tr>
</tbody>
</table>
analyze, which group shows higher sensitivity/indirect network effects. Finally, she can estimate, which group is easier to attract, for instance, through subsidizing membership fees or increasing membership benefits). Based on all these factors she can decide, which combination of initial number of users and sellers to chose.

2.4.5 Short-term versus long-term optimization

As was discussed before, we assume an S-curve population development. Carrying capacity \((1 - \frac{N_i}{K_i})\) limits platform growth. As was pointed out in Section 2.3.1, this factor ensures that the number of users of an app platform cannot grow higher than total world population that can afford a mobile device or that can program an app. Hence, in the long run, platform participants numbers will converge (cf. Figure 2.4). This results in the non-linear curve with three possible life-cycle phases: i) underproportional growth, ii) stronger overproportional growth and, finally, iii) a slow down as carrying capacity is reached.

Its non-linear character suggests that there might be a difference between long-term and short-term optimization. As explained in detail in Kouris (2012), different life-cycles of the platform development require different strategic approaches. This has also impact on pricing. In the launch phase, platforms tend to set very low prices to attract a critical mass of participants. Later on, it might be beneficial to increase the prices to cash the profits. And once competition appears, price reductions can be necessary. Hence, depending on perspective, there might be differences for price setting strategies. To see these differences we compare prices and population dynamics for 3 different time horizons: 30, 50 and 70 periods. We observe that optimal prices can differ by more than 50% (cf. Table 2.2).

<table>
<thead>
<tr>
<th>Number of periods</th>
<th>(A^B)</th>
<th>(A^S)</th>
<th>((1 - \gamma))</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>69</td>
<td>1</td>
<td>20%</td>
</tr>
<tr>
<td>50</td>
<td>103</td>
<td>1</td>
<td>30%</td>
</tr>
<tr>
<td>70</td>
<td>150</td>
<td>1</td>
<td>30%</td>
</tr>
</tbody>
</table>

Table 2.2: Fees optimized for 30, 50 and 70 periods.

In general, the shorter the time horizon, the lower the fees. Both membership fees (for users) and commission fee are affected: \(A^B = 69, (1 - \gamma) = 20\%\) for

\(^{18}\)In the static case, price elasticities are used to indicate this sensitivity.
30 periods versus \( A^B = 150, (1 - \gamma) = 30\% \) for 70 periods. This supports our hypothesis, that in the launch phase optimal prices tend to be lower than later on. The second reason for setting lower fees over the shorter horizon is that membership cost must be recovered over a shorter horizon. That is, expected costs and benefits are calculated over 30 periods instead of 50 or 70 periods. Simulations show that if platform owner would set the same prices for 30 periods as those that would be optimal for 70 periods (namely \( A^B = 150, A^S = 1, (1 - \gamma) = 30\% \)), users would be forced to leave the platform, since expected costs are too high compared with expected benefits over 30 periods (cf. Figure 2.11).

![Platform dynamics](image)

Figure 2.11: Platform dynamics over 30 periods with \( A^B = 150, A^S = 1, (1 - \gamma) = 30\% \).

Also population dynamics do not look the same, although the overall form remains similar. Figures 2.12 and 2.13 show platform dynamics for users and developers compared over 30, 50 and 70 periods (each with optimal prices). We observe that the longer the horizon the more participants are attracted and willing to invest membership fees both on users’ and developers’ sides. Hence, in general, short-term and long-term profit maximization might lead to quite different results. Therefore, it is necessary to evaluate carefully the differences and to clearly define, which perspective to focus on.
Figure 2.12: Users’ dynamics over 30, 50 and 70 periods.

Figure 2.13: Developers’ dynamics over 30, 50 and 70 periods.
2.4.6 Price adjustments

We observe that in some real-world situations platforms adjust their rules, and especially prices, over time. For instance, eBay alters its rules from time to time (cf. Steiner, 2010). At the same time, we have observed that app platforms did not change their fees much, at least not in obvious ways, that is, commission fee of 30% remains the same over time and across most app platforms. Also membership fees, which are the costs of the devices, seem not to change much. But a more close look shows that there are some changes going on. For instance, recently the App Store has adjusted the app price levels (cf. Essers, 2012). This has a similar effect to increasing commission fees. So we want to understand, what would our model suggest in terms of price adjustment. We model a setting, where after a certain period of time the platform obtains the opportunity to adjust its prices.

Our Matlab simulations show that the optimal platform owner’s strategy is to increase fees if given a chance. Also, simulations show that fees increase should be the higher, the later it occurs, since platform owner can afford to set the higher prices if more agents have already joined the platform. First, we consider the usual profit optimization situation (all parameters remain the same as before, $\lambda^B = 2$, $\lambda^S = 0.5$). In this case, optimal prices are $A^B = 103, A^S = 1$ and $(1 - \gamma) = 30\%$. Then we assume that the platform owner decides to adjust prices after 10 periods. In this case, the optimal prices going forward are $A^B = 124, A^S = 1$ and $(1 - \gamma) = 30\%$. The user’s membership fee rises, other fees remain the same. Subsequently, we consider price adjustments after 15, 20 and 30 periods. The results are summarized in Table 2.3. We observe two phenomena: i) for users, there is an increase in membership fees; ii) membership fees for developers remain the same and as low as possible; iii) commission fees become smaller and smaller. This means that the platform owner keeps attracting more and more developers, therefore being able to provide higher utility for (potential) users. And due to the increasing utility, the platform owner is able to charge higher membership fees.

Therefore, if there is no competition, it would be optimal from the platform owner point of view to increase membership fees for the users over time. Also, the later possibility of price change occurs, the higher fees platform owner can afford to chose. For instance, membership prices for users increase by 20% after 20 periods. Now the question occurs, how competition would influence this strategy.
Table 2.3: Adjustment of optimal fees depending on the time point (after 0, 10, 15, 20 and 30 periods).

<table>
<thead>
<tr>
<th>Number of periods</th>
<th>$A^B$</th>
<th>$A^S$</th>
<th>$(1 - \gamma)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>103</td>
<td>1</td>
<td>30%</td>
</tr>
<tr>
<td>10</td>
<td>124</td>
<td>1</td>
<td>30%</td>
</tr>
<tr>
<td>15</td>
<td>125</td>
<td>1</td>
<td>20%</td>
</tr>
<tr>
<td>20</td>
<td>129</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>30</td>
<td>153</td>
<td>1</td>
<td>10%</td>
</tr>
</tbody>
</table>

To analyze this, we introduce external shocks in form of competition in the next section.

2.4.7 Reaction to external shocks

This section is devoted to exogenous disruptive influences. While in the previous sections we have considered platform development influenced by endogenous factors only, here we will cover situations where exogenous impulses occur. This is an important extension from applied point of view, since analysis of reaction to disruptions due to external influence (like introduction of competition, adjustments of regulations or introduction of new technologies) is crucial for such industries as app platforms for mobile devices.

We begin Matlab simulations with one platform evolving over time (as before). But at a certain point of time a disruption will occur, caused, for instance, by new competitor’s entry. The main influence of a new competitor manifests itself in luring developers and users from the incumbent platform. As a result, the incumbent can attract less new participants in the short run and even loose churning participants on the long run.\textsuperscript{19} The same approach can be used also in case of other disruptions, e.g., new regulations or new technology. This is due to the fact that all of them result the same threat, namely reduction of potential participants.

Reduction of the number of new participants can be modeled by introducing a new parameter $\phi^i \in [0; 1], i \in B, S$, showing which of the 2 competing platforms a participant decides to join. $\phi^i$ can be different for developers and users, depending on the context.

\textsuperscript{19}Since we consider time periods shorter than 2 years, which is the usual duration of a mobile contracts, churn is negligible, but it can be easily introduced as an extension.
on attractiveness of the new platform. This would alter platform dynamics in the following way:

\[
\Delta N^i(t + 1) = \phi^i \lambda^i \bar{E} U^i(t) \left(1 - \frac{N^i(t)}{K^i}\right), \ i \in \{B, S\}.
\] (2.4.1)

Now let us assume that after a certain number of periods (e.g., \( T = 10 \)) a new platform enters the market claiming a share of the new market participants (e.g., 1/2). We assume for now that participants who already belong to the incumbent platform do not churn. With help of Matlab simulation we want to find out, how this exogenous shock impacts choice of optimal prices. We consider two cases: in the base case no competitors enter the market, in the new case, a competitor enters the market. In the first case optimal membership prices are \( A^B = 95 \) and \( A^S = 188 \) for a given commission \((1 - \gamma) = 50\%\).

In the case where a new competitor enters claiming 1/2 of new potential customers, the optimal price combination is as follows: \( A^B = 93, \ A^S = 181 \). Hence, change in the optimal membership fees amounts to less than 5%. Taking into account that we assumed relatively high \( \phi^i \) of 50% for each market side, this seems an astonishingly week reaction.

As was mentioned before, the canonical oligopoly theories like Bertrand or Cournot competition would suggest a noticeable price adjustment. The first aspect that is responsible for these discrepancies are indirect network effects: once the critical mass is reached, the new competitors are much less dangerous, than in the situation without network effects. The second aspect that plays an important role for the platform price setting strategy is availability of multi-homing. If multi-homing is costly (as it is the case for app platforms), the new competitor would have more difficulties while trying to enter the market as Sun and Tse (2007) show.

One more interesting question pertains to the status of subsidy side. Matlab simulation shows that entrance of a competitor might lead to switching between subsidizing one side to subsidizing the other. Consider the usual setting (initial number of participants \( N^i(t = 0) \) equals 2000 and 500 respectively), assume constant \((1 - \gamma) = 30\%\). Optimal prices without disruption equal \( A^B = 86 \) and \( A^S = 284 \). Now consider a disruption after 10 periods. Then optimal prices starting in period 10 would be \( A^B = 89 \) and \( A^S = 238 \). While prices for sellers go down as expected

\[20\]1/2 is a rather high share for a new platform, but looking at the real-world platforms launches, like Android in 2008, it can be plausible.
as a reaction to the competitor entry, price for users goes up slightly. This is done to compensate for revenue losses from the sellers’ side. Hence, platform moves toward a situation where the price for users goes up, so that they start subsidizing the other side. This effect gets stronger, the later in time disruption occurs. Also, similar to the previous case the price adjustment remains quite low (around 15% in this case). These results remain robust with variation of parameters.

The key finding of this section, namely, that new competitor entry not necessarily results in noticeable price reductions, can help to explain, what was observed for the app platforms during the last years. After the success of the App Store, many other app platforms were launched. But Apple has never changed their pricing strategy, neither the membership fees, nor the commission payments. Also other platforms like Google Play or BlackBerry App World practically do not alter their pricing. The simulations at hand might provide an explanation for that, namely, once a certain number of platform participants is achieved, optimal pricing strategy is not affected strongly by new competitors entry.

2.5 Conclusion

This research paper focuses on a dynamic two-sided market model. This model aims at overcoming limitations of static two-sided models. It is based on the dynamic systems theory, examples from life sciences and differential game theory. The dynamic model at hand builds on the integrated two-sided market model (cf. Kouris, 2011). It includes several new extensions like adjustment of the number of interactions and commission payments between market sides, and integrates several prevailing parameters into one model. Based on system dynamics, examples from life sciences and differential game theory, we develop a dynamic model. Profit calculation and optimization is implemented in Matlab in form of computer simulation, since the mathematical problem at hand is too complex to be solved analytically.

Section 2.4 shows that it is possible to determine a unique profit maximum for the platform. The combination of usage/commission and membership fees to reach the maximum is also unique in the dynamic case. The next result pertains to the “chicken & egg” problem. It can be avoided if membership benefits are large enough to compensate for low network effects. It is also possible to determine the
minimal number of participants on both market sides which is necessary to start-off the platform as was shown in Section 2.4.4.

In Section 2.4.5 we have demonstrated that despite of convergence of the population dynamic, short-term and long-term strategies might differ. This should be taken into account when developing strategies for platforms. The next research question considered in Section 2.4.6 was touching upon possibility to adjust prices after a certain period of time. We were able to show that platform owner should increase prices, in particular, membership fees for the users if there is a chance to do so. The later this price adjustment happens, the higher fees platform owner should chose.

After having analyzed possible price adjustments, we proceed with consideration of external shocks in Section 2.4.7. Reaction to external shocks, such as competition, new technologies or new regulations, is an important question from the platform-owner point of view. Matlab simulations show that optimal price reduction due to entrance of new competitors might turn out surprisingly small (less than 5%), even in cases where a competitor attacks 1/2 of the new participants. This is in line with real-world observations: commission fee remains constant over time across all app platforms, and also membership fees do not change much.  

Overall, the dynamic model proves to be a powerful instrument to understand the behavior of two-sided markets, and especially of app platforms. The model at hand provides the first step towards modeling of dynamic platform behavior. The next steps can include mitigating limitations of this model or using different research methods, for instance, empirical, to extend and validate our results.

Our research presented here displays several limitations. We consider pricing variables, that is, membership, usage and commission fees being the only parameters to be set by the platform. In reality, there are many more strategic parameters, like marketing and advertising spend, open versus closed approach to app development, content providing and compatibility of adjacent fields (e.g., other hardware and content should be ideally compatible with the operating system used by the app platform). Furthermore, we have explored one possible mathematical approach to the dynamic two-sided market models, based on dynamic system theory, examples from life sciences and differential game theory. It would be interesting to try to develop an analogous model (including membership, usage and commission fees)

\[21\]

We observe a slight price reduction for mobile devices due to the technological progress and increased supply.
using other mathematical approaches mentioned in Section 2.2.2, for instance that of Sun and Tse (2007) or Cabral (2011). We believe, it would be insightful to find out, if it is possible to build such models at all, and if the results developed with help of different mathematical approaches are compatible. If not, it is necessary to understand, how this can be overcome to arrive at viable recommendations for the real world platforms.

Other simplification we used is restricting ourselves to the 3 most important kinds of stakeholders – platform owner, users and developers. In reality, more other participants contribute and depend on mobile ecosystems around app platforms, e.g., mobile operators, content providers and advertisers. These stakeholders can have significant impact on the mobile ecosystem, platform owner decisions and pricing strategies. Although we refrained from including further stakeholders in our models to avoid further complexity, we believe that it would be a great opportunity for future research to include these stakeholders in two-sided market models and thereby develop a real multi-sided model.

One more large avenue for future research are empirical surveys and applications of our model to various real-world platforms. Also simulation of entry deterrence in this setting could provide an interesting line for future research. Introduction of stochastic behavior might be a valuable extension allowing to reflect the uncertainty which we observe in the real world.
Bibliography


[56] www.interbrand.com
3


Abstract

“App platforms” are electronic software distribution markets for mobile devices like smartphones or tablets. They gained popularity after Apple launched its App Store in 2008. Since then, app platforms have transformed the entire mobile communications industry, including mobile network operators, device producers, software suppliers, content providers, advertisers, etc.

Platforms (like the App Store) which intermediate between two distinct groups of customers connected through indirect network effects can be effectively analyzed by applying the theory of two-sided markets. The interdependence between customers, platforms, and developers require consideration of strategic issues not present in traditional models. These issues may pertain to all development phases, including platform design, launch, and competition, and thus have an effect on existing and new business models in this sector.

Economics literature on two-sided markets focuses on theoretical analysis, paying only little attention to managerial implications. Strategic management literature, on the other hand, rather provides practical guidelines. This paper discusses strategic issues arising in the app platform industry, combining these two streams of literature. Based on a thorough analysis of the key stakeholders in the app platform industry (platform owner, developers, and users), we use our findings
to provide management recommendations and discuss possible developments of the industry.

Keywords: Business models, two-sided market, app platform, mobile industry, pricing strategy, competition.

JEL classification numbers: L8, L81, L82, L86, L96.
3.1 Introduction

“App platforms” are electronic software distribution platforms for mobile devices like smartphones or tablets. They gained popularity after Apple launched its App Store in July 2008. Since then, app platforms have transformed the entire mobile communications industry, including mobile network operators, device producers, software suppliers, content providers, advertisers, and so on. Although the App Store’s advantage seemed incontestable, other app platforms such as Google Play for Android OS have managed to enter the market and gain high popularity (cf. comScore Reports, 2011). Other platforms have followed Apple and Google, forming coalitions and trying to create niche markets. This has lead to differentiation and further development of the business model.

App platforms are not a single example but part of large-scale change. Over the last decade, platforms became the “invisible engines” of our economies (Evans et al., 2006). Amazon, eBay, and Google have advanced to top brands worldwide. Following Gawer and Cusumano (2007, p. 2), we define platforms as “systems of technologies that combine core components with complementary products and services usually made by a variety of firms.” Platforms spread across many industries, leading to the creation of new business areas and products. Moreover, they change the entire economic structure and fundamentally influence business strategies.

The underlying structure of a platform is that of a network. One crucial feature of networks are network effects. These denote the phenomenon that participants’ profit depends on the number of other participants in the market (Katz and Shapiro, 1985, 1986, Farell and Saloner, 1985, 1986). There are direct and indirect network effects. Direct network effects (or same-side effects) occur between members of the same customer group, for instance, the more participants join a telephone network, the more people can be reached, the higher the utility of each single participant. Indirect network effects (or cross-side effects) occur between members of the disjunct groups, like developers and users. That is, the more developers join a platform, the higher the users’ benefit. Strategic management literature

---

1. “The runaway success of Apple’s iPhone App Store, the online site where iPhone and iPod Touch owners can download free or cheap software for their devices, has transformed the mobile software marketplace.” – Taylor (2009).

on platform management (e.g., Gawer and Cusumano, 2008, Eisenmann, 2007) provides practical guidelines on how to deal with these effects. However, it does not provide an adequate theoretical framework to thoroughly analyze complex interactions. Economic literature, on the other hand, analyzes platforms that intermediate between two distinct groups of customers connected through indirect network effects in so called two-sided market models (e.g., Rochet and Tirole, 2003, Evans, 2003, Tag, 2008). However, the analysis focuses on the theoretical aspects of two-sided markets, and not so much on the managerial implications of these theories. With this paper, we aim to bring these two streams of literature closer together. We analyze the app platform industry and the business models of the stakeholders involved. The main contribution of our paper are applications of the theoretical findings to the app platform industry: We show which strategic decisions are the most important ones in the different lifecycle stages of an app platform. We will primarily cover the app platform owner’s perspective, leaving developers’ and customers’ perspectives to future research.

The remainder of the paper is organized as follows. We begin with a literature review on platform analysis and two-sided market models in Section 3.2. We explain the key economic principles of two-sided markets to arrive at a framework for industry analysis. Subsequently, we consider app platforms for mobile devices in Section 3.3. We provide an industry overview and discuss the platform business model and key stakeholders. Section 3.4 covers strategic issues and insights structured according to the three lifecycle phases (design, launch, and competition). Although we focus on app platforms for mobile devices as the underlying industry, the insights apply to many other Internet-based platforms. Section 3.5 concludes and points out interesting aspects for further research from a managerial perspective.

### 3.2 Literature Review and Background

In this section, we provide the background for platform analysis. We begin with a brief literature overview on platforms and two-sided markets and then explain the key economic principles of two-sided market models. The focus is on understanding the main features of such models and their implications.
3.2.1 Platforms

In recent years, platform competition has become a key element in many (and in particular high-tech) industries (Evans et al., 2006, Gawer and Cusumano, 2008). Hidding et al. (2011) identify four fundamental drivers for the rise of platforms: Modularity, increased interconnectivity, self-organization, and low marginal cost of production. Given the increased number of industries with platform character, it is not surprising that management literature on this topic is growing. The main research directions include network analysis, platform competition, and management of complementors, which are briefly described in the following paragraphs.

In the literature on networks, platforms assume a key role among actors (Eaton et al., 2010). Platforms, as a bottleneck, may constrain the overall performance (Baldwin and Clark, 2006) and limit the service level of the network (Teece, 1986). On the other hand, the gate keeping position allows the platform owner to extract a significant share of the economic value of the network (Baldwin and Clark, 2006) and thus sustain a competitive advantage (Porter, 1985). Basole (2009) shows how a structural analysis of networks can be used to visualize the ecosystem of actors. This can be used to identify a platform’s competitive position and characterize its business strategy.

The literature on platform competition addresses what business and technology decisions help companies become and remain platform leaders (Gawer and Cusumano, 2008). While there is a certain advantage of being the first to market (established customer base, switching costs, network effects), Hidding et al. (2011) find that in their sample of 15 platform industries, the first mover continues to be the leader in only one market. Successful followers mainly used a “platform envelopment strategy” (Eisenmann et al., 2007), which means that the entrant combines its own functionality with the leader’s platform to leverage shared user relationships and common components.

Companies providing complementary services are crucial, since they significantly enhance the platform’s value. Platform owners should therefore pay close attention to how they attract and manage their complementors. In an extensive case study on Intel’s strategy, Gawer and Henderson (2007) find that Intel established a good balance of encouraging entry, despite the fact that Intel has the potential to “squeeze” entrants ex-post. Related to this issue is the level of a platform’s openness. Parker and van Alstyne (2009) analyze the tension between innovation
and open access. In essence, they find that the platform sponsor has to establish a balance between fostering platform adoption and complementary investment versus capturing immediate profits from the platform itself. Boudreau (2010) analyzes different modes of open access to a platform. He finds that licensing complementary hardware developers had a strong, inverted U-shaped effect on innovation. The effect of IP sharing in the form of reference design was smaller. With respect to giving up platform control, he also finds a positive, yet small effect of openness on innovation. However, as the focus of Boudreau’s paper is innovativeness, the effects on platform profits are not analyzed. Eisenmann (2007) analyzes factors that favor proprietary versus shared models when designing new platforms. For the subsequent lifecycle stages (network mobilization and platform maturity), he explains how management challenges differ between these two types of platforms.

While the strategic platform management literature clearly provides several valuable recommendations for platform management, it does not offer an adequate theoretical framework to fully describe the complex network interactions. We therefore now turn to the (more theory-based) economic literature on two-sided markets.

3.2.2 Two-sided markets

Two-sided markets can roughly be defined as platforms that enable interactions between two groups of customers who value each other’s presence (Rochet and Tirole, 2003, Evans, 2003, Tag, 2008). Research on two-sided markets builds on network economics and complementary product pricing (cf. Rochet and Tirole, 2003, earlier assessments are, e.g., from Katz and Shapiro, 1985, 1986, Farell and Saloner 1985, 1986). One of the key concepts for two-sided markets is that of “indirect network effects”: The utility of those on one side of the market increases with the number (and/or quality) of participants on the other side. Examples of platforms that can be interpreted as two-sided markets range from credit card systems and software platforms to night clubs and shopping malls. Due to the diversity of two-sided market examples, various extensions are necessary to describe different types of platforms.

A large body of literature on two-sided markets has emerged over the last decade (cf. Rochet and Tirole, 2003, 2006, Caillaud and Jullien, 2003, Evans, 2003, and Armstrong, 2006, to name just a few). The emphasis has clearly been on two
research directions – the development of extensions for monopoly and duopoly cases. Other research thrusts, such as dynamic two-sided market models or empirical evaluations are still quite rare and definitely represent interesting development opportunities for future research.

3.2.3 Two-sided market models

Two-sided market models are usually based on three equations: The platform profit equation and the two utility equations for the two market sides (Rochet and Tirole, 2003) – the one for the seller side, the other for the user side. Each of them can consist of membership and usage parts. Membership benefits, fees and costs are induced only once, while usage benefits, fees, and costs are recurring and depend on the number of transactions, e.g., downloads.

The key insight of two-sided market models is that the solution does not only depend on the total fee level, but on the pricing structure. Hence, total demand (and total revenue) depends on the allocation of fees among the two market sides. Imagine two customer groups (sellers and buyers) whose respective demand curves are presented in Figure 3.1. Assume that sellers’ fees are reduced and buyers’ fees are increased by the same amount. As a result, the number of sellers increases significantly, attracting new buyers so that the buyers’ demand curve shifts. The total effect is a relatively small reduction in revenue on the seller’s side, which leads to a strong increase in revenue on the buyers’ side. This example denotes the interdependence between the two market sides and the importance of determining the optimal fee allocation.

Traditional economic intuition suggests that if prices are equal in the beginning for both sides, a price increase is more effective on the side with the steeper demand curve, while a reduction is more effective on the side with the curve that is less steep. This also holds for two-sided markets. One prominent example is the pricing strategy of night clubs. Often, women do not only get in free of charge, they even get a free drink. If there are many women in a night club, men are willing to pay more to compensate for the revenue loss of free drinks.

What is new in two-sided market theory is that in equilibrium, the ratio of fees for the two market sides should be proportional to the ratio of their price elasticities (not the other way around). The market side with the lower price elasticity pays less than the other side and is often even subsidized (“subsidy side”)

Key feature of the two-sided markets is that the platform owner has to take into account two interdependent demand functions.

Figure 3.1: The key feature of the two-sided market is that the platform owner has to take two interdependent demand functions into account.

to attract the other side (“money side”). This result was first reported in Rochet and Tirole (2003). It is often seen as counterintuitive, since the more elastic market side is supposed to pay more (Bolt and Tieman, 2005). Price elasticities cannot be treated as constants, but should be seen as functions of prices. The inverse slopes of demand curves are not equivalent to price elasticities. As Krueger (2009) points out, this resolves the seeming contradiction.

For the model to reflect the app platform structure, we have to adjust the canonical model of Rochet and Tirole (2003). We have to consider additional parameters and extensions, like usage fees, membership fees, payment between customer groups, and quality review of participants, which were discussed in different papers on two-sided markets in a different context or industry. Armstrong (2006) and Rochet and Tirole (2006) introduce membership fees and payments between customer groups, and Hagiu (2009) and Jeon and Rochet (2010) analyze quality reviews. Furthermore, new parameters must be introduced, like segmentation of participants, commission payments, and adjustments for the number of interactions. Kouris (2011) explains these additional elements and derives a solution for the resulting model based on price elasticities. Understanding the impact of parameters like membership fees, quality of apps, and customer segmentation, etc., is key for addressing challenges pertaining to app platform stakeholders.
For competition between platforms, multi-homing is an important issue. “Multi-homing” refers to a situation in which participants might join more than one platform (cf. Rochet and Tirole, 2003, 2006, Armstrong, 2006, Armstrong and Wright, 2007, Sun and Tse, 2007). Market participants might choose between three possibilities: To not join any platform, to join only one platform ("single-homing") or to join more than one platform ("multi-homing"). The decision is taken at the individual participant’s level, that is, not all participants need to join more than one platform in the case of multi-homing, but only some. For single-homing, not all agents have to be part of the same platform, but they might decide to join different platforms (albeit only one at a time). Single-homing behavior can be driven by the requirements imposed by platforms, like exclusive contracts. Alternatively, it can be driven by the costs of multi-homing, for instance, when platforms are incompatible or charge high membership fees. The more single-homing behavior is observed, the more likely it is for a single platform ("winner-takes-all" dynamic) to dominate. We will return to this aspect in Section 3.4.

Economides and Katsamakas (2006) compare a proprietary with an open source platform. They find that when users prefer application variety, the total profits of the proprietary industry are larger than the total profits of an industry based on an open source platform. Application variety, however, is larger in the open source platform.

Another key factor for platform competition are the same-side effects. There are networks with positive same side effect, for instance, file exchange is only possible between computer users if they have the same (or a compatible) operating system. For many networks, the side effects are negative due to crowding out and increasing competition: The higher the number of developers who participate in a platform, the lower the attention a single developer gets. Both effects exist for app platforms as we will discuss in the following Section 3.3. In most models, network effects are exogenously given. Bakos and Katsamakas (2008) address this gap in the literature and allow for investments by the platform owner to influence network effects. They show that an independent platform owner invests too little compared to the social optimum.

Given the theoretical insights of this stream of literature, we now aim to derive managerial implications for app platforms, using the findings of strategic management literature on platforms as well. We first describe the app platform industry and the key stakeholders. Consequently, we discuss how the insights gained
from the two-sided market theory can be applied to address strategic challenges arising in the app platform industry and how they affect business models in these markets.

3.3 App platforms

App platforms are a special form of electronic markets. Software developers can distribute their software applications (apps) among users of mobile devices like smartphones or tablets via app platforms. Hence, developers and users are indirectly connected: Developers profit from the users who purchase their apps and users benefit from the apps. The groups are not disjunct, since some users are also developers and many developers are also users, but they are nonetheless distinct enough. Due to these direct and indirect network effects, app platforms can be analyzed using two-sided market theory.

In this section, we provide background information on app platforms and identify those parameters from two-sided market theory which are relevant for app platforms. We begin with a brief industry overview and proceed with a description of business models and key stakeholders of app platforms. This creates a foundation for understanding the industry’s key challenges and issues.

3.3.1 Industry overview

Apple’s App Store and Google Play for Android OS are probably the best known app platforms. In fact, there are many more app platforms – and some of them were founded as early as 1999. For example, Handango has been offering apps for mobile phones since 1999. But it was not until the App Store opened that app platforms gained momentum. Several hypotheses can be provided to explain why it took until 2008 for app platforms to gain popularity, for example, usability (size of screen), connectivity (3G and 4G coverage) or the hardware price might have contributed to the development of the app platform. The launch of the App Store has changed the mobile phone industry in practically all dimensions. After three years on the market, there were 425,000 apps available in the App Store. The number of downloads exceeded 14,000,000,000 (Apple, 2011).

\[^3\text{Cf., for instance, the remark by Steve Jobs, the founder and former CEO of Apple: “The App Store is like nothing the industry has ever seen before in both scale and quality.” Apple (2009).}\]
The app platform industry as a whole thrived especially in 2011, growing by around 150% and reaching USD 5.6 billion in revenues in 2011. Apple managed to remain the market leader, accounting for 75% of total market revenues, by far outpacing other market participants (Kent, 2011). Projections for the future are positive as well: In 2013, total revenues are expected to reach USD 26 billion and this number is estimated to grow up to USD 77 billion in 2017 (Gartner, 2013).

In 2011, Apple, Google, Nokia, and RIM were the most important players in the market. Apple will probably remain the leader in terms of revenues for the next 2–3 years, but other platforms will also gain traction. Android currently enjoys high shares in the smartphone market (53% in the USA) and high sales (e.g., 61% in Germany in 2011). Windows and Nokia are continuously losing market share (Nokia from around 70% in 2006 to under 30% in 2011 in terms of the number of handsets worldwide), however, together they have an interesting value proposition for the future. Due to the consolidation and merging of mobile devices and computers, Windows could become the key player in this process. Nokia has the capacity to produce low-cost devices that can boost sales as soon as the high-end market is saturated (Virki, 2012).

3.3.2 Business models and key stakeholders

In this section, we provide a brief description of app platform business models and operations. There are three key types of participants in app platforms: The platform owner, developers, and users. Platform owners connect developers and users, specify the rules and provide services. Developers program apps and submit them to the platform so users can download them. In the following, we describe each group of participants in detail.

**App platform owners**  App platform operators provide the entire infrastructure (like user interface, server space, etc.) and determine the rules for the interaction between the two market sides. They can also provide information about apps and developers and serve as a trusted third party by controlling app quality.

Belleflamme and Peitz (2010) refer to the business model used by platforms as an intermediary business model. They distinguish between 4 major roles of intermediaries: Dealer (resells goods), platform operator (connects sellers and buyers), infomediary (facilitates information gathering and procession), and trusted
third party (certification agent). Many platforms have chosen a hybrid business model. For instance, in 1995, Amazon started off as a dealer of books only, subsequently adding many other product categories. Then, following eBay in 2001, Amazon launched Amazon marketplace. This transformed Amazon from a 'pure' dealer into a platform operator. At the same time, Amazon assumed the infomediary and trusted third party role. There are also examples where companies have skipped the dealer role: Apple was never perceived as a pure re-seller. Its "pre-platform phase" included offering own apps before launching the App Store. The main difference between a dealer and a platform operator is that the latter does not control the transaction price in a direct way by buying and reselling products, instead, he or she charges for platform membership and transactions. App platform owners are platform operators in the first place, and some combine this function with infomediary and/or trusted third party roles. The neglect of some roles by certain (prominent) players leaves room for entrants in this market to perform these duties.

App platforms can be classified in various ways. Following Distimo (2011), we divide app platforms into 4 categories: Native platforms, pure mobile device manufacturers, mobile network operators, and independent. Examples are presented in Figure 3.2. In contrast to Distimo, we suggest differentiating between native platforms (which provide an operating system and hardware) and pure mobile device manufacturers, instead of device manufacturers versus operating system developers. Our classification allows taking the fact into account that many successful app platforms provide both the hardware and the operating system (Apple, BlackBerry, Nokia/Windows). Moreover, there are key strategic differences between companies which offer an integrated experience like Apple and BlackBerry versus those which provide hardware only, like HTC. For instance, if an app platform provides an operating system and/or mobile hardware, it can more easily assess whether apps will work well on their system. Hence, their own apps are better adjusted to the other parts, can offer better functionality, and can review third-party apps with less effort. Mobile network operators already have a customer base and a billing system in place, so they can quickly acquire customers for new products like apps and/or take over the payment procedure.

Native (or integrated) platforms belong to the largest platforms (in terms of available apps and downloads) and have had the highest impact on the industry so far. Figure 3.3 provides an overview of the major native app platforms. These
app platforms are built around different operating systems and use different programming languages and software tools. Hence, compatibility is very low. This is important for multi-homing and has an impact on the market structure as we will see in Section 3.4.

Due to the explosion in the number of app platforms, challenges surrounding platform competition are currently the focus of the app platform industry. However, new platforms are also being launched. For these new entrants platform launch and design are the most important features. Incumbent platforms should also occasionally re-evaluate their design and consider adjustments to pricing and/or quality to deter the entry of new platforms and to remain competitive. We will discuss strategies to address all these challenges in Section 3.4.

When Apple’s App Store was created, it was not supposed to yield high revenues, but rather strengthen the ecosystem and drive demand for iOS-devices.\(^4\) As we have seen, app platforms are now a business in their own right, especially for the large native platforms. The main source of app platform revenue are the

<table>
<thead>
<tr>
<th>Name</th>
<th>Owner</th>
<th>Launch Date</th>
<th>Number of apps</th>
<th>Number of downloads</th>
<th>Installed base</th>
<th>Operating system</th>
<th>Developer membership fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Play (Android market)</td>
<td>Google</td>
<td>22.10.2008</td>
<td>1 000 000 (Jul 2013)</td>
<td>50 bn (Jul 2013)</td>
<td>500 mn (Jun 2012)</td>
<td>Android</td>
<td>25 USD</td>
</tr>
<tr>
<td>App Catalog</td>
<td>Palm/HP</td>
<td>06.06.2009</td>
<td>10 000 (Dec 2011)</td>
<td>108 mn (Aug 2011)</td>
<td>2.6 mn (Jul 2010)</td>
<td>webOS</td>
<td>free</td>
</tr>
<tr>
<td>App Store</td>
<td>Apple</td>
<td>10.07.2008</td>
<td>900 000 (Jul 2013)</td>
<td>50 bn (Mar 2013)</td>
<td>500 mn (Jan 2012)</td>
<td>iOS</td>
<td>99 USD per annum</td>
</tr>
<tr>
<td>BlackBerry World (App World)</td>
<td>BlackBerry (RIM)</td>
<td>01.04.2009</td>
<td>120 000 (May 2013)</td>
<td>3 bn (May 2012)</td>
<td>75 mn (Jan 2012)</td>
<td>BlackBerry OS</td>
<td>free</td>
</tr>
<tr>
<td>Nokia Store (Ovi Store)</td>
<td>Nokia</td>
<td>26.05.2009</td>
<td>120 000 (Aug 2012)</td>
<td>6 bn (Aug 2012)</td>
<td>885 mn (Mar 2012)</td>
<td>Multiple (e.g., Symbian, Java, MeeGo)</td>
<td>1 EUR (+ additional cost)</td>
</tr>
<tr>
<td>Samsung Apps</td>
<td>Samsung, Handmark</td>
<td>14.09.2009</td>
<td>13 000 (Mar 2011)</td>
<td>120 mn (Jun 2013)</td>
<td>5 mn (Mar 2011)</td>
<td>Multiple (e.g., Android, bada)</td>
<td>free</td>
</tr>
<tr>
<td>Windows Phone Store</td>
<td>Microsoft</td>
<td>21.10.2010</td>
<td>160 000 (May 2013)</td>
<td>54 per person (Dec 2012)</td>
<td>31 mn (Mar 2013)</td>
<td>Windows Phone</td>
<td>99 USD per annum</td>
</tr>
</tbody>
</table>


Commission payments made by developers as a percentage of the downloaded apps’ price. Additionally, app platforms charge participant membership fees in the form of an annual lump sum payment and complementary products like mobile devices and software tools. This will be described in more detail in the following sections.

Developers The first challenge for many (especially professional) developers is the question, which platform to join. App platforms do not require single-homing (limitation to one platform), i.e., developers are allowed to develop apps for more than one platform. Since apps are information goods (cf. Shapiro and Varian, 1999), the main costs are the fixed costs of programming – the marginal costs are basically zero. But transition to another platform costs around 50% of the development costs due to the differences in programming language, operating system, and hardware.
The possibility of programming universal apps that run on all platforms are still very limited (cf., Newel 2011). There are several engines like Titanium, Ramp or PhoneGap which allow development for more than one platform simultaneously, but additional work is still necessary to adopt the apps. Therefore, many (especially small) development companies have to decide which platform(s) to join and which ones to reject.

In 2008, Apple’s App Store was virtually the only relevant platform. Since 2009, Google Play for Android OS has gained popularity. Later, other platforms started attracting attention. Developments such as the launch of Amazon’s Appstore and the cooperation between Nokia and Windows indicate that the industry landscape is changing, often in a disruptive way. Currently, there are several well established app platforms. Joining the biggest one is not necessarily the best decision. The bigger platforms have a larger customer base, but there is a congestion problem – with over half a million apps on the market, how will a new app be noticed? Nonetheless, Apple’s App Store continues to be the winner, since three times more new app projects are introduced for the App Store compared to Android (cf. Dredge, 2011).

Once the decision about which platform(s) to join is made, developers have to sign up with the platform(s) and obtain the necessary tools consisting of hardware (computer) and software (e.g., software development kit) components. Some platforms charge membership fees for this service, which can vary for private developers, enterprises, and non-profit organizations. In return, developers gain access to the software development kit and other tools and services.

Developers program apps which they submit to the app platform. In general, they are entitled to choose app prices themselves. Different pricing strategies exist, including “simply buy it”, “in-app-purchase”, and financing through advertisement (cf. Gans, 2012). The key instruments for extracting revenue are versioning (lite vs. prime), free trials, and personification of information goods (cf. Shapiro and Varian, 1999).

This information problem provides business opportunities for knowledge brokers simplifying the search for relevant apps.

Some platforms restrict prices to certain values like USD 0.99, 1.49, 1.99 and so on. There is also a new development regarding app prices: Since March 2011, Amazon has been offering another model whereby it determines app prices itself (cf. http://business.chip.de/news/Amazon-Android-App-Store-oeffnet-fuer-Entwickler_46573233.html). This allows Amazon to determine its own pricing policy, which is consistent with the firm’s overall interests.
Some platforms conduct quality reviews before they make apps available to users (e.g., App Store), others do not (e.g., Google Play). If an app is accepted, the platform “publishes” it, that is, the app becomes available to users. Users may search and download apps. Depending on the platform, 20-60% of the submitted apps are free (Distimo, 2010). The share of free apps among the total apps downloaded amounts to 80%-90% (Gartner, 2009). The payment process in the case of apps that can be purchased occurs through the platform. Developers receive their share of the revenue (usually around 70%). The remaining 30% represents platform’s commission fees.

**App platform users** The other market side of an app platform are its users. They determine which apps are successful and, ultimately, which ecosystem will win. Hence, it is important for the platform operator as well as for developers to understand the users’ side.

App platform users access the platform through their mobile devices. Mobile devices are complementary goods and can be considered a one-time membership fee. The features of mobile devices are key for consumer experience, they determine which apps can be installed and used. For users, it is not only the apps that count, they consider their mobile device and the software that comes with it as a whole. Value and benefits are determined by the ecosystem.

Users search, download, pay for, and rate apps. The best way to understand the consumer side of the market is probably to conduct a segmentation analysis. Segmentation divides users into several groups according to their needs, income, demographic factors, etc. This helps to decide which groups to target and allows addressing them in a better way. Interestingly enough, customer segmentation surveys uncover differences between the customer bases of different app platforms. For instance, Apple and RIM BlackBerry users were found to be wealthier than Android users (cf. Prosper Mobile Insights, 2011). This is reflected by the cost of mobile devices and also has an impact on the app platform, since more affluent customers are more willing to pay for apps. This is evident in the app platforms’ revenues: The same apps on the Android market generate only about 25% of the App Store’s revenues (cf. Farago, 2011). These differences between the users of

---

7Since apps cannot be consumed without a mobile device, they are perfect complements. If built-in apps are neglected, mobile devices are also fairly useless without apps.
different platforms are key for the “winner takes all” question (see next section), since niche creation allows companies to survive in the app platform market.

3.4 Key strategic issues and insights

Business models based on two-sided markets must consider strategic issues excluded from traditional models. In the following, we analyze which characteristics of app platforms specifically are affected by the factors described in Section 3.2. We structure our arguments along the three lifecycle stages described in Eisenmann (2007): platform design, launch, and competition.

3.4.1 Platform design

From a strategic perspective, it is first necessary to determine the criteria for a product to become a platform. Gawer and Cusumano (2007) argue that a product needs to (i) perform one essential function or solve one essential problem for several actors in an industry, (ii) be easy to connect or build upon, and (iii) be difficult to substitute. Clearly, the leading app platforms satisfy these criteria. In order to make the platform successful, the authors then recommend a “coring strategy”, which aims at making the platform the “core” of a technological system. That was exactly the strategy implemented by Apple when the company realized the potential of the App Store: Before its launch, the mobile industry was organized around mobile devices and mobile network operators, with device features and network coverage being the key differentiation factors. Since the App Store’s launch, the mobile industry’s structure has changed profoundly, now having software (operating system plus apps) at its core. As the “Gesellschaft für Konsumforschung” (GfK), the largest German consumer research agency, suggests in its press release from 7 October 2010:

“Amidst a landscape where overall handset sales are declining, sales of smartphones have steadily increased as more consumers gravitate towards mobile applications. The survey of 1,000 adults found that the value of the smartphone and selection of mobile applications were greater priorities to consumers than reliable coverage and customer service. ’Our research shows that we are at a mobile application tipping point, where the applications are driving customer purchases of the
technology more so than the smartphones themselves,’ said [David] Krajicek, [Managing Director of GfK Business & Technology]” (GfK, 2010).

Hence, app platforms have recognized the importance of the coring strategy and managed to apply it, arranging the entire mobile industry around them. Once this factor is taken into account, other important platform design issues should be considered, like pricing and quality settings. As we have seen in Section 3.2.3, pricing is more complex in two-sided markets and requires consideration of the interaction between different market sides. Regarding pricing strategy, two decisions need to be made: Firstly, which side to subsidize, and secondly, what kind of fees to charge.

Which side to subsidize is a non-trivial decision (Eisenmann et al., 2006). For instance, in the video game industry consoles are sold to users at or even below cost (“subsidy side”). The developers’ side is the “money side” and it has to pay high royalties for the development of the games. In the personal computer industry, the situation is reversed: Users pay high prices for the operating system software while developers obtain free software development kits. The differences can even be observed within one and the same industry – Apple tried to charge developers USD 10,000 for the Mac software development kit, but was not successful with this strategy after having lost market shares in the mid-1990s to Windows and open source operating systems.

For app platforms, we observe that users are usually the “subsidy side” and developers the “money side”. Around 80-90% (depending on the platform) of app downloads are free of charge. The remaining apps are charged with a commission of 30% that goes to the platform. Apart from that, the mobile device price can be partly interpreted as membership fee for the app platform.

Clearly, there are differences between the platforms. Apple charges USD 600-800 for the iPad which costs around USD 300 in production, Amazon charges only USD 200 for its Fire tablet – which is below the manufacturing cost (iSupply tear-down report, 2012). Amazon is aspiring to install another business model, extracting even more revenue from developers.8 Hence, we observe that there are different business models, even within the app platform industry. It would

8In addition, Amazon is hoping to achieve cross-financing from other areas like advertising and additional sells in their Amazon online store and Kindle ebooks store.
be interesting to empirically evaluate, which side has higher price elasticity and whether the two-sided market fee allocation rule is complied with. If not, it opens opportunity to improve pricing and extract additional revenues.

The second question pertains to the different kinds of applicable fees. In different industries, different kinds of fees are used. The two types that are considered in the two-sided markets literature are membership fees (one-time or periodical) and usage fees. Membership fees (also called lump sum or access fee) is charged independently of interactions between the two market sides. Membership fees are especially useful if transactions between participants cannot be observed, like on partner search platforms. Usage fees, on the other hand, apply per transaction.

The literature on static two-sided markets suggests that the optimal combination of membership and usage fees is not unique (Rochet and Tirole 2006, Reisinger 2010). In a dynamic setting, the combination is unique for most situations due to the uniqueness of market dynamics. Therefore, for most settings, it is possible to make an optimal subdivision between usage and membership fees (cf. Kouris, 2012).

It generally depends on the cost structure which type of fees should be incurred. Here, not only the platform cost structure but also the developers’ costs and revenue structure play an important role. Usually, for information goods like apps, fixed costs are high and marginal costs are virtually zero, or as Shapiro and Varian (1999, p.3) put it, “information is costly to produce but cheap to reproduce.” In contrast, revenues are obtained on a per-download basis. Generally, information goods like apps should be priced not based on production costs, but based on the value to the customers (Shapiro and Varian, 1999). Thus, app platforms can best contribute to the developers’ success if they charge a per-transaction commission.

Besides optimal price setting and allocation, the quality of apps is an important issue. One of the most prominent examples for which the quality of participants is crucial are partner search agencies. Agencies such as Parship.com or ElitePartner.com charge high membership fees. This is not due to the high costs they have, but rather serves as a signal: Someone who is able to pay such a high membership fee is probably wealthy and is serious about his partner search. Many partner search agencies check potential participants and might exclude someone even though he is willing to pay the high membership fees. Another example of quality requirements on two-sided markets comes from the computer console and game industry. Game developers pay high royalties to game console producers.
This is (at least partially) to ensure that low-quality games are not profitable and to exclude them from the platform (Hagiu, 2009).

Quality belongs to the key platform design factors for app platforms as well. For users it is important for downloaded apps to at least not contain malware, viruses, and spyware. That is the first level of quality differentiation – and it is objective. The next level is that of usability and the content quality of apps. This may be perceived differently, and is therefore subjective. App platforms differ in their approach toward certification of app quality. Apple is known for its rigorous approach: They review all apps before placing them in the App Store. Other platforms like Google Play do not have a pre-placement review process, but they do occasionally delete low-quality apps. In addition to these types of quality certification processes, every app platform has a ranking mechanism in place so users can rate the app quality and comment on it.

Theoretical analysis shows that the side in a two-sided market which requires higher quality (consumers) should be subsidized (Hagiu, 2009, Eisenmann et al., 2006). In reality, we observe that App Store app developers pay more for platforms in which a quality review process is installed (e.g., App Store). The exclusion of low quality apps leads to higher benefits for users, a larger customer base, and – through the indirect network effects – to a higher interest to develop for high-quality platforms. One more benefit for developers is that negative same-side effects are reduced through exclusion, thus decreasing the congestion problem. Kouris (2011) provides a suggestion, how to determine whether a quality review process would be beneficial.

With regard to platform quality, no general recommendations can be made that cover every situation. However, it is crucial for platforms to decide whether they want to differentiate between quality and quantity. Those who cannot decide will easily be dominated by other platforms in one direction or the other.

3.4.2 Platform launch

The so-called “chicken & egg”-problem is the main issue during the launch phase. Caillaud and Jullien (2003) use this expression in their first paper on two-sided markets. The key challenge for two-sided markets is that the platform must win both customer sides to do business. But as long as there are no users, no developers would join and vice versa. As explained in Section 3.2.3, platform owners’
revenues consist of two components, membership and usage parts. When the usage component is too small due to a low number of participants, the membership component may suffice to get the platform up and running. This requires the membership component of utility and the profit equation to be high enough to compensate for low usage benefits. This also explains the phenomenal success of Apple’s App Store or Amazon’s marketplace. Due to high membership benefits, they managed to attract users first, then developers, and independent sellers who followed very quickly.

At the outset, membership fees are the key platform engine. Later in the lifecycle, the importance of usage fees increases due to two effects. The number of participants on both sides is high enough for many interactions, which leads to a higher profit from platform usage. At the same time, the number of new customers per period will ultimately decrease, so that the contribution of the membership component to the platform’s profit decreases. On the whole, this suggests that a shift occurs in many platforms from membership fees at the beginning of the lifecycle to usage fees at a later point.

The first implication for platform operators is that new entrants may be able to prevent the “chicken & egg” problem” by charging low membership fees and providing high membership benefits. The second implication is that at a later stage, platforms might want to reassess their pricing strategy and adjust their prices. In reality, we have not yet observed any major price changes. Kouris (2012) explains, why and under which circumstances such behavior is justified.

Once the platform is launched, its degree of openness appears to be a key strategic decision for the two-sided market (Rysman, 2009). Most app platform owners pursue a proprietary strategy, which means that they have full control over the platform and can therefore capture most of the added value themselves. Following Eisenmann (2007), this is the right strategy for leaders in the market. Followers, however, might choose a more open, collaborative approach (i.e., cooperating with competitors or complementors) in order to differentiate themselves and exert competitive pressure.

When entering into an already existing market, it is of strategic importance for the remaining market to still be large enough to create substantial network effects or, if possible, to attract customers and developers from existing platforms. Eisenmann et al. (2007) and Hidding et al. (2011) describe platform envelopment as a promising strategy for followers. Google successfully linked many platform
markets to its search platform (like Google Docs or Chrome) and naturally also used this position to support Android OS and Google Play. Through indirect network effects, the market share of developers also affects users. As some key developers (Cheezburger Network, Foursquare) considered Microsoft’s market share to be too small to justify the development of a new app for the Windows Phone, Microsoft reacted by incentivizing developers. Not only did Microsoft provide developers with free phones and prime spots in its app store, in some cases, Microsoft even financed the app development (cf. Wortham and Wingfield, 2012). This is similar to the strategy of in-house complements described in Eisenmann (2007).

3.4.3 Platform competition

Many managers in the mobile industry wonder whether app platforms will evolve a “winner-takes-all” dynamic or allow for the existence of several competitors. This question is crucial for all business areas around mobile ecosystems. The winner-takes-all dynamic emerges due to network effects and increasing returns to scale. For instance, the market for keyboards is 100% dominated by the “qwerty”-keyboard (with small variations for different languages). On the video market, the VHS format wiped out Sony’s Betamax video format. At the same time, there are markets in which several platforms coexist. For instance, there are several web-browsers like Mozilla Firefox, Safari, Chrome, and Internet Explorer. The market for computer operating systems is divided among several companies (Windows, iOS, Linux, and Unix). The crucial question is then how to decide whether the “winner-takes-all” dynamic will evolve in the app platform market or not.

There are 4 conditions that follow from two-sided market theory and make the “winner-takes-all” dynamics probable (cf. Eisenmann et al., 2006, Sun and Tse, 2007):

1. It is costly to multi-home – at least for one market side,

2. There are high indirect network effects – at least for the side with high multi-homing costs,

3. Same-side effects are not negative and strong, that is, the congestion effect is not too high,

4. The goods are rather homogeneous and there is no demand for differentiation.
In the following, we explain these conditions in detail and examine whether they apply to the app platform market. The first condition pertains to multi-homing. To “multi-home” means to have access to more than one platform as explained in Section 3.2.3. If platforms are not perfectly compatible, multi-homing incurs costs, like additional equipment or the time necessary to learn how to use other platforms. In the case of app platforms, the incompatibility is quite high: Different app platforms use different operating systems, different programming languages, and they run on different mobile devices with different functionalities. For instance, it is costly to port an app that was created for iOS to Android OS or Windows Mobile OS.9 Developers must possess both programming languages and know the differences between them. They must also understand the differences in the operating systems and in the middleware of both platforms. Additionally, developers have to buy certain hardware. For instance, in order to develop for Apple’s iOS, it is necessary to have a Mac. In addition, SDKs and other tools are required. And some platforms charge membership fees, as was discussed in Section 3.3. Hence, development for different platforms entails quite an investment.

For consumers, multi-homing costs are also high. In order to use more than one native app platform, users have to purchase and carry more than one mobile device that is compatible.10 In addition, there is a lock-in effect: If a user has spent some money and time on apps of a given platform, she might be reluctant to switch systems. Generally, we can conclude that the costs of multi-homing are quite high for both market sides of app platforms. That supports the consolidation of the market toward a single platform.

Developers can only profit if there are users who download and buy their apps. Hence, indirect network effects are relatively high. This causes the participants in the app market to converge onto one platform. Once there is a clear leader, other platforms’ chances to secure enough customers diminish. Vogelsang (2010) shows that these network effects increase the possibility of entry deterrence by incumbents. As a consequence, the market leader does not exploit the monopoly profits in early stages of the market, but rather in a more mature stage. Hence, the second condition applies as well and reinforces consolidation.

---

9Porting costs are estimated to be around 50% of the initial programming costs, on average.
10RIM has announced that it will introduce Android market for the BlackBerry, but there are many problems relating to insecurity, incompatibility, and sub-optimality of Android-based apps.
The effect of the third condition is not as clear as that of the first two. On the developers’ side, there are negative same-side effects, since they prefer to have fewer competitors. With more than half a million apps on a platform, the marginal visibility and utility of an additional app diminishes. Then, other things like quality and the variety of apps and good platform infrastructure become more and more important. On the users’ side, there are positive same-side effects: People can share apps and communicate easily. For instance, they may use the same chat apps, some of which are also platform-specific, e.g., BlackBerry messenger. In general, we can say that negative same-side effects might work against platform consolidation.

The fourth condition implies that if different features are necessary, there might be room for niche building and, therefore, for more than one platform. Hence, the effect of the fourth condition is also not obvious. On the users’ side, there are different customer segments: there are, for instance, business customers with a preference for security, very high quality, and the ability to pay for it, on the one hand, and budgeters, on the other, who are not willing to pay much, and those who want to be able to adjust apps as they wish, etc. All these customer groups have different needs. While it is possible to serve all of them on one platform, it requires the co-existence of specialized platforms. Also, developers are different, for instance, in terms of their motives: Some develop for monetary rewards, others for fun, and still others for the recognition they receive from their peers (Harhoff et al., 2003). Hence, there are still opportunities for niche-building and co-existence of several platforms.

The factors discussed above arise from two-sided market theory and have an impact on the app platforms’ business models and strategy. Besides these factors, there are several other aspects that are not part of two-sided market theory, but must be taken into account when talking about app platform strategies. These are, for instance, the brand image of the platform owner and the platform ecosystem (Kotler, 2004), possible disruptions like new coalitions between key players, new mobile devices, trends from adjacent industries like smart home, and questions regarding possible vertical integration. These aspects must be taken into account when considering strategic issues on app platforms.

Summarizing all factors addressed in this subsection, we can conclude that the app platform industry shows a high tendency toward convergence, but leaves room for niche building and differentiation. Moreover, this market is subject to a wide range of innovations, including technologies and services. It is crucial to develop
unique features and bundle products, and to provide incentives to complementors to innovate in order to remain competitive. Gawer and Cusumano (2008) call this a “tipping strategy” for platform owners. The key issue for the incumbent app platforms is to push for further consolidation. Possible challengers have to find their niche to be successful. And developers should not spread their resources too much and carefully scan the market for disruptions and trends toward consolidation.

3.5 Conclusion

In this paper, we have analyzed the key issues and strategies of the app platform industry from a two-sided market perspective. We combined the strategic management literature on platforms with the economic literature on two-sided markets to establish a solid background for our analysis of the app platform industry. We have analyzed the current industry situation and trends, platform business models, and key stakeholders. Building on existing literature and the industry analysis, we have discussed key strategic issues in the app platform industry. Along the lifecycle of a platform (launch, design, and competition), we have developed several management recommendations and perspectives for this industry.

We have seen that two-sided market business models require consideration of strategic issues which are not present in traditional models. These issues may pertain to all development phases, including platform design, launch, and competition. Pricing represents the key strategic challenge for platform design. Two-sided market theory suggests that in equilibrium, fees should be proportional to the price elasticities (contrary to the usual economic intuition). Furthermore, it provides recommendations on types of fees to charge (usage, membership, one-time or periodical fees). Subsequently, we have discussed the impact of quality on platform design. Quality is – in addition to price – the key parameter that determines platform design. In two-sided markets, the side that requires higher quality gets subsidized. During platform launch, the “chicken & egg” problem arises. Two-sided market theory helps us understand and reduce or avoid this problem by determining an optimal membership component. Platform competition pertains to the possible market structure – the “winner takes all” dynamic and the number of competing platforms that can share the market. Four factors specific to two-sided markets influence the market structure: Multi-homing, size of indirect network effects, same-side effects, and differentiation opportunities. Our analysis points
out that the app platform industry shows a high tendency toward convergence, but leaves room for niche building and differentiation. The key implication for the incumbent app platforms is to push for further consolidation while possible challengers have to find their niche to be successful. For developers, it is crucial to scan the market for disruptions and trends toward consolidation in order to efficiently allocate their resources.

For the future research agenda, we suggest further investigation of three aspects from a theoretical as well as from an applied perspective. The first pertains to pricing strategy reassessment in different development phases, which seems to be recommendable from a theoretical point of view, but is not observed in reality. However, as important as the pricing aspect appears to be in these markets, other factors like creating a trustworthy relationship with complementors, encouraging internal and external innovation, and reacting strategically to competitors’ actions (Cusumano and Gawer, 2002) must not be discarded.

The second aspect concerns the empirical evaluation of compliance with the fee allocation rule. This requires empirical estimation of the price elasticities of the two market sides of different app platforms. If the allocation rule does not hold, it might open opportunities to improve pricing and extract additional revenues. Generally, more empirical studies on strategic behavior in the app platform industry are desirable.

A third factor that appears interesting is the level of openness (Eisenmann, 2007). Collaboration of firms to provide users with different but compatible versions of app platform seems like a promising strategy for followers to capture a large enough market share to be competitive alongside the big players. Moreover, we did not go into much detail regarding the strategic perspective of developers. Collaboration of developers and the openness of platforms naturally has a considerable effect on this side of the market, which deserves further analysis.

On the whole, two-sided market theory proves helpful in addressing strategic issues of real-world app platforms. It provides tools to analyze app platform business models and their strategic issues during all development phases.
Bibliography


[66] Surur (2013) Microsoft touts 190,000 apps, 10 million Windows Phone Store transactions per day, WMPowerUser. Available at http://wmpoweruser.com/microsoft-touts-10-million-windows-phone-store-transactions-per-day/.


Appendix A

List of variables

Parameters from the canonical model by Rochet and Tirole (2003)

- $a^B$, $a^S$ – usage fee per interaction
- $p^B = a^B$, $p^S = a^S$ – average transaction fee
- $b^B$, $b^S$ – benefit from an interaction
- $\eta = \eta^B + \eta^S$ – price elasticity of demand
- $N^B = D^B(p^B) = Pr(b^B \geq p^B)$ – number of buyers/users
- $N^S = D^S(p^S) = Pr(b^S \geq p^S)$ – number of sellers/developers
- $c$ – cost per interaction for the platform owner

Extensions and adjustments for the integrated two-sided market model

- $x(b^B, b^S, a^B, a^S, \gamma) \in [0, 1]$ with $X \equiv E[x(b^i, a^i, \gamma)]$ – probability of interaction
- $f$ – adjustment function, invertible, with an inverse $f^{-1}$
- $XN^B f(N^S)$ – adjusted number of interaction
- Segmentation of participants with $A^S_k$, $B^S_k$, $C^S_k$ and $N^S_k$
- $A^B$, $A^S$ – membership fees
- $B^B$, $B^S$ – membership benefit
- \( C^B, C^S \) – membership costs for the platform owner

- \( r \) – average app price

- \( \gamma \) – revenue share of developers, \( 1 - \gamma \) – platform commission

- \( \gamma r \) – payments between customer groups

- \( q \) – app quality with a distribution \( Q \). \( \overline{b^B} = \alpha \overline{q} \) with \( \alpha = \text{const}, \alpha > 0 \) and \( \overline{q} = E(Q) = \sum_{i \in I} q_i w_i \). We assume that \( Q \) follows Bernoulli distribution with average quality \( \overline{q}(\beta_H, \beta_L) = \frac{\nu \beta_H q_H + (1 - \nu) \beta_L q_L}{\nu \beta_H + (1 - \nu) \beta_L} \)

- \( \kappa \) – quality review setup cost

**Additional parameters for the dynamic view**

- \( \sigma \) – discounting factor

- \( t \) – time

- \( T \) – end point

- \( K^i, i \in B, S \) – carrying capacity, that is, maximal number of market participants

- \( \lambda^B, \lambda^S \) – proportionality factors

- \( \Delta N^B, \Delta N^S \) – change of populations per period

- \( \phi^i \in [0; 1], i \in B, S \) – share of market participants, who join the platform after the disruption. \( 1 - \phi^i \) is then share of market participants, who chose to join competitive platform