TUCS

Sami Hyrynsalmi

Letters from the War of Ecosystems

An Analysis of Independent Software Vendors in Mobile Application Marketplaces

TURKU CENTRE *for* COMPUTER SCIENCE

LETTERS FROM THE WAR OF ECOSYSTEMS

by

SAMI HYRYNSALMI

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An Analysis of Independent Software Vendors in Mobile Application Marketplaces

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ACADEMIC DISSERTATION

To be presented, with the permission of the Faculty of Mathematics and Natural Sciences of the University of Turku, for public criticism in Auditorium Beta on December 19th, 2014, at 12 noon.

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To my parents
Tarja & Matti Hyrynsalmi

Typography exists to honour content.

*It is a craft by which meaning of a text
(or its absence of meaning) can be clarified,
honoured and shared, or knowingly disguised.*

— Robert Bringhurst,
in The Elements of Typographic Style, 2004.

It's a dangerous business, Frodo, going out your door.
You step onto the road, and if you don't keep
your feet, there's no knowing where
you might be swept off to.

— J.R.R. Tolkien, *The Lord of the Rings*

PREFACE

This work was initially driven by a simple question: *How can a small independent software vendor from Southern Finland compete and survive in a new highly competitive, global mobile application market?* The answer is not a simple one and, fortunately to the local economy, the software producing companies figured out the answer long before this book went to print.

This dissertation studies the App economy through a lens of Software Ecosystems. The thesis is motivated by the challenges faced by software developers in the application market. Thus, three themes were selected to this work—monetization and value creation, multi-homing of application developers and the effect of electronic Word-of-Mouth on the sales. When I (re)started the post-graduate process, there was little academic or commercial research available on the App economy; however, this has since drastically changed and there are now plethora of research reports, analyses and forecast produced on the topic. Therefore, also the focus of this work shifted from practicality-driven toward more theoretically-oriented research.

Although the purpose of this thesis is not to present a universal formula of success, I hope the results of this work might help application developers, both locally and globally, in their work. The style of the thesis is, naturally, academic; however, some practical implications of this research are also discussed.

The revolution caused by this new phenomenon was bloody and rapid, at least to the old kings of the castle. However, the App Economy seems to constantly reshape itself. Recently, it was reported that the growth of application installation numbers has halted. Thus, in the future, the App Economy—or its possible descendants—are likely to change and more research will be needed to understand them.

See Thomas and Bradshaw [2014].

ABSTRACT

The recent emergence of a new generation of mobile application marketplaces has changed the business in the mobile ecosystems. The marketplaces have gathered over a million applications by hundreds of thousands of application developers and publishers. Thus, software ecosystems—consisting of developers, consumers and the orchestrator—have emerged as a part of the mobile ecosystem.

This dissertation addresses the new challenges faced by mobile application developers in the new ecosystems through empirical methods. By using the theories of two-sided markets and business ecosystems as the basis, the thesis assesses monetization and value creation in the market as well as the impact of electronic Word-of-Mouth (eWOM) and developer multihoming—*i.e.* contributing for more than one platform—in the ecosystems. The data for the study was collected with web crawling from the three biggest marketplaces: Apple App Store, Google Play and Windows Phone Store.

The dissertation consists of six individual articles. The results of the studies show a gap in monetization among the studied applications, while a majority of applications are produced by small or micro-enterprises. The study finds only weak support for the impact of eWOM on the sales of an application in the studied ecosystem. Finally, the study reveals a clear difference in the multi-homing rates between the top application developers and the rest. This has, as discussed in the thesis, an impact on the future market analyses—it seems that the smart device market can sustain several parallel application marketplaces.

KEYWORDS: software ecosystem, app economy, two-sided market, eWOM, mobile application ecosystem, software business

ABSTRAKTI

Muutama vuosi sitten julkistetut uuden sukupolven mobiilisovellusten kauppapaikat ovat muuttaneet mobiiliekosysteemien

liiketoimintadynamiikkaa. Nämä uudet markkinapaikat ovat jo onnistuneet houkuttelemaan yli miljoona sovellusta sadoilta tuhansilta ohjelmistokehittäjiltä. Nämä kehittäjät yhdessä markkinapaikan organisoijan sekä loppukäyttäjien kanssa ovat muodostaneet ohjelmistoekosysteemin osaksi laajempaa mobiiliekosysteemiä.

Tässä väitöskirjassa tarkastellaan mobiilisovellusten kehittäjien uudenlaisilla kauppapaikoilla kohtaamia haasteita empiiristen tutkimusmenetelmien kautta. Väitöskirjassa arvioidaan sovellusten monetisaatiota ja arvonluontia sekä verkon asiakasarviointien (engl. *electronic Word-of-Mouth*, eWOM) ja kehittäjien moniliittymisen (engl. *multi-homing*) — kehittäjä on sitoutunut useammalle kuin yhdelle ekosysteemille — vaikutuksia ekosysteemissä. Työn teoreettinen tausta rakentuu kaksipuolisten markkinapaikkojen ja liiketoimintaekosysteemien päälle. Tutkimuksen aineisto on kerätty kolmelta suurimmalta mobiilisovellusmarkkinapaikalta: Apple App Storesta, Google Playstä ja Windows Phone Storesta.

Tämä artikkeliväitöskirja koostuu kuudesta itsenäisestä tutkimuskäsikirjoituksesta. Artikkelien tulokset osoittavat puutteita monetisaatiossa tutkittujen sovellusten joukossa. Merkittävä osa tarkastelluista sovelluksista on pienten yritysten tai yksittäisten kehittäjien julkaisemia. Tutkimuksessa löydettiin vain heikkoa tukea eWOM:in positiiviselle vaikutukselle sovellusten myyntimäärissä. Työssä myös osoitetaan merkittävä ero menestyneimpien sovelluskehittäjien sekä muiden kehittäjien moniliittymiskäyttäytymisen välillä. Tällä havainnolla on merkitystä tuleville markkina-analyyseille ja sen vaikutuksia on käsitelty työssä. Tulokset esimerkiksi viittaavat siihen, että markkinat pystyisivät ylläpitämään useita kilpailevia kauppapaikkoja.

AVAINSANAT: ohjelmistoekosysteemi, applikaatiotalous, kaksipuolinen markkina, verkon asiakasarviointi, mobiilisovellusekosysteemi, ohjelmistoliiketoiminta

PUBLICATIONS

This article-based dissertation consists of the following original publications by the author and his colleagues:

P-I Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas and Knuutila, Timo. The emerging application ecosystems: An introductory analysis of Android ecosystem. *International Journal of E-Business Research*, 10(2):61–81, April–June 2014. ISSN 1548-1131. doi:10.4018/ijebr.2014040104.

P-II Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas; Järvi, Antero and Knuutila, Timo. Revenue models of application developers in Android Market ecosystem. In Cusumano, M.A.; Iyer, B. and Venkatraman, N., editors, *ICSOB 2012*, number 114 in Lecture Notes in Business Information Processing, pages 209–222. Springer, Heidelberg, 2012. ISBN 978-3-642-30746-1. doi:10.1007/978-3-642-30746-1_17.

P-III Hyrynsalmi, Sami; Seppänen, Marko and Suominen, Arho. Sources of value in application ecosystems. *The Journal of Systems and Software*, 96:61–72, October 2014. ISSN 0164-1212. doi:10.1016/j.jss.2014.05.064.

P-IV Hyrynsalmi, Sami; Seppänen, Marko; Aarikka-Stenroos, Leena; Suominen, Arho; Järveläinen, Jonna and Harkke, Ville. Busting myths of eWOM: The relationship between customer ratings and the sales of mobile applications. Accepted for publication in the *Journal of Theoretical and Applied Electronic Commerce Research*, October 2014.

P-V Hyrynsalmi, Sami; Suominen, Arho and Mäntymäki, Matti. The influence of application developer multi-homing and keystone developers on competition between mobile application ecosystems. Submitted to review, September 2014.

P-VI Tuikka, Anne-Marie; Hyrynsalmi, Sami; Kimppa, Kai K. and Suominen, Arho. Challenges in entering application

markets among software producers in developing countries. In Ward Bynum, Terrell; Fleishman, William; Gerdes, Anne; Møldrup Nielsen, Gitte and Rogerson, Simon, editors, *Proceedings of the Thirteenth International Conference: The possibilities of Ethical ICT (ETHICOMP 2013)*, pages 478–487, Kolding, Denmark, June 2013. Print & Sign University of Southern Denmark. ISBN 978-87-92646-72-9.

In addition to the aforementioned, some ideas and figures might have appeared previously in the following publications:

- Suominen, Arho; Hyrynsalmi, Sami and Knuutila, Timo. Young mobile phone users: Radical and individual — not. *Telematics and Informatics*, 31(2):266–281, May 2014. ISSN 0736-5853. doi:10.1016/j.tele.2013.08.003.

- Hyrynsalmi, Sami; Suominen, Arho; Seppänen, Marko and Mäkilä, Tuomas. The relevance of customer reviews in the mobile application marketplaces. In Zawislak, Paulo A. and Hosni, Yasser, editors, *"Science, Technology and Innovation in the Emerging Markets Economy"*, *Proceedings of the 22nd International Conference on Management of Technology*, IAMOT'2013, 12 pages, Porto Alegre, Brazil, April 2013. International Association for Management of Technology. ISBN 0-9815817-6-5. Paper no. 1569675819.

- Hyrynsalmi, Sami; Suominen, Arho and Seppänen, Marko. Differentation within mobile application ecosystems — the unspecialized marketplaces. In Zawislak, Paulo A. and Hosni, Yasser, editors, *"Science, Technology and Innovation in the Emerging Markets Economy"*, *Proceedings of the 22nd International Conference Management of Technology*, IAMOT'2013, 17 pages, Porto Alegre, Brazil, April 2013. International Association for Management of Technology. ISBN 0-9815817-6-5. Paper no. 1569675111.

- Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas and Järvi, Antero. Analyzing developers' challenges in mobile application marketplaces. In Buxmann, Peter; Jansen, Slinger; Kude, Thomas; Popp, Karl-Michael and Przewloka,

Martin, editors, *Proceedings of the European Workshop on Software Ecosystems 2012*, EWSECO'2012, pages 32–37. Synomic Academy, 2012.

- Hyrynsalmi, Sami; Mäkilä, Tuomas; Järvi, Antero; Suominen, Arho; Seppänen, Marko and Knuutila, Timo. App Store, Marketplace, Play! An analysis of multi-homing in mobile software ecosystems. In Jansen, Slinger; Bosch, Jan, and Alves, Carina, editors, *Proceedings of the Fourth International Workshop on Software Ecosystems*, volume 879 of *CEUR Workshop Proceedings*, IWSECO'2012, pages 55–68, MIT Sloan School of Management, Cambridge, MA, USA, June 2012. CEUR-WS.

- Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas and Knuutila, Timo. The emerging mobile ecosystems: An introductory analysis of Android Market. In *Proceedings of the 21st International Conference on Management of Technology*, IAMOT'2012, 16 pages, Hsinchu, Taiwan, March 2012. International Association for Management of Technology.

- Hyrynsalmi, Sami; Suominen, Arho and Knuutila, Timo. A discussion of software product conceptualizations. In Seppänen, Marko; Mäkinen, Saku; Ortt, Roland J. and Hosni, Yasser, editors, *Proceedings of the 5th European Conference on Management of Technology, EuroMOT2011*, pages 226–240. Tampere University of Technology, 2011.

The publications included in this thesis, have been reprinted with the permissions of the respective publishers.

*Every journey into the past
is complicated by delusions,
false memories, false namings
of real events.*

— Adrienne Rich

ACKNOWLEDGMENTS

Every best-selling book I have read, every blockbusting film I have seen, and both good albums I have listened to have been about *journeys* in sought after destinations. Although not as interesting as the aforementioned, the pile of paper you are holding is that kind of a story. This dissertation is a result of a long trip with ups and downs, sweat and tears, villains and fellows as well as defeats and victories—and with surprising turns of events. As in so many other stories, it took time for me to understand it was not about the destination. It was, from the beginning, all about the journey itself.

And every acknowledgments of dissertations.

. . . while being aware that this is the only part of the dissertation that people will actually read.

As this journey draws to a close, hopefully, I wish to thank reviewers Professor SLINGER JANSEN and Professor PASI TYRVÄINEN for preparing me to meet the finale with their detailed comments and suggestions. I am thankful to esteemed Professor TOMMI MIKKONEN for standing as the final opponent for me and my journey. I hope the fight will be fair.

As it so often is with good stories, I luckily had a fellowship of my own for this journey—unfortunately they are not allowed to participate in the finale. I am most grateful for my supervisors, Research Director TIMO KNUUTILA, Professor VILLE LEPPÄNEN, and D.Sc. VILLE HARKKE, not only for sending me on this journey but also for redirecting me from time to time. I acknowledge that I have been rather mercurial and, most likely, a challenging disciple.

During this journey, I have met and worked with wonderful individuals who all deserve to be mentioned and commended here. However, due to the page[1] and the physical limitations of

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1 Please, see my Master's thesis for further information.

this media, I am able to only name a few. Do not feel gutted if not mentioned here; it does not remove my gratefulness.

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2 Oh, and sorry for the thing I called *'humour'*.

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ACRONYMS

API   Application Programming Interface

CS   Computer Science

eWOM   electronic Word-of-Mouth

GQM   Goal-Question-Metric

ICT   Information and Communications Technology

IPR   Intellectual Property Right

IS   Information Systems

ISV   Independent Software Vendor

MDM   Mobile Device Manufacturer

MECO   Mobile ecosystem

MNO   Mobile Network Operator

MPP   Mobile Platform Provider

OS   Operating System

RG   Research Goal

RQ   Research Question

SaaS   Software-as-a-Service

SE   Software Engineering

SECO   Software ecosystem

SLR   Systematic Literature Review

URL   Uniform Resource Locator

WOM   Word-of-Mouth

Part I

We have seen that computer programming is an art,
because it applies accumulated knowledge to the world,
because it requires skill and ingenuity, and especially
because it produces objects of beauty.

— Donald E. Knuth [1974],
Professor Emeritus of
The Art of Computer Programming

INTRODUCTION

> *The battle of devices has now become a war of ecosystems,*
> *where ecosystems include not only the hardware and software*
> *of the device, but developers, applications, e-commerce,*
> *advertising, search, social applications, location-based*
> *services, unified communications and many other things.*
>
> — CEO Stephen Elop, Nokia Corporation, 2011

This chapter briefly presents the aims of this thesis, the research questions and the individual publications included. The chapter also introduces the theoretical background of this thesis as well as the App economy phenomenon.

1.1 PREMISES OF THE STUDY

The launch of App Store for iOS smart devices by Apple in the summer of 2008 revolutionized the mobile ecosystem, and the change is spreading to the software business. Although different application stores existed for several years before the launch, Apple's marketplace seems to be the first that successfully combined all necessary components, from technological and business platforms to a distribution channel and customer engagement. While there are different views on the factors that assisted the growth of Apple's innovation [*cf.* Sharma, 2010; West and Mace, 2010; Basole and Karla, 2011], the launch, nevertheless, accelerated the growth of the mobile applications business dramatically by increasing the number of software vendors interested in the new platform and market. The concept then started to spread to other markets [*e.g.*, Edwards, 2009; Anthes, 2011; Jansen and Bloemendal, 2013].

The fast development of mobile application markets has led to the birth of a new industry, descriptively called the *App economy* by *e.g.* Jeffries [2009]; MacMillan *et al.* [2009]; McKendrick [2013]; Clawson [2014]. Although this term is loosely defined, it

Table 1.1: Characterizing magnitudes of the study subjects with the number of developers and applications available in the studied ecosystems [Hyrynsalmi *et al.*, 2012a].

ECOSYSTEM	DEVELOPERS	APPLICATIONS
Apple App Store	117,817	428,384
Google Play	91,514	363,861
Windows Phone Store	18,426	65,166

App Economy generally refers to all economic activities relating to mobile applications. In this thesis, it is used similarly to refer to economic activities of modern mobile applications.

Currently, there are three major mobile application marketplaces: Google Play[1] for Android devices, Apple's App Store for smart devices with an iOS operating system and Windows Phone Store[2] for Windows Phone devices. Nowadays these *Big Three* together offer over a million applications by hundreds of thousands software vendors to the consumers (Table 1.1). In addition to these, several smaller mobile application marketplaces have emerged and perished.

For a comparison, the budget proposal of Finnish government for 2014 is 53.9 B€, US$ 72.6 B (billion = 10^9). The whole App economy was estimated to reach a total revenue of US$ 25 billion [ABI Research, 2013], US$ 68 billion [VisionMobile and Plum Consulting, 2013] or US$ 75 billion [AppNation, 2013] by the end of 2013. Similarly, foresights for the year 2017 indicates growth of between US$ 92 billion [ABI Research, 2013] and US$ 151 billion [AppNation, 2013]. Despite the significant differences among the estimates, it is noteworthy that just a few years ago the whole App economy was virtually nonexistent. Furthermore, Mandel [2012] estimated that the App economy created over 450,000 jobs in the United States alone during its first four years of existence. He, however, concluded that the App economy is only few years old and a fluid environment; therefore, radical shifts in the future are possible.

In addition to the global scope, more local studies have been presented. Recently, the size of the App economy in Europe was estimated to be between approximately US$ 13.5 billion (10 bil-

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1 Previously Android Market
2 Previously Windows Phone Marketplace

lion €) [VisionMobile and Plum Consulting, 2013] and US$ 23.7 billion (17.6 billion €) [Mulligan and Card, 2014] in revenue during 2013. While product sales and advertisements generated a portion of this revenue, a mere 65% of it was generated by contract labour [Mulligan and Card, 2014]. These developers are hired by companies that are not in the application business but release applications to support their main offerings. Furthermore, the report forecast that application development will provide employment for 4.8 million workers in Europe during 2018. Only 2.1 million of them are estimated to be programmers, while the rest work for support activities from testing to design [Mulligan and Card, 2014].

US$ 1 ≈ 0.742 €

To put the different industries into perspective, a simple example is given. Nokia Corporation's total net revenue was approximately US$ 40.7 billion (30.176 billion €) in 2012 [Nokia Corporation, 2013a], while the net revenue had been constantly declining since 2007 when it peaked at approximately US$ 68.8 billion (51.068 B€) [Nokia Corporation, 2008]. The total net revenues in the fiscal year 2012 of Electronic Arts Inc. and Activision Blizzard Inc., two of the largest gaming companies in the world, were US$ 4.856 billion and US$ 4.143 billion, respectively [Electronic Arts, 2012; Activision Blizzard, 2013]. That is, while the App economy was estimated to be smaller than one of the former mobile device giants and a few of the largest gaming companies together, it is predicted to surpass these combined in a few years.

An often-seen calculation also claims that Finland needs a dozen of the largest game companies to overcome the lack of Nokia.

The rapid change in the application business also challenges the software producers working in the domain. For instance, the monetization of products and services offered through the emerged ecosystems has been seen as a difficult task. As a result of challenging monetization, several applications are relying on different 'Freemium'-based business models [see Anderson, 2009], where a part of a product is offered for free and a premium part of it is subject to charge. However, to the author's knowledge there is a lack of evidence on how to utilize Freemium models effectively. Furthermore, to the author's knowledge, there is only evidence that the superstars of the markets are selling well with in-application sales [*e. g.* Wingfield, 2012]; we are not currently aware if Freemium publishing models and in-

E. g. Gartner [2014] forecasts that only 0.01 % of applications will be financially successful in 2018.

application payments earn enough for a non-superstar application.

While writing an introduction to this thesis, the ripple effect created by the new generation of smart phones and the App economy is rather visible. On one hand, Nokia Corporation announced in September 2013 that it would sell its mobile phone manufacturing division to Microsoft for 5.44 B€. In the future, the former leading mobile phone manufacturer will focus on, in addition to the network infrastructure service and technology licensing, its HERE mapping and location services [Nokia Corporation, 2013b], *i.e.* content production for smart devices. In addition, Facebook Inc. recently acquired mobile application producers WhatsApp for US$ 16 billion [Facebook, 2014] and Instagram for US$ 1 billion [Facebook, 2012] in combination of cash and shares.

While the phenomenon has torn down giants, it has also enabled the birth of a new industry of application analytics.

On the other hand, the success of a few Finnish mobile gaming companies, *e.g.* Rovio Entertainment Ltd and SuperCell Oy, has created hype around the mobile gaming industry in the country. In Finnish newspapers, mobile gaming is every now and then argued to be "a new Nokia"—a high-technology area that will create jobs in and improve the trade balance of the country. Not surprisingly, universities and polytechnic schools have adjusted their curricula to teach new professionals, and several funding organizations have devoted themselves to supporting the growing mobile gaming industry. The hype seems to be, to some extent, unearned, and it has some similar characteristics, in the view of the author, to the dot-com bubble in the end of 1990s.

Producer & developer refers here more to a publishing organization instead of a single programmer.

The aim of the previous discussion is not to argue that mobile content producers are insignificant; on the contrary, in this thesis it is believed that mobile developers are a crucial element in the success of the current Mobile ecosystems (MECOs). However, the aim is to emphasize that a rigorous approach is needed when studying the App economy phenomenon. Instead of being limited to the superstars of the App economy, the focus of this work is broader: developers as well as applications from all levels of the mobile application marketplaces are included in the scope of this thesis.

This manuscript, presented to the Faculty of Mathematics and Natural Sciences of the University of Turku to be accepted as a dissertation by the author, studies this phenomenon under the

research paradigms of Software Engineering (SE). Focus is put on the challenges and opportunities created by the new marketplaces for software-producing companies.

1.2 BACKGROUND

This section will present and define the software business as the context of this study. Subsections 1.2.2 and 1.2.3 will briefly define Mobile ecosystem (MECO) and Software ecosystem (SECO), respectively. These are the two key industry conceptualizations that this study relies on—they help to characterize the market and its actors that are under study. Subsection 1.2.4 briefly reviews related theories and, finally, related works are presented in Subsection 1.2.5.

1.2.1 *The business of software*

Software and the changes it has introduced to society and business have been studied from several viewpoints and by different fields [see Cusumano, 2004; Messerschmitt and Szyperski, 2003]. The intangibility, as well as the almost meaningless copying costs, together with the ubiquitous nature of software, have made it an interesting research target for scholars. There have been requests to note the business side of software also in SE. As discussed by, *e. g.*, Hohmann [2003], software engineers should move their focus beyond the software architecture and address the business issues.

I. e. *the price of producing a new copy of a piece of software is practically insignificant when compared to the price of producing the software.*

A research domain focusing on the commercial activities of the software companies is often categorized under the name *software business* [Tyrväinen and Jansen, 2010]. This domain of research shares common themes and questions with other fields from several disciplines, while there has been discussion and even critique [see *e. g.* Rönkkö *et al.*, 2010] on the question of whether software business constitutes a research discipline of its own. However, the special characteristics of the software industry make it an interesting subject to study. As such, the concept of 'software business' is a useful tool to delimit the scope of research. Therefore, in this thesis, software business is seen as an upper-level domain defining the study.

To specify the field and its boundaries, a definition by Rönkkö and Peltonen [2011, p. 1] is followed:

> *"Software business is business of selling software (including systems software, application software, and games) either as licenses or as services and services related to development and deployment activities of this software. This definition does not include operation of software produced by third parties (e.g. operating a server farm), business and operations consulting related to software systems, and deployment projects of third-party software.*
>
> *Not all revenue of firms operating in the software industry is necessarily software business."*

Therefore, in this thesis *software business* as a research topic is seen as a study of commercial activities, defined broadly, in the terms of the above-mentioned quote by Rönkkö and Peltonen [2011]. It contains elements, *e.g.*, from internationalization and management of software companies to value creation by individual products. In other words, this research belongs to the topic category 'Computing/information as a business' in the computing disciplines' topic taxonomy presented by Glass, Vessey, and Ramesh [2002].

The domain of software business is broad. For example, Buxmann, Diefenbach, and Hess' [2013] recent book on the *software industry*, a synonym for software business, discusses the economic principles of software markets and strategies of Independent Software Vendors (ISVs) as well as, *e.g.*, outsourcing and offshoring. In addition, the book addresses some specific issues of software business: platforms, Software-as-a-Service (SaaS), and open-source software.

An important aspect of software business research is *business models*. While there is no generally accepted definition of a 'business model' [*e.g.*, Camponovo and Pigneur, 2003], at the simplest, it can be defined as a blueprint of how a company is working. Software companies' business models have been studied exhaustively [see *e.g.* Seppänen, 2008; Rajala, 2009; Zott *et al.*, 2011; Luoma, 2013, for literature reviews]. Nevertheless, a business model has certain key elements [Luoma, 2013, 28–29]: 1) Value proposition to the users; 2) Activities performed by the

firm to create value; 3) Internal structure of the firm and its position in the value network; and 4) Revenue logic, *i.e.*, how the firm makes money. The revenue logic, or the revenue model [see *e.g.* Popp and Meyer, 2010], can consist of different 'revenue streams' such as advertising or pay-per-use.

The aim of this thesis is to study companies selling software or services in mobile application marketplaces. The focus is on the issues which challenge the developers and developing companies. As noted by Wegner [1976, p. 323], a researcher of engineering disciplines *"is more concerned with the practical implications of his research than the empirical scientist or the mathematician."* The emphasis on practical implications also characterizes this thesis.

While SE is a systematic approach to produce and operate as well as maintain software, including management of previous activities [Mills, 1980], *Software Engineering Economics* is defined by Boehm [1984] as an economic analysis technique applied to SE and management. Here, software business is seen as a similar extension to SE; furthermore, software business is seen as a cross-disciplinary domain luring researchers from marketing and management to Information Systems (IS) and SE.

1.2.2 *Mobile ecosystems*

Inspired by the widespread use of a *business ecosystem* analogy by Moore [1996], the scientific community has since applied the term and identified a plethora of different ecosystems. Thus, it is no surprise that the complex network of organizations focused on producing, selling or offering services to mobile phones and devices has been described and studied as a MECO.

A business ecosystem is defined by Moore [1996, 26] as *"an economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world"*. A Mobile ecosystem is a specialized type of a business ecosystem. It depicts the economic community that aims to build the modern smart phones and produce content for them. Currently, there are several competing MECOs, and each one of them is structured around a few central companies.

Mobile Ecosystem

Despite the common name, there seem to be different views on the structure of a MECO. For example, Xia *et al.* [2010] use a narrow view of the ecosystem when they study the business
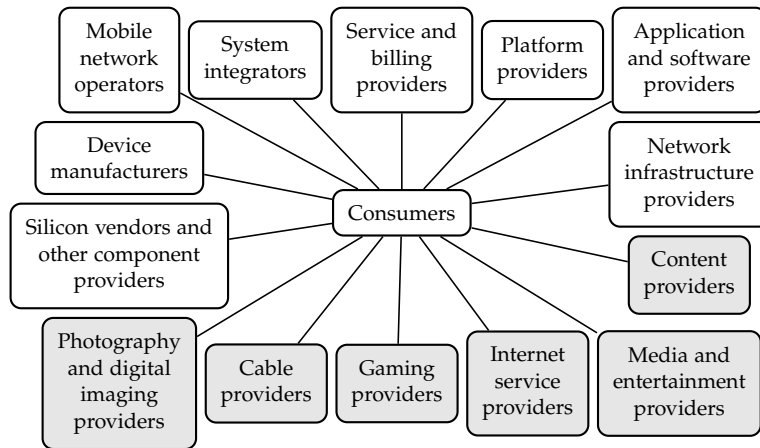
Figure 1.1: The 15 segments of MECOs as defined by Basole [2009, adapted]. The segments with grey background are emerging and those with white background are existing.

models in MECOs. Xia *et al.* [2010] define three stakeholders of a MECO: mobile network operators, handset manufacturers, and mobile operating systems providers. As a result, they argued that the complexities of business models forced the different stakeholders to interact and create a more interconnected ecosystem.

In contrast, Basole's [2009] approach is remarkably broader. He reviewed the work of several authors in defining the actors of MECO, finally classifying 15 segments that form an ecosystem. The classification contains, *e. g.*, Mobile Network Operators (MNOs), Mobile Platform Providers (MPPs), Mobile Device Manufacturers (MDMs), cable providers, and even silicon vendors. The classification is presented in Figure 1.1, where segments marked with a grey background were still emerging ones at the time when the original work was done. The segments with a white background, instead, were already existing at the time of the study. Nowadays, for example, the gaming and content provider segments have considerably grown in the MECOs.

Gueguen and Isckia [2011] argued that the borders between different MECOs are unclear, *i. e.* the actors contribute on several ecosystems. They reviewed the business ecosystem of mobile handsets and pointed out a few distinctive factors. Firstly, the Information and Communications Technology (ICT) sector as a

whole is a highly dynamic interdependent market [Eisenhardt and Brown, 1999]. In this interdependent market, actors are looking for dominance and stability through the adoption of standards. This has resulted in a development where competitors have collaborative arrangements while competing in the same market—called 'co-opetition' [Luo, 2004]. The aim of co-opetition, as said by Brandenburger and Nalebuff [1997, 14], is *"– about finding ways to make the pie bigger rather than fighting with competitors over a fixed pie."*

Secondly, business communities are often structured around a leader. In the case of MECOs, the structure is more complex, with several dominant organizations [Gueguen and Isckia, 2011]. Using the same strategy, these dominant organizations have established marketplaces, which would entice a large number of actors to join the ecosystem. The application marketplace leverages a large developer base that would ultimately establish a dominant position in the market [Evans *et al.*, 2006].

1.2.3 *Software ecosystems*

In addition to the studies from the viewpoint of a MECO, often utilized by the telecommunication policy researchers, mobile application marketplaces can be approached from a different perspective of Software ecosystem (SECO). Although SECOs existed already in the 1990s [Bosch, 2009], to the author's knowledge, the term was first used in the book by Messerschmitt and Szyperski [2003]. The new concept was then defined by several scholars and practitioners, for instance, by Lungu [2009]; Popp and Meyer [2010]; and Hanssen [2012]. One of the most used definitions, according to Manikas and Hansen [2013a], is:

See Section 2.2 for in-depth discussion of SECO

> *" – a software ecosystem is a set of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently underpinned by a common technological platform or market and operate through the exchange of information, resources and artefacts."*
> — Jansen, Finkelstein, and Brinkkemper [2009b, 187–188]

Software Ecosystem

The definition emphasizes interactions and common interests of the ecosystem's actors. In this thesis, the conceptualization of SECO might be more useful than MECO, as it contains only a few different actor groups which are more clearly connected to the application marketplaces. In this thesis, I will use Manikas and Hansen's [2013a] definition of a SECO, which advances the original work by Jansen *et al.* [2009b]. They define SECO as:

> " – *the interaction of a set of actors on top of a common technological platform that results in a number of software solutions or services. Each actor is motivated by a set of interests or business models and connected to the rest of the actors and the ecosystem as a whole with symbiotic relationships, while, the technological platform is structured in a way that allows the involvement and contribution of the different actors.*"
>
> — Manikas and Hansen [2013a, 1297–1298]

Depending on definitions, a SECO partially overlaps with the MECO in the case of the Android ecosystem, the Apple mobile ecosystem and the Windows Phone ecosystem. For example, the silicon vendors are not players in a SECO; although they are a crucial part of a MECO.

In this study, the application platforms are assessed from the SECO point of view, as we focus our discussion specifically on mobile software applications and not on the overall interactions within the mobile device and service domain. However, to acknowledge the background of the research, the name *mobile application ecosystem* has been adopted to depict the specific features of both worlds. In this thesis, a Mobile application ecosystem contains an ecosystem orchestrator, mobile application vendors, *i. e.* ISVs, and consumers. It is defined as follows:

Mobile
Application
Ecosystem

> MOBILE APPLICATION ECOSYSTEM *is a software ecosystem subtype consisting of mobile application vendors, an orchestrator and consumers. The relationship of these actors is underpinned by a common application market where the products and services are sold to the consumers and the technological platform of a mobile device.*

SECOs can be analysed from different perspectives. For example, Campbell and Ahmed [2010] classify three dimensions
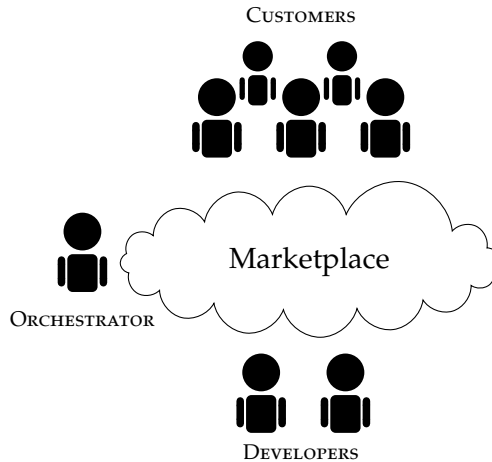
Figure 1.2: A mobile application ecosystem and its actors. The actors here also present different views to the ecosystem.

for views: 1) Architectural dimension; 2) Business dimension; and 3) Social dimension. While the first two are self-explanatory, the last-named focuses on the openness of the SECO, *i. e.* involvement of third parties to participate in the development, and the social aspect that the ecosystems have brought to the software engineering processes. Although this might be a useful approach to classify SECO literature, it presents a unilateral view of the phenomenon. Another way to look at a SECO is to use the viewpoints of its actors: the orchestrator's, developers' and customers' viewpoints. This is illustrated in Figure 1.2.

SECOs have been studied with increasing interest during the last few years as Hanssen and Dybå's [2012] and Barbosa *et al.*'s [2013] Systematic Literature Reviews (SLRs) show. However, a considerable amount of recent studies of SECOs either focus on theorization and modelling of the ecosystem or study the ecosystem from the viewpoint of the ecosystem orchestrator *i. e.* the business and technical platform provider [see *e. g.* Jansen *et al.*, 2009b; Popp and Meyer, 2010; Kabbedijk and Jansen, 2011; Hanssen, 2012]. While there is some work that focuses on the viewpoint of a single developer [*e. g.* Holzer and Ondrus, 2011], the number of articles assuming this viewpoint is clearly smaller. To the author's best knowledge, there are no publications on the customer's view on a general SECO. However, the consumer's

Despite a large platform literature (cf. Salminen [2014]), a platform, in this thesis, refers to the central technological platform of an ecosystem.

viewpoints in a mobile application ecosystem have been studied [see *e. g.* Suominen *et al.*, 2014].

1.2.4   *Theoretical background*

The theoretical background of this thesis is four-fold. First, the software ecosystem conceptualization is used to describe the mobile application marketplaces and their actors. The SECO research is built on top of seminal business ecosystem work by Moore [1993, 1996, 2006]. While the business ecosystem is a conceptualization or a model that can be used to explain industrial organizations, the original work also predicts the life-cycle phases of an ecosystem. According to Moore [1993], a successful business ecosystem will eventually ignite competition for the leadership position of the ecosystem.

Two-sided Market

Second, the application stores in the heart of the ecosystems can be described as platforms with two different sides of users—as shown in Figure 1.2. The theory of a *two-sided market*, by Rochet and Tirole [2003], is defined as an economic platform where beneficial cross-group network effects, discussed in the third point in the next page, exist [Armstrong, 2006]. *I.e.*, a two-sided market can, in its simplest form, be defined as a business platform that attracts two kinds of users: those who produce content and those who use the offered content.

Described in detail through several examples by, *e. g.*, Rochet and Tirole [2006] and Parker and Van Alstyne [2005], markets with network effects are characterized by the presence of two, or more, sides whose ultimate benefit comes from interaction through a common platform. In the case of mobile application ecosystems, consumers and ISVs form the two sides of the market. In this context, the orchestrator is the economic platform provider *i. e.* the keystone organization of the two-sided market.

Or three, when the orchestrator is included

Due to the different needs of these two sides of the platform, the pricing by the orchestrator in a two-sided market is argued to be challenging and requiring a distinct business model [Parker and Van Alstyne, 2005].

In multiple parallel two-sided markets, both sides can often decide to which and how many markets they commit themselves. *Multi-homing* is a publishing strategy where an actor of two-sided markets has joined in more than one market. For ex-

ample, in the case of the App economy, an application developer is multi-homing when she offers the same application for different kinds of mobile application ecosystems. Respectively, a consumer is multi-homing when she uses smart devices and products from more than one ecosystem. The opposite, joining only in one ecosystem, is called *single-homing*. Recently, Sun and Tse [2009] presented that there are differences in the dynamics of the two-sided markets based on the single- and multi-homing behaviours of two-sided market actors. According to their theory, a single-homing market would support only one marketplace, in the long term, while a multi-homing market can sustain several parallel markets.

Third, the *network effect theory*, by Katz and Shapiro [1985] *i. a.*, is an integral part of the two-sided market concept. The network effect theory describes how the value of a product or a service grows by the number of users it has. In other words, a telephone or a social media service such as Facebook is more useful for a consumer when there are more users that she can contact. Due to the network effect, growing numbers of users might also attract more consumers to buy the product. Therefore, luring a large number of consumers to use the product might be the key to success. An orchestrator of a mobile application ecosystem is enticing both the content vendors and users to commit to the MECO for achieving a *positive feedback loop*, or a *virtuous cycle* [see *e. g.* Holzer and Ondrus, 2011]. In this loop, it is claimed that more developers and more content entice more consumers to the ecosystem. Similarly, the growing number of potential customers for their products, in turn, attracts more developers to join in the ecosystem. Due to this cycle, the orchestrators have been fighting over the largest number of ISVs and applications available at the marketplace.

Fourth, this dissertation relies on the different models of *electronic Word-of-Mouth* (eWOM) [*e. g.* Dellarocas, 2003; Dellarocas *et al.*, 2007; De Maeyer, 2012]. To differentiate from a myriad of applications offered in the application marketplaces nowadays, a developer can rely on the positive feedback and reviews received from the actual users of the application. In other words, for example, *valence*, a numeric value such as an average of star ratings left by reviewers, has been often argued to be positively linked to increases in sales (see Table 2.7 on page 75). All major

application stores have implemented an eWOM platform where a consumer can rate and write feedback on products that she has used. A relationship between positive consumer ratings and the sales of applications is an interesting topic that has been frequently addressed in the eWOM studies. In other words, it is often studied whether positive feedback and ratings help a product to sell more.

1.2.5 *Previous work on the domain*

Previous work on the domain of the mobile application ecosystem has been diverse. For example, Laugesen and Yuan [2010] and West and Mace [2010] have discussed the reasons for the success of Apple's iPhone and its marketplace, while Feijóo *et al.* [2009a] have classified the content of the ecosystems' applications. In addition, security issues of mobile applications have created an active research stream [see *e. g.* Ongtang, 2010].

Relating to themes addressed in this dissertation, there has been a little prior work. From the specific viewpoint of how the software producers see the ecosystem, some studies have been presented. Holzer and Ondrus [2011] discuss how the ecosystems are evolving as marketplaces. They note that the marketplaces are moving towards centralized portals. Furthermore, they suggest that their preliminary results should be used as the starting point for future work. To the author's knowledge, only Xia *et al.* [2010] and Bernardos and Casar [2011] have analysed business models in the marketplaces. The first one approached the topic through a larger concept, the MECO, and second one focused only on the narrow subsegment, mobile augmented reality applications.

Lee *et al.* [2010] argue that enticing even more software developers to contribute to the ecosystem is the key to the success of an ecosystem. This is quite a common argument, following the virtuous cycle and the network effect theory, presented with different words and in different contexts [see Evans *et al.*, 2006; Yamakami, 2010; Holzer and Ondrus, 2011; Schultz *et al.*, 2011, *i. a.*].

There is only a limited number of studies addressing the impact of eWOM on the sales of mobile applications. Chen and Liu [2011] showed that top-ranked paid applications do not seem to

correlate well with the customer ratings in the ecosystem. Carare [2012] found that the ranking in the top lists seems to indicate well the future demand, thus implying that the previous popularity is more important than eWOM in the purchase decision. Finally, Yan and Chen [2011] noted that application rating requires laborious handwork and this might impair the impact of eWOM. Furthermore, the results of previous eWOM studies in different domains are inconsistent, as discussed in Subsection 2.3.3.

Multi-homing of software producers has rarely been empirically addressed. Landsman and Stremersch [2011] analysed multi-homing in the video game console industry. They showed that high multi-homing levels of games hurt the sale of the consoles, while the effect vanishes as the console ages. However, the entry barriers to the video game market are considerably higher—*e. g.* an average size of a video game development project, the price of development tools—when compared to those of mobile application markets. In the video game console markets, the multi-homing rates varied from a few percent to almost totally multi-homing markets [Landsman and Stremersch, 2011]. Recently, Burkard *et al.* [2011, 2012] studied multi-homing in software ecosystem markets evolved around SaaS business solutions. They found only 70 multi-homers from the dataset of over two thousand vendors. This indicates, in this respective domain, a rather low multi-homing rate.

In the mobile application domain, Idu *et al.* [2011] investigated multi-homing in Apple's ecosystem with the top 1,800 applications of three sub-ecosystems. They studied whether the developers offer the same product for all, two or only one of sub-ecosystems. They found that developers' multi-homing rate was 17.2% in their dataset. The result is, however, limited by the focus on the ecosystems by a single orchestrator. Boudreau [2007, 2012] studied mobile applications of multiple technical platforms prior to the new generation of smart devices. He noted that less than 1% of producers multi-homed in his datasets. However, since his study the numbers of both producers and products in marketplaces have grown exponentially.

Boudreau's dataset contains applications sold in 1999–2004.

1.3   THE MOTIVATION AND RESEARCH GAP

In the 2012 Hype Cycle report by Gartner [2012], Application Stores were just past the peak of inflated expectations. Gartner forecast that the plateau should be reached in 5–10 years.

As stated previously, the mobile application stores revolutionized the mobile ecosystems. Similar software and application marketplaces are spreading into other domains. For example, Apple's OS X Operating System (OS) has the *Mac App Store* and Windows 8 as well as Windows RT OS contain *Windows Store* for distributing software similarly to the mobile application stores. Steam, a digital distribution and rights management channel for games, by Valve Corporation, shares some characteristics (*e. g.* centralized marketplace, built-in eWOM mechanism) found in mobile application ecosystems. However, the changes caused by the introduction of application stores had scarcely been studied—at the point when this research project was started.

This study is motivated by the challenges introduced by the new application store innovation and the growing number of SECOs. More research focusing on the application developer's perspective and the developer's role in an ecosystem is especially needed. For example, Basole and Karla [2011, 320] noted that *"[a]nother opportunity for future research includes an examination of the role of mobile application developers in the mobile ecosystem"*. In addition to the MECO field, SECO researchers also have asked for studies addressing ISVs who have joined an ecosystem. Jansen *et al.* [2009a, 47], for instance, calls *". . . for more detailed case studies of SECOs and their specific characteristics, to further illustrate the effects of SECOs on independent software vendors."*

This thesis relies on a literature gap-spotting [see *e. g.* Sandberg and Alvesson, 2011]. That is, the dissertation aims to help in fulfilling the aforementioned calls for further research on the ISVs' roles in, and impacts on, a software ecosystem. The mobile application marketplaces have been selected due to their newness and the rapidly growing number of software developers actively publishing for the ecosystems.

The dissertation is also driven by the challenges faced by software developers in the markets. Although the aim is not to solve all problems or present a formula of success, it is hoped that the results of this work can help the application developers in their work. Therefore, in the following, the aim is to select research objectives that are practical and might help ISVs in making strategic decisions.

1.4 RESEARCH OBJECTIVE AND QUESTIONS

The basis of this dissertation is the argument that the emergence of application markets of a new kind is revolutionizing the software industry 'step by step.' Software-producing organizations have faced new opportunities as well as challenges in the marketplace. Some of the companies have created a sustainable business solely around the new markets, while others have been able to offer complementary value through the mobile application ecosystems. Some of the companies in the markets have utterly failed. Unsurprisingly, a growing number of published studies (see Section 2.3.4 for a review of existing studies) approach the new marketplaces via research. This thesis is a part of the growing literature that seeks to identify and explain the changes caused by the mobile application ecosystems. The focus of this thesis is on the issues which challenge the developers and developing companies.

Thus, the objective of this dissertation can be defined as follows:

> The objective is to examine and produce new insight to the App economy revolution that could help participating ISVs to better understand the market.

RESEARCH OBJECTIVE

The author sets three Research Goals (RGs) that will, by increasing our understanding, help the scientific community to reach this common research target. The first research goal to be addressed in this study, in order to understand the marketplace better, is this:

> Finding out who the software producers are and how they are creating value and monetizing it in the mobile application ecosystems.

RG1

Two of the distinctive characteristics of the mobile application ecosystems are the low entry barrier together with a large number of buyers. These factors have led to ever-growing numbers of applications offered to the customers by the large number of software developers. It has been argued that developers have an increasing need for effective eWOM to separate themselves from the masses. Thus, the second goal of this study is:

RG2   Explaining how consumer-generated ratings, such as
         eWOM mechanisms, affect sales (measured by the num-
         ber of installations) in a mobile application ecosys-
         tem.

In addition to luring new developers to join in a mobile ap-
plication marketplace, virtually nonexistent barrier-to-entry has
increased horizontal integration, *i. e.* the acquisition or found-
ing of new business activities in the same level of the value
chain, of application developers. That is, the same products
are offered by the same developers in several mobile application
ecosystems. In the context of multiple two-sided markets, this is
called 'multi-homing'. This phenomenon is of interest due to its
consequences: *e. g.* Sun and Tse [2009] theorized differences in
dynamics for single- and multi-homing markets. Therefore, to
assess this phenomenon, the third research goal is set as:

RG3   Clarifying how multi-homing affects the mobile appli-
         cation ecosystems.

The goals are rather large ones, and they need concretization
to be useful. For this research, the Goal-Question-Metric (GQM)
approach, originally presented for the software measurement de-
velopment model by Basili *et al.* [1994, 2009], is adapted. A set
of Research Questions (RQs) are set to characterize the research
goal and to help the assessment of it. To answer each question,
sub-questions—*i. e.* metrics on the GQM—are defined and used
in individual publications.

The first goal helps us to understand the software producers
more. Therefore, first we need to understand what kinds of
developers are entwined in mobile application ecosystems and
how their businesses are working. Second, to characterize their
business more, the value creation and monetization of mobile
applications need to be clarified. Thus, RG1 is characterized by
the following research questions:

RQ1.1   What are the different kinds of ISVs that produce mobile
        applications, and what countries do they come from?

RQ1.2   How do application vendors create value and monetize
        their products?

The second research goal assesses how a developer can differentiate her offering from the masses available in the marketplace. In the mobile application ecosystems, there are a few built-in features for this: the marketplace offers different most popular application lists for customers, most of the marketplaces promote editorial picks or staff choices, and the users of mobile application are able to write verbal reviews and leave numerical ratings of applications that they have installed. The reviews created by the customers, a part of eWOM, have often been argued to be important for the sales of different products [see *e. g.* De Maeyer, 2012, for a recent literature review]. In the over-populated markets, it might be a crucial way to promote a product—and there are even services where a developer can buy reviews [see Foresman, 2010; Chen, 2012]. Therefore, in this study, the second research goal is characterized by the following questions:

RQ2.1 What kind of effect does a high valence or volume of consumer ratings have on the future sales of a mobile application?

RQ2.2 Can a high valence together with a high variance indicate sales improvement of a niche application?

For the third research goal, the author focuses on the other consequences of the low entry barrier: the software developers are, in growing numbers, participating in at least two mobile platforms. Although multi-homing is visible also in other industries and domains of software business, the scale of the phenomenon in mobile application ecosystems is remarkable. In order to discuss its effects, the rate of multi-homing at the seller level and at the platform level also need to be examined. Therefore, the third research goal is characterized by these two research questions:

RQ3.1 What are the multi-homing rates at the seller level and at the platform level at this domain?

RQ3.2 How does multi-homing affect the dynamics of a mobile application ecosystem?

To answer these questions we have conducted research, the results of which have been presented in several independent scientific publications. These articles address individually subquestions of the presented research questions and, thus, will help to

We, as the disputant and his colleagues.

reach the research goals of this dissertation. The publications are discussed in Section 1.7.

1.5   METHODS AND THEORETICAL FRAMEWORKS

Computing disciplines—broadly defined as the study of computers and surrounding phenomena [Newell *et al.*, 1967] and consisting of, *e. g.*, Computer Science (CS), Software Engineering and Information Systems [Glass *et al.*, 2004]—have studied their subjects through various research methods and paradigms. Decades ago, Wegner [1976] identified dominant paradigms used in CS research during three decades: empirical in the 1950s, mathematical in the 1960s and the engineering research paradigm in the 1970s. Nowadays, according to Eden [2007], the engineering (or technocratic) paradigm and its tenets dominate. However, a multitude of research approaches and methods utilized in the computing disciplines are still visible [see *e. g.* Vessey *et al.*, 2002; Glass *et al.*, 2004; Ramesh *et al.*, 2004].

Of all research disciplines of computing, SE has been most often criticized. For example, SE has been attacked for a lack of rigorous research [see Shaw, 1990; Potts, 1993; Fenton *et al.*, 1994; Glass, 1994; Tichy *et al.*, 1995; Zelkowitz and Wallace, 1997; Shaw, 2001; Glass, 2002; Bossavit, 2013]. Furthermore, there have been even discussion of whether computing disciplines, and specifically SE, are science at all [*e. g.* Gregg *et al.*, 2001; Tedre, 2011]. Therefore, in the following, the scientific background of this work will be briefly clarified.

As emphasized by Basili [1993], software is an artefact that does not exist in nature; it needs to be studied where it exists: in the industrial settings. As this thesis' study subject is fairly new and extant knowledge was sparse at the time when this study started, a large amount of data was collected to study the subject with 'exploratory surveys' [see Cheon *et al.*, 1993]. As the knowledge on the domain increased, the methods used moved towards qualitative. According to Bridgman and Holton [2000], this kind of an empirical method is *"necessary in entering hitherto completely unexplored fields, and becomes less purely empirical as the acquired mastery of the field increases"*.

However, the empirical method itself remains too narrow to guide this dissertation work. Therefore, I have used the re-

A notable example of SE's problems is the so-called Chaos Reports, by the Standish Group International, which have been criticized for serious problems in their methods [see e. g. Laurenz Eveleens and Verhoef, 2010]. However, the numbers of IT project failures presented in the reports are still widely used.

search approaches taxonomy by Järvinen [2004a,b].   In terms   *See Chapter 3*
of Järvinen's classification, this work belongs to the class 'Re-
searches stressing what is reality'.   That is, this dissertation ad-
dresses the mobile application ecosystems as a part of reality
because controlling or building an ecosystem for study is practic-
ally infeasible. In the classification framework, this category can
be divided into Conceptual-analytical approaches and Empirical
approaches. In this dissertation, we utilize both sub-approaches.

In addition to defining the theoretical framework, this thesis
is defined in terms of the five-part research classification frame-
work presented by Glass *et al.* [2002]. The aim of this is to locate
this thesis as a part of the growing literature of computing discip-
lines. Glass *et al.*'s classification framework consists of defining
1) the topic of the research, 2) the research approach, 3) the re-
search methods, 4) the reference disciplines used and 5) the level
of analysis of the research.

The computing topic in this study is *'Computing/information as
a business,'* while the utilized research approach is *'Evaluative-*   *Topic class 7.11*
Deductive' [or *'Positivist'* according to Orlikowski and Baroudi,   *in Glass et al.*
1991]. The research is mainly conducted with quantitative meth-   *[2002] taxonomy*
ods (*i.e.* Data analysis). In addition to these, Conceptual analysis
is utilized. The main discipline is SE, while reference disciplines
that support the work are Management and Economics. This
thesis level of analysis is *'External business context'* when using
the terminology of Glass *et al.*'s [2002] framework.

1.6 RESEARCH PROCESS AND PUBLICATIONS

In order to collect data for the study, *web crawling*, also known as
web scraping, is used for gathering data from the marketplaces.
As an algorithmic challenge, web crawling has been studied ex-
tensively [see *e.g.* Thelwall, 2002; Castillo, 2004; Olston and Na-
jork, 2010], and it can be seen as mainly solved as there are ef-
fective tools available. The web crawling can be, at the easiest,
described as being a simple breadth-first search in the online
environment.

In this study, two data-gathering platforms were used. The
first one was implemented in November-December 2011 by the
author with the Java programming language and the standard
library. The crawler was used regularly in the data collection

from the Google Play marketplace. The first platform was used as a proof of concept to show that the research strategy is feasible and it was later updated to cover Windows Phone Store and Apple App Store too. At that stage, it was decided to limit the study to the Big Three mobile application ecosystems.

An updated version of the data-gathering platform was implemented in the summer of 2012 and put into use in the autumn. The development was done by B.Sc. (tech) Miika Oja-Nisula under the guidance of the author and Dr. (tech) Tuomas Mäkilä. The platform was implemented with the Python programming language and Scrapy web crawling framework.

The gathered data was used as a basis for the first exploratory study [Hyrynsalmi *et al.*, 2012d, revised in P-I], which aimed to characterize the study subject. In this article the research lines, addressed later in depth, were set: monetization and value creation, and the effect of eWOM on application sales. The publication shows that, by median, developers' average revenues from direct sales are rather humble, and it did not find in cross-sectional analysis (*i.e.* an analysis of a static situation) a correlation between installations and average ratings. Furthermore, it notes the need to study multi-homing developers more to fully understand value creation in the mobile application ecosystems.

Here, we limited the study to analysis on applications with more than 1,000 installations

The first paper led quickly to the article P-II, where the monetization of the software publishers was studied with a random sample of 100 Google Play software publishers. In the article, it was noted that treating all software developers in the marketplace as one homogeneous group is not a feasible approach; mobile application ecosystems have lured a wide variety of developers with different backgrounds and interests. Therefore, in P-III, we classified developers into categories and selected 27 developers from different groups to study their value creation by hand.

The eWOM research, first addressed in P-I, was further elaborated in Hyrynsalmi *et al.* [2013] and again in P-IV. The article P-IV addresses WOM in a mobile application ecosystem (Google Play) using datasets gathered at three points in time with timespans of approximately 3 and 18 months. The study found a statistically significant, although rather small, positive correlations between ratings and sales between the studied time spans.

Table 1.2: Research questions and related, included publications

	RQS	PUBLICATIONS
RG1	RQ1.1	P-II, P-III, P-VI
	RQ1.2	P-I, P-II, P-III
RG2	RQ2.1	P-I, P-IV
	RQ2.2	P-IV
RG3	RQ3.1	P-V
	RQ3.2	P-III, P-V

Finally, multi-homing research, first requested in P-I, was started in Hyrynsalmi *et al.* [2012a] by analysing the multi-homing levels. The publication P-V discusses the effects of multi-homing and P-III puts special focus on this kind of developers.

During the research process, a question regarding the possibilities of developing-country software vendors in the mobile application marketplaces arose during the writing of P-I. In other words, although the average revenue earned seems to be rather small for western software developers, the amount might be highly lucrative for developing-country software producers. Furthermore, the features of the marketplaces, virtually insignificant entry barrier—*e. g.* Android's development tools are offered for major operating systems for free and publishing in Google Play requires only a one-time fee of US$ 25—together with a large number of potential customers through one centralized distribution channel, should favour this kind of developers. This possibility is addressed in P-VI, which studies the locations of the top developers and discusses the issues preventing these developers from joining a marketplace.

The relations of the research questions and included publications are shown in Table 1.2. Summarizing, this thesis consists of the following articles:

P-I THE EMERGING APPLICATION ECOSYSTEMS: AN INTRODUCTORY ANALYSIS OF ANDROID ECOSYSTEM
by Sami Hyrynsalmi, Arho Suominen, Tuomas Mäkilä and Timo Knuutila [2014c]

This publication lays the basis for the further studies included in this thesis. It presents the data collection method used, *i.e.* web crawling, and contributes to the research questions RQ1.2 and RQ2.1. This is an extension of a conference paper, Hyrynsalmi *et al.* [2012d].

P-II   REVENUE MODELS OF APPLICATION DEVELOPERS IN ANDROID MARKET ECOSYSTEM

by Sami Hyrynsalmi, Arho Suominen, Tuomas Mäkilä, Antero Järvi and Timo Knuutila [2012b]

Revenue models of application vendors are studied in this paper with a random sample of one hundred applications from Google Play. The publication shows that several of the studied applications are lacking a clear revenue model and discusses identified revenue models in relation to the general business strategies. The publication contributes to the research questions RQ1.1 and RQ1.2.

P-III   SOURCES OF VALUE IN APPLICATION ECOSYSTEMS

by Sami Hyrynsalmi, Marko Seppänen and Arho Suominen [2014b]

The value creation mechanisms of 27 different mobile application developers are studied in this article by using Amit and Zott's [2001] renowned framework. A special focus is given to multi-homing developers. The results show an emphasis on the efficiency as a value source, while complementaries as a value source were seldom used. The article contributes to the research questions RQ1.1, RQ1.2 and RQ3.2.

P-IV   BUSTING MYTHS OF EWOM: THE RELATIONSHIP OF CUSTOMER RATINGS AND THE SALES OF MOBILE APPLICATIONS

by Sami Hyrynsalmi, Marko Seppänen, Leena Aarikka-Stenroos, Arho Suominen, Jonna Järveläinen and Ville Harkke [2014a]

The impact of eWOM in Google Play is studied in this article by using three measurement points. We found statistically significant correlation between high average customer ratings and high sales in the different measurement periods. The article thus contributes to the research questions

RQ2.1 and RQ2.2. This is an extension of a conference paper, Hyrynsalmi *et al.* [2013].

P-V THE INFLUENCE OF APPLICATION DEVELOPER MULTI-HOMING AND KEYSTONE DEVELOPERS ON THE COMPETITION BETWEEN MOBILE APPLICATION ECOSYSTEMS
by Sami Hyrynsalmi, Arho Suominen and Matti Mäntymäki [2014d]

This publication studies multi-homing rates (platform- and seller-level) of the Big Three mobile application ecosystems and discusses the effects of multi-homing on the dynamics of the marketplaces. It contributes mainly to the research questions RQ3.1 and RQ3.2. The study extends data analysis presented in a conference paper, Hyrynsalmi *et al.* [2012a].

P-VI CHALLENGES IN ENTERING APPLICATION MARKETS AMONG SOFTWARE PRODUCERS IN DEVELOPING COUNTRIES
by Anne-Marie Tuikka, Sami Hyrynsalmi, Kai K. Kimppa and Arho Suominen [2013]

One consequence of mobile application ecosystems' low entry barriers is studied: through the marketplaces, developing-country software developers can easily reach a huge potential market. This article studies in which countries the top developers are located and discusses the challenges preventing application developing. The results of this paper are combined with those achieved in P-III. The article mainly contributes to the research question RQ1.1 by identifying the locations of the developers.

In addition to these, some of the ideas, arguments and figures appearing in this dissertation might have been presented previously in publications by the author and his colleagues. The list of relevant publications is presented on page xv.

1.7 ORGANIZATION OF THE THESIS

This dissertation consists of three parts. Part I, Synopsis, will briefly define the context of the research, present the results and discuss the implications as well as future work. The first part is divided into four, in addition to this introduction, chapters:

CHAPTER 2 reviews related literature from two perspectives: artificial ecosystems and the broad theme of the App economy;

CHAPTER 3 presents research methods utilized in this thesis with more details;

CHAPTER 4 discusses the original publications included in this thesis as well as the research goals and questions; and, finally,

CHAPTER 5 concludes the dissertation by summarizing the implications of the research for commerce and academia, as well as pointing out a few topics for which further work is needed.

Part II is composed of the independent publications. This part consists of six original articles by the author and his colleagues. These and their relations to the research questions are described in the following. Finally, Part III consists of appendices included in the thesis.

STATE OF THE ART

Indeed, one of my major complaints about the computer field is that whereas Newton could say "If I have seen a little farther than others, it is because I have stood on the shoulders of giants", I am forced to say, "Today we stand on each other's feet".

— Richard W. Hamming, Ph.D., 1968

This chapter reviews the extant knowledge of Business, Mobile and Software ecosystems. In addition, it presents previous research on the broad theme of the App economy.

2.1 ARTIFICIAL ECOSYSTEMS

According to Håkansson *et al.* [2009], metaphors derived from nature have been used for a long time to explain the complex relationships in business. For instance, the old *'Jungle'* metaphor has been used to illustrate how the strongest company conquers the markets and drives the competitors to the verge of extinction, while the *'Rainforest'* metaphor emphasizes interdependence and interactions between the companies [Håkansson *et al.*, 2009]. Although there are several business metaphors inspired by nature, the *'Ecosystem'* seems to be one of the most often used nowadays.

However, every now and then 'ecology' seems to be used as a synonym for the term 'ecosystem.'

In this thesis, I will use the term *'artificial ecosystems'* to refer to various man-made ecosystems. While there are a great number of different ecosystems, here the focus is on the different *'commercial ecosystems'*, where the relationships and evolution occur among commercial actors, instead of *e. g. 'social ecosystems'* or *'human ecosystems'* where relationships can be defined as social connections between individual humans.

In the following, a definition and boundaries of a business ecosystem are addressed. I will also briefly discuss the problems of the use of metaphors. This is followed by a presentation of the evolution of a business ecosystem and a brief discussion of MECOs.

2.1.1 *Business ecosystem metaphor*

Business ecosystems were first addressed in Moore's seminal essay [1993] and later refined in a book [1996]. In his work, Moore found parallels between biological ecosystems and industrial networks where companies are evolving as predators and prey in nature. He noted that nowadays companies are co-evolving around a new innovation; actors of one business ecosystem work cooperatively around the innovation and competitively against another ecosystem.

Thus, Moore [1996, 26] defined business ecosystem as a community supported by interactions of its companies and individuals. As illustrative examples, he used IBM's and Apple's battle in personal computer ecosystems in the 1980s and Wal-Mart's and Kmart's competition in discount retailing ecosystems.

Since Moore's work, scholars as well as practitioners have derived several different kinds of ecosystems. In addition to previously discussed SECOs and MECOs, there has been research on such business ecosystem derivatives as 'innovation ecosystems' [see Adner, 2006; Rohrbeck *et al.*, 2009; Adner and Kapoor, 2011] as well as 'digital ecosystems' [see *i. a.* Briscoe and De Wilde, 2006; Dini *et al.*, 2008; Stanley and Briscoe, 2010]. Recently, Vahtera [2014] combined smart business networks and business ecosystems in his approach and defined 'industry ecosystem'.

However, it should be noted that the definitions or boundaries of the different ecosystems are not clear. Moreover, the same term has had different meanings for practitioners and scholars. For example, the term 'Mobile ecosystem' has been used to describe an integrated system where mobile devices can share content (*e. g.* music, videos) seamlessly while the term 'Software ecosystem' was recently used to illustrate interconnected issues of programming methods, tools and abstractions. The use of the terms for these contexts differs a lot from their traditional meanings in academic literature.

Another example of ambiguousness of the terms can be seen in a quotation by a former CEO of Nokia Corporation, Stephen Elop [Philip, 2012]:

> *"– the definition of an ecosystem is evolving. When we first talked about an ecosystem, we were referring to a*

device, the software around the device, the applications and all the services around it. Now the pattern is changing where the ecosystem is becoming the broader digital experience – your phone, tablet, gaming platform, your TV and even your automobile."

Therefore, as shown through these examples, a rigorous definition of discussed terms is needed before they are used. In Subsection 2.2.1, definitions presented for a SECO are reviewed and discussed.

While metaphors are useful, in order to communicate a new idea or concept as well as inspire new perspectives on a phenomenon, there are certain limitations in the use of them. Although Iansiti and Levien [2004a] noted that the business ecosystem analogy is useful for widening the focus of managers on the modern business networks, the reverse is also true: the overuse of metaphors might attract too much attention to the insignificant issues both in academia and in industry.

"The line, even in science, between serious theory and metaphor, is a thin one—if it can be drawn at all." [Scheffler, 2010, 35]

Beinhocker [2006] notes in his book that the field of economics is often misguided by the use of metaphors. He uses as an example the late-19th-century economists who used physics as a starting point in their studies. According to Beinhocker, this has misguided the development of the field: *"– borrowing of equilibrium from physics was a crucial scientific misstep that has had lasting consequences for the field"* [Beinhocker, 2006, 32]. Furthermore, Beinhocker uses the comparison between the computer industry and biological systems as an example of a problematic analogy. Similarly, Krugman [1997], a Nobel laureate in economic sciences, has criticized early works that combined economics and evolution for a lack of profound understanding of both economics and biological evolution.

Young-Eisendrath [2003] has noted the similar scientific reductionism towards biological metaphors in human sciences. She called this *'biobabble'* and stated that [Young-Eisendrath, 2003, 125]

> *"This* [biobabble] *is the widespread tendency to use terms (e. g. adaptation) that come from various aspects of the biological sciences to attempt to explain human actions and moods without even a reasonable understanding of the*

> *term, the science, the associated theory (or lack of it), and/or the target of explanation."*

Similar use of adaptation of originally biological concepts into the research of networked software organizations has been seen. For example, Yu *et al.* [2007] derived the relationship forms of SECO from natural ecosystems. While the metaphor between the actors of SECO and biological organisms in nature seems to work well in this case, it is an example of unwary and misguided reasoning caused by the selected metaphor.

"Similarity is not sameness." [Beinhocker, 2006, 65]

Finally, as a noteworthy parenthesis to the discussion on metaphors, Stallman [2010, 96] criticizes the use of the term 'ecosystem' to describe either the software or human community. He argues that this word implies a lack of intentions and ethics which are, however, the unique factors specifying mankind. The software, as argued by Stallman [2010], is a result of both: intention and ethics. Based on Stallman's and others' critiques discussed above, the analogy between a biological ecosystem and a networked community around common interests or the central software technology should be further clarified.

2.1.2   *Evolution of business ecosystem*

Moore [1993] identified four evolutionary stages of business ecosystems: *Birth*, *Expansion*, *Leadership* and, finally, *Self-Renewal* or *Death*. He notes that the borders between these stages are blurred. The stages, with the cooperative and competitive challenges identified by Moore [1993], are shown in Table 2.1.

i. *Birth*   In the first stage, companies work with the value proposal. Moore [1993] notes that in the first stage it is often beneficial to cooperate with other companies. Furthermore, attracting an important company is crucial as, according to Moore, it will stop them helping other emerging ecosystems. Moore [1993] argued that when a market is in its first stage, it is often better for established companies to wait and watch how the new market will become organized. After the market has stabilized, the established companies can replicate the successful ideas and offer their value proposals to a wide audience.

ii. *Expansion*   The emerged ecosystems start to grow, which most likely will lead to direct battles overt market share between the ecosystems

Table 2.1: Evolutionary stages and challenges of a business ecosystem according to Moore [1993, adapted, 77]

STAGE	COOPERATIVE CHALLENGES	COMPETITIVE CHALLENGES
BIRTH	Work with customers and suppliers to define the new value proposition around a seed innovation.	Protect ideas from competitors who might be working toward defining similar offers. Tie up critical lead customers, key suppliers, and important channels.
EXPANSION	Bring the new offer to a large market by working with suppliers and partners to scale up supply and to achieve maximum market coverage.	Defeat alternative implementations of similar ideas. Ensure that your approach is the market standard in its class through dominating key market segments.
LEADERSHIP	Provide a compelling vision for the future that encourages suppliers and customers to work together to continue improving the complete offering.	Maintain strong bargaining power in relation to other players in the ecosystem, including key customers and valued suppliers.
SELF-RENEWAL	Work with innovators to bring new ideas to the existing ecosystem.	Maintain high barriers to entry to prevent innovators from building alternative ecosystems. Maintain high customer switching costs in order to buy time to incorporate new ideas into your own products and services.

in the second stage [Moore, 1993]. Moore points out that the war might lead to a triumph of one ecosystem or co-living of a few ecosystems.

iii. Leadership   Moore [1993] argues that the third stage is emphasized by the struggle of leadership in the ecosystem. According to him, there are two conditions that, when satisfied, will open the way for a leadership struggle. First, the ecosystem must be strong and profitable enough to be worth fighting for. Second, the ecosystem's value proposal and its implementation must be stable enough. Moore [1993, 81] notes that *"bargaining power comes from having something the ecosystem needs and being the only practical source"*.

Moore [1993] used IBM's personal computer ecosystem as an example of a leadership struggle. While IBM was able to conquer the most of the PC markets in the 1980s, Microsoft and Intel were able to reach the role of *central ecological contributor*, thus superseding IBM in this position in the 1990s. In other words, as Moore defines it, they were able to reach a position where the other actors in the ecosystem could not live without them.

iv. Self-Renewal or Death   In the fourth stage, the mature ecosystem faces changes in business environment or new innovations. Moore [1993] argues that ecosystems have to continuously renew themselves in order to be able to compete in changed markets. If the ecosystem fails to renew itself, it will die and be replaced by successors. Furthermore, he notes that the ultimate challenge for the dominant companies is how to deal with change.

The business ecosystem metaphor has been used to describe rather different industries, from retail stores to high technology areas, such as ICT and biotechnology, and from fashion and retail to energy and oil production [Moore, 2006]. Similarly, the emerged mobile application marketplaces can be easily evaluated with this business ecosystem conceptualization: In the birth of marketplaces, the ecosystem orchestrators worked together with customers and application suppliers to define the new value proposition. In the expansion phase, the orchestrators together with suppliers and partners (*e. g.* application providers, mobile network operators, phone manufacturers) fight for the maximum market coverage.

Currently, the new innovation, the mobile application marketplace concept, is somewhere between expansion and leader-

ship evolutionary phases in Moore's evolution framework. Although there is ongoing 'ecosystem war' where the orchestrators try to conquer each other's market shares as well as shares previously dominated by the feature phones, the orchestrators must be ready to struggle for the leadership of the ecosystem—otherwise, IBM's destiny in the PC industry at the end of the 20th century might recur.

2.1.3 *Mobile ecosystems*

Considering the domain of this thesis, there are several different artificial ecosystem concepts that have been used—or could be used—to assess the mobile application marketplaces. Further, often the borders and relationships of the ecosystem concepts are not clear. While, *e. g.*, van den Berk *et al.* [2010] define SECO as a direct subtype of business ecosystem, Jansen and Cusumano [2012] see SECOs as a subset of digital ecosystems. Moreover, discussion of digital ecosystems has moved towards the *'Digital business ecosystem'* concept [Corallo *et al.*, 2007], thus confusing even more the ecosystem classifications.

E. g. *Lapointe [2011] discusses the myriad of ecosystems and their meaning for the IT sector.*

However, for the sake of brevity, I will here focus only on two artificial ecosystem concepts: Mobile ecosystem and Software ecosystem. While this work focuses on the last-named, it is important to acknowledge the first-named, as it has affected the creation of the new industry and it still influences the mobile application markets. This subsection will briefly present the former concept while the following section discusses at length the latter.

As discussed by Basole [2009], the mobile industry has been in the midst of continuous change that is driven by new technological innovations, technological convergence of the mobile device and consumers' demand for new services and products. The history of technological development and changes in the industry have been discussed by, *e. g.*, Kumar [2004]; Dunnewijk and Hultén [2007] and West and Mace [2010]. The convergence of mobile technologies, products and services has created a large, complex network of firms producing the present-day smart mobile devices and services for them.

Here, smart devices include smartphones, tablets, phablets, etc.

Thus, it is not surprising that several academics have studied these networks [see Li and Whalley, 2002; Maitland *et al.*, 2002;

Tilson and Lyytinen, 2005, 2006; Coursaris *et al.*, 2008; Funk, 2009, *i. a.*], and they have done so every so often through the ecosystem concept [*e. g.* Basole and Rouse, 2008; Feijóo *et al.*, 2009a,b; Peppard and Rylander, 2006; Yamakami, 2009; Zhang and Liang, 2011; Solberg Søilen *et al.*, 2012; Karhu *et al.*, 2014]. Most of these works focus on analysing the evolving value networks in the mobile industry; however, under the MECO concept there also has been research into such topics as the business models of application developers [Bernardos and Casar, 2011; Xia *et al.*, 2010], mobile gaming [Feijóo *et al.*, 2012], and even industry policies [Amoroso and Ogawa, 2011; Ramos *et al.*, 2012]. While there have been several definitions for SECO and its special characteristics have been investigated [Manikas and Hansen, 2013a,b], MECO is often treated only as a general business ecosystem with a domain-specific name [see *e. g.* Basole *et al.*, 2012; Basole and Putrevu, 2013].

Interfirm relationships of companies involved in a Mobile ecosystem have been analysed by Basole [2009]. The data used in his study represents the situation of 2006–2008 and the mobile industry has since evolved a lot. He noted that there are strong relationships between software platform providers and application vendors; however, the ties between the software actors and the companies providing the hardware technological foundations (*e. g.* mobile network operators, device manufacturers) of MECO are, instead, weak.

E. g. *App Store was opened in July 2008 while virtually all competitors followed shortly after with their replicas.*

This indicates that the application marketplace, and the SECO, that has emerged inside the mobile industry is, to some extent, separate from the larger network. In some recent industry analyses, the App economy has been even ignored [*e. g.* Dedrick *et al.*, 2011; Raivio and Luukkainen, 2011]. However, there are indirect, though crucial, effects between the two ecosystems. For example, a lack of proper content or popular applications might affect sales of mobile devices—and *vice versa*, a lack of competent devices, *i. e.* lack of consumers, might affect sales of applications in a SECO.

…and added a yet another ecosystem concept to the discussion.

Due to interwoven fates of the two ecosystems, we have adapted the term 'mobile application ecosystem' to describe a SECO that has emerged inside a MECO. In this work, the 'mobile application ecosystem' concept is seen as a subtype of the SECO concept. However, as a result of the characteristics of mobile ap-

plication ecosystems, which will affect the generalization of the results, it is reasonable to use a more specific term.

Lately, the effects of application marketplaces, *i. e.* in practice the mobile application ecosystems, on the dynamics of MECOs have been addressed. Basole and Karla [2011] used structural analysis and visualization to show how MECOs have evolved before and after the introduction of application stores. They note that the fundamental reason for the latest rapid transformation of value creation in MECO is the creation of application marketplaces. Their analysis shows how the mobile platform providers have moved towards the centre of the network and, thus, changed the dynamics of the ecosystem. In a newer article, Basole and Karla [2012] studied how value creation in MECOs have been transformed by the growth of the application stores. They state that the success of a mobile application marketplace is inseparably linked to its enabling MECO and they expected the mobile network operators to enter the application stores. Further, they state that mobile games are the key driver for the App economy.

Also Rajala et al. [2007], prior to the App Store phenomenon, argued for the importance of games for mobile industry.

2.2 SOFTWARE ECOSYSTEMS

As discussed in Subsection 1.2.3, the term 'Software ecosystem' was first used by Messerschmitt and Szyperski in 2003 in their book with the same name. However, Bosch [2009] notes that SECOs have been existing longer but they have been addressed by different names. According to the traditional view by Messerschmitt and Szyperski [2003, xi-xii], SECO refers to a complex web of relationships including participants from software and content suppliers to service providers and end-user organizations. However, the focus of their book was on the cross-disciplinary nature of software, and its topics vary from software creation to value chains and Intellectual Property Rights (IPRs). They did not address SECO *per se*.

Another bio-inspired metaphor that could be used to explain the complex relationships is 'colonies' [see Porra, 1999].

Since then, the term has been adopted by the researchers addressing the networks of organizations gathered around a technical, *i. e.* software, platform. After the book by Messerschmitt and Szyperski, first studies addressing the complex relationships of software organizations with the term 'SECO' were published in 2007 by Yu *et al.* [2007] and Scacchi [2007]. However, research

According to Manikas and Hansen [2013a].

interests have grown remarkably since the end of the 2000s, as recently published SLRs on SECO research show [Barbosa and Alves, 2011; Barbosa *et al.*, 2013; Hanssen and Dybå, 2012; Manikas and Hansen, 2013a]. For instance, in their systematic literature review Manikas and Hansen [2013a] identified 90 articles studying SECOs, of which 35% were published in 2011. Furthermore, Jayaraman [2011] identified three research lines in the SECO literature: 1) ecosystems as organizational interactions, 2) ecosystems as a new abstraction layer for a software platform and 3) ecosystems as business and economic systems.

In the following, I will first review the definitions of the SECO concept and actors that are often entwined with SECOs. This is followed by a discussion on the relationship among actors in an ecosystem and the recent studies on the health of the ecosystem.

2.2.1 *Definitions*

For a discussion of software vs. natural ecosystem metaphor, see Dhungana et al. [2010, 2013].

There are lots of definitions of SECO, as often scholars present a definition for the use in a single study. However, a few reoccurring definitions can be found. For example, the definition by Jansen *et al.* [2009b], that was presented in page 11, is one of the most often used. The often-used definitions are collected into Table 2.2.

In addition to the definitions presented in the table, a definition:

> *"Traditionally, a software ecosystem refers to a collection of software products that have some given degree of symbiotic relationships"*

is every so often used and credited to Messerschmitt and Szyperski [2003] by, *e. g.,* Manikas and Hansen [2013a]; Santana and Werner [2013] and Yu *et al.* [2008]. This definition emphasizes the technical perspective ("a collection of software products") of the ecosystems similarly to the definitions by Lungu [2009] and Lungu *et al.* [2010] ("a collection of software projects"). In contrast, the definitions of a SECO by Bosch [2009]; Bosch and Bosch-Sijtsema [2010]; Jansen *et al.* [2009b] and Kittlaus and Clough [2009] clearly focus more on the business perspective of the ecosystem.

Table 2.2: Definitions of Software ecosystems

REFERENCE	DEFINITION
Bosch [2009, 112]	"– – consists of the *set of software solutions* that enable, support and automate the *activities and transactions* by the actors in the *associated social or business ecosystem* and the *organizations* that provide these solutions."
Bosch and Bosch-Sijtsema [2010, 68]	"– – consists of *a software platform*, *a set of internal and external developers* and *a community of domain experts* in service to *a community of users* that compose relevant *solution elements to satisfy their needs*."
Jansen *et al.* [2009b, 187–188]	"– – consists of the *set of businesses* functioning as a unit and *interacting with a shared market* for software and services, together with *the relationships among them*. These relationships are frequently underpinned by *a common technological platform or market* and operate through the exchange of information, resources and artefacts."
Kittlaus and Clough [2009, 25]	"Informal network of *(legally independent) units* that have a positive influence on the *economic success* of a software product and *benefit from it*."
Lungu [2009, 27]	"– – is *a collection of software projects which are developed and co-evolve* in the same environment."
Manikas and Hansen [2013a, 1297–1298]	"– – as the interaction of a *set of actors* on top of a *common technological platform* that results in a number of software solutions or services. Each actor is *motivated by a set of interests or business models* and connected to the rest of the actors and the ecosystem as a whole with *symbiotic relationships*, while, the technological platform is structured in a way that *allows the involvement and contribution* of the different actors."

Emphases are added by the author.

Jansen *et al.* [2009b] emphasizes organizations or individuals ("set of businesses") and their relationships in a shared market ("interacting with a shared market"), while technological perspective is only mentioned as a connecting theme ("a common technological platform or market"). Similarly, Bosch [2009] emphasizes organizations ("consists of ... and organizations that provide these solutions"). Furthermore, both Jansen *et al.* [2009b] and Bosch [2009] extend the definition of a SECO from products to software services also.

Bosch and Bosch-Sijtsema [2010] redefine the definition given by Bosch [2009]. This definition states the common base ("a software platform"), and it contains the actors ("a set of internal and external developers", "a community of domain experts" and "a community of users") as well as the aim for a SECO ("satisfy their needs").

Manikas and Hansen [2013a] studied presented definitions of SECO in their SLR. They identified three frequent elements that were, to some extent, present in most of the definitions. These are:

COMMON SOFTWARE for which the actors built their extensions or business;

BUSINESS implying both companies or actors as well as benefits, both financial and non-financial, an actor of the ecosystem would be able to reach;

CONNECTING RELATIONSHIPS between actors of the ecosystem, *i.e.*, the actors are not isolated.

From these elements, Manikas and Hansen [2013a] derived their own definition which is shown in Table 2.2. However, here the focus is on these elements instead of a verbal description—I argue that a list of characteristics is more useful in the discussion of a phenomenon than an unstructured text.

The first item from the three reoccurring elements naturally emphasizes the software industry's special characteristic for ecosystems. From Moore's [1996] business ecosystem point-of-view, the last two points are clear: An ecosystem consists of organizations with their interests towards the ecosystem as well as the relationships between these organizations.

When mobile application marketplaces are studied with elements presented by Manikas and Hansen [2013a], the first item can be found in the technical platform used for building applications. While some application developers in the mobile application marketplaces are driven by profits, there are also developers pursuing non-financial benefits such as fame, CV merits or spreading their ideological message. The connecting relationships in the marketplace vary widely from beneficial to competing and to neutral relationships.

Note e. g. *large number of the Bibles available at the marketplaces.*

While a discussion of definitions and their differences is, to some extent, unproductive, it should be noted that the emerged mobile application marketplaces, with their actors, might not qualify as a SECO when, *e. g.,* the definition by Lungu [2009] is used. Furthermore, Hanssen and Dybå [2012] and Barbosa and Alves [2011] emphasize in their SLRs that the terminology used in SECO research is vague. In this thesis, a definition of a SECO by Manikas and Hansen [2013a] is followed as the focus is on the application developers and their businesses.

. . . or even futile

2.2.2 *Platforms and ecosystems*

A confusing issue in the field of SECO research is the ill-defined relationship between a platform and an ecosystem. They can be seen, and are sometimes used, as synonyms for the same phenomenon. Similarly, they can be treated as two distinct, although highly intertwined, research subjects. Therefore, I will briefly present platform literature and then discuss a platform's relationship to the ecosystem concept. Finally, I will define how platforms and ecosystems are seen in this work.

As well as between these two and a marketplace.

Even prior to the ecosystem hype, *platforms* were an active research area. Due to the popularity, there are several views and definitions for a platform. On one hand, Ulrich and Eppinger [2008, 20] use the term *'platform product'* to refer to a product built upon an existing technological system, *i. e.* a *'technical platform'*, in the context of designing and developing more traditional tangible products. *E. g.,* Gawer and Cusumano have extended product-focused definitions and divided platforms into two main groups. According to Gawer and Cusumano [2013, 2], an *'internal platform'* is *"a set of assets organized in a common structure from which a company can efficiently develop and produce*

For a recent platform literature review, see Salminen [2014].

a stream of derivative products", and, thus, is quite similar to the aforementioned view. In addition to this, an *'external platform'* is defined as [Gawer and Cusumano, 2013, 2]:

> *"– products, services, or technologies that are similar in some ways to the former but provide the foundation upon which outside firms (organized as a 'business ecosystem') can develop their own complementary products, technologies or services."*

On the other hand, Evans [2003a] simply defines platforms to *"coordinate the demand of distinct groups of customers who need each other in some way"*. His definition includes, *e. g.*, heterosexual dating clubs where women and men seek each other [Evans *et al.*, 2006].

A variety of platform types can also be seen from platform taxonomies. For example, in the context of platforms of two-sided markets, Evans and Schmalensee [2007a] identified four platform types: 1) Media (*e. g.* TV, radio), 2) Exchange (*e. g.* eBay, stock exchange), 3) Transaction systems (*e. g.* credit cards) and 4) Software platforms (*e. g.* OS, game console).

As discussed and shown by these examples, the term 'platform' is used rather broadly to illustrate different kinds of industries and, as noted by Gawer and Cusumano [2013], ubiquitously appears in research fields from industrial economics to technology strategy. However, instead of a unified view or theory of platforms, and despite of a plethora of research, scholars have relied only on similar constructions and assumptions [Salminen, 2014].

From a more narrow viewpoint, software platforms in particular have awoken remarkable research interests by scholars from SE to IS and economics as their importance for the whole economics and society have highlighted. For example, Evans [2011, Ch. 14] argues that software platforms, what he calls invisible engines, have actually been the drivers of the economic progress during the last few decades. However, as so many other concepts discussed in this thesis, the term 'software platform' is ambiguous. For example, the definition by Pohl *et al.* [2005], who adapted the definition of *'product platform'* by Meyer and Lehnerd [1997], emphasizes the software architectural viewpoint

Evans et al.'s *[2006] book's modest subtitle "How software platforms drive innovation and transform industries" shows the perceived importance of the topic.*

regarding the software platform. According to them, a *'software platform'* is [Pohl *et al.*, 2005, 15]:

> *"– a set of software subsystems and interfaces that form a common structure from which a set of derivative products can be efficiently developed and produced"*.

However, this approach does not fully capture platforms that focus to add value by extensions, *i. e.* applications; instead, it focuses on reselling the same code base to a wider market through mass customization. In addition, the term has been used more or less as a synonym for an OS [*e. g.* Verkasalo, 2009], a core of product line engineering [*e. g.* Bosch, 2002, *cf.* internal platform], generally any software product that can be extended with applications [*e. g.* Taudes *et al.*, 2000], or even for the whole ecosystem [*e. g.* Bergvall-Kåreborn and Howcroft, 2011] *i. a.*

Finally, to return to the aim of this subsection, *i. e.* to clarify the differences and similarities between the concepts 'ecosystem' and 'platform', it can be stated that this relationship is highly dependent on the definitions of these two terms. From the platform literature, a few 'schools of thought' can be identified. First, a platform is seen and used as a synonym for two-sided markets [see *e. g.* Evans, 2011, vi]. The second view seems to classify a platform as a structure that allows the company to produce internally derivative products (*e. g.* Pohl *et al.* [2005] and the 'internal platform' by Gawer and Cusumano [2013]). The third view sees that a platform allows the platform owner to build an ecosystem around the core technology (Baghbadorani and Harandi [2012]; 'external platform' and 'industry platform' by Cusumano [2010]; Gawer and Cusumano [2013]). The last view is illustrated in Figure 2.1. The figure also depicts network effects seen in the ecosystem.

Network effects are discussed more in Subsection 2.3.2.

In this work, I have adopted the viewpoint of Manikas and Hansen's [2013a] definition for SECO and Cusumano's [2010] view of 'platform ecosystem' which is illustrated in Figure 2.1. In this thesis, it is assumed that a SECO is built upon a software platform so that the platform is the central technological base for the actors of the SECO. While for each SECO there is only one central software platform or a set of interconnected platforms, several ecosystems can be built upon one platform. For example, Amazon Appstore for Android and Google Play are both using

Similarly, Evans et al. [2006] point out that a software platform is the heart of an ecosystem.
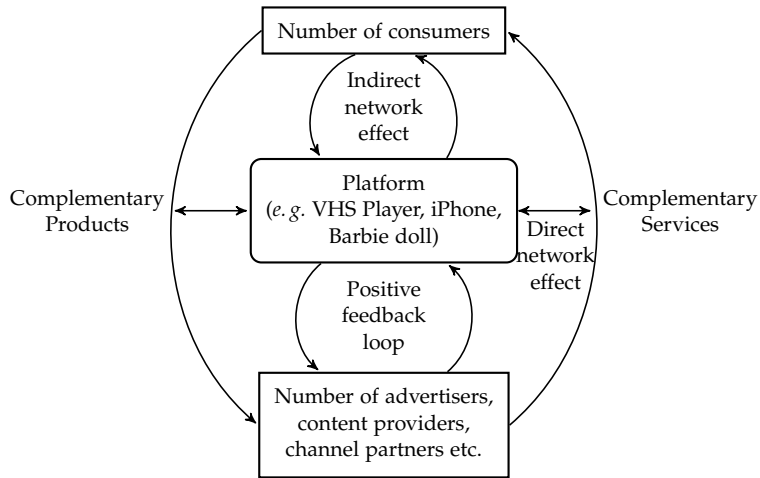
Figure 2.1: Platform ecosystem according to Cusumano [2010, adapted].

the Android platform as their base software platform. However, they could be assessed as two different mobile application ecosystems.

2.2.3 *Actors of SECO*

The definition of SECO by Bosch and Bosch-Sijtsema [2010] identified different actor classes that are involved in an ecosystem: it noted both internal and external developers as well as domain experts and users. Although this definition acts as a starting point, a further clarification is needed as, for example, the role of the domain experts remains unclear. Jansen *et al.* [2009b], on the other hand, identified customers, standards organizations and Independent Software Vendors (ISVs). They noted that ISVs can have different roles and refer to game developers of the App Store as ecosystem followers and Apple as its leader and orchestrator.

In comparison to the previous works, *e. g.*, Hanssen [2010] discussed only three different actor classes in his dissertation. He used 1) a keystone organization (*i. e.* an ecosystem orchestrator), 2) end-users of the ecosystem and 3) third-party organizations who use the software platform to produce solutions and ser-

vices. Similarly, Iyer *et al.* [2006] defined only three roles for orchestrator companies, although these differ a lot from other classifications due to the network approach used. These roles are: 1) the hub, which is the central company (*i. e.* a keystone, an orchestrator or similar) in the network; 2) the broker, which is an actor that creates connection between two firms; and 3) the bridge, which presents *"a link critical to the overall connectedness within the network"* [Iyer *et al.*, 2006]. Handoyo *et al.* [2013a,b] studied literature and identified 5 major and 12 minor actor roles. However, this classification is too fine-grained for the use in this thesis.

In addition to studying the definitions presented for a SECO, Manikas and Hansen [2013a] classified different roles associated with the actors of an ecosystem in their SLR. They identified five roles from the literature:

A. Ecosystem Orchestrator;

B. Niche Player;

C. External Actor;

D. Independent Software Vendor; and

E. Consumer.

According to Manikas and Hansen [2013a], an *external actor* is using or developing on a top of the software platform but is not part of the management of the SECO, and an *Independent Software Vendor* is an actor who is making profits by selling services and products linked to the SECO. A *niche player*, instead, is an actor who is adding value to the ecosystem by producing functionality to the platform or the products.

In the domain of this thesis, these three aforementioned roles are fused to one actor class, *i. e.* the individual organizations producing applications on the platform and selling them in a restricted market. I will discuss and use, in this thesis, the following three different roles for actors intertwined in an ecosystem: Ecosystem orchestrator, Software vendor and Consumer.

They actually used the terms 'customer' and 'end-user' but these names could also refer to ISVs who are developing for the software platform, i. e. they are also users of the platform. Therefore, I have adopted the term 'consumer' to avoid misunderstandings.

ECOSYSTEM ORCHESTRATOR is the actor — *i. e.* a company, organization, set of actors or individual — whose responsibility is to keep the SECO functioning. The orchestrator is

responsible for managing the technical platform as well as rules, regulations and relationships of actors in the SECO. In the case of mobile application ecosystems, the orchestrator is the company offering both the technical as well as the business platform and governing (or dictating) the ecosystem.

Apple Inc., Google Inc., and Microsoft Corporation are acting as the orchestrator in the respective mobile application ecosystems. They are controlling direct application sales, and all three orchestrators currently take 30% of the selling price to cover their expenses [Campbell and Ahmed, 2011]. Furthermore, they control the development of the technological as well as economical platform and are supervising the relationships between the actors. For example, recently Google removed applications from the marketplace after complaints by copyright holders [Zeidler, 2013], applications providing an advertisement blocking feature [Ruddock, 2013] and several low-quality applications [Perez, 2013].

SOFTWARE VENDOR or ISV, in this study, is an actor who develops and publishes an application or applications for an ecosystem. ISV, or 'producer' or 'developer' which are used as synonyms in this thesis, can be a company, organization, set of actors, or individual person.

In this work, we identified a subset of ISVs: a KEYSTONE DEVELOPER is a producer of a successful application (a *superstar* application) or otherwise an important developer for the whole ecosystem. These ISVs and their importance are discussed later in this work (*cf.* P-V). It should be noted that in our use 'keystone' refers an actor that produces important content for the SECOs instead of referring to the actor responsible managing the ecosystem, *i.e.* the ecosystem orchestrator.

Vendors in the mobile application ecosystems are mainly participating in them by producing content for the customers. Although there might be individual developers contributing to the core or results from other projects included into the technical platform, in this analysis these kinds of actors are omitted, as the focus is on the interactions in

the marketplace and not on the interactions in the development community.

As mentioned earlier, vendors have different reasons for joining a SECO. In mobile application ecosystems, some developers are gathering revenue from direct application selling; some developers are offering only a thin mobile client to their services (*e. g.* Facebook and Spotify) and creating monetization outside the marketplace; and some are offering products or services to spread their ideological messages (*e. g.* HappyPlayTime[1]). Furthermore, it is worthwhile to note that orchestrators are often publishing and promoting their own applications in the marketplace. Even more, Microsoft, for example, publishes their applications for all three major mobile application ecosystems.

CONSUMER is an individual person, organization or company using products or services of a SECO, either directly or indirectly via offerings by ISVs and external actors. As noted by Jansen and Cusumano [2012], it is often questioned whether the consumers are part of a SECO, and that the answer depends on the context. In mobile application marketplaces, consumers also participate in the value creation of the ecosystem and therefore they are, in this thesis, included into it. They, *e. g.*, contribute information to the ecosystem with verbal and numerical evaluations of the applications.

The presented classification does not separate the actors by their type. *I. e.*, an individual person, a loose consortium of individuals or a multinational corporation can act in any of the mentioned roles. Furthermore, in this work, no difference is made between an open-source and a closed-source organization. While open-source developers and organizations have important roles in SECOs, *e. g.* in the development of the Linux-based Android OS, their actions do not differ from those of closed-source organizations.

See Jansen et al. [2012, 2013] for a discussion on openness of companies involved in SECOs.

As noted by Hanssen and Dybå [2012] and Barbosa and Alves [2011] in their SLRs, the terminology used in ecosystem research is not established. This is quite clear as the term associated to

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1 http://www.happyplaytime.com/ Accessed on October 16th, 2013.

the role of an ecosystem leader or a hub company varies. For example, several SECO researchers, and we, call this actor an 'orchestrator' while, *e.g.*, Iansiti and Levien [2004a] use the term 'keystone organization' in the context of business ecosystems.

The differences in the word choices are, however, understandable from the perspective of the case under analysis at that moment. For example, Apple is clearly *orchestrating* its application ecosystem by tightly controlling the devices, content, developers and, to some extent, even the customers.

On the contrary, IBM's role during its heyday of the PC ecosystem was, and Microsoft's role in today's PC ecosystem is, much weaker. Instead of playing the role of an ecosystem dictator, they act more as enablers and ecosystem establishers. Thus, the naming of 'keystone organization', 'hub company' or 'ecosystem leader', in this domain, would be more applicable than the name 'ecosystem orchestrator'. Similarly, the governmental leverages available for these central actors differ among different kinds of ecosystems; therefore, a direct comparison of these kinds of companies and respective ecosystems is challenging.

2.2.4 *Relationships forms*

In SECOs there are several different ways how a symbiotic relationship can occur between participants. For example, two actors might be directly benefiting from each other, they might be direct competitors or one might be benefiting from another while the other is unaffected. Yu *et al.* [2007, 2008] used natural systems as the base and derived six forms of symbiotic relationships, which are presented in Table 2.3, between actors of an ecosystem. Although Yu *et al.* [2008] used the framework in product and source code level discussions, they noted that the actors interact also through non-software elements.

While some of the relationship forms, such as Competition and Neutralism, are clearly occurring in marketplaces, some are not easily identifiable, *e.g.* Amensalism. However, it should be noted that classifying a relationship might not be unambiguous.

For example, there are applications that improve a player's situation in a single-player mobile application game, *e.g.*, by opening all levels of the game. One might argue that the relationship between the developer of this scam application and

Table 2.3: Six relationship forms that are possible between two actors in a SECO [Yu *et al.*, 2007, adapted]

RELATIONSHIP	DEFINITION
Neutralism	The relationship does not affect the actors.
Commensalism	The relationship benefits one actor while the other is not affected.
Amensalism	The relationship harms one actor while the other is not affected.
Parasitism	The relationship benefits one actor while the other is harmed.
Competition	The relationship harms both actors.
Mutualism	The relationship benefits both actors.

the developer of an original game takes a form of Parasitism as it harms the original game developer, by modifying the product, and benefits the other. Similarly, someone could argue that the relationship's form is Commensalism as the original game developer is not affected by the hoax: the game has already been sold or installed and advertisements are still shown.

In addition to the ambiguousness, Yu *et al.* [2008] note that there might exist multiple relationships between two actors. As an example, they used the open-source OS Linux and BSD OS: while they compete on the same market for customers (*i. e.* Competition relationship), they might borrow each other's components and source code (*i. e.* either Mutualism or Commensalism depending on the case).

The relationships of large companies, or certain parts of them, might be even more complicated. *E. g.,* Teixeira [2014a,b,c] and Teixeira and Lin [2014] used repository data of WebKit, an open-source rendering engine utilized in both PC and mobile devices, in their longitudinal analysis of developer collaboration. Their study shows *coopetition* between mobile giants, *i. e.* the mobile ecosystem actors Apple and Samsung, still continued cooperation in WebKit development while they were fighting on the courts on IPR issues—or at least software developers of the companies continued to modify the same files despite the patent war.

Coopetition = *simultaneous cooperation and competition among actors [Bengtsson and Kock, 2000].*

In spite of the ambiguousness, the relationship classification framework by Yu *et al.* [2007] shows the complexity of relationships between actors of SECOs. In addition, as shown by the above examples, the relationship between two actors of an ecosystem might be rather multifaceted.

2.2.5   *Views on SECOs*

This subsection presents different classification frameworks and taxonomies for SECOs. To understand how and to what extent the result of SECO research can be generalized, it is important to show the variety of SECOs existing. This can be seen through different classification schemes presented in the following.

While the definition of a SECO varies, there are a few established classifications for the ecosystems. The foremost division can be seen between *open* and *closed ecosystems*. While an open SECO offers free and open access to its source code and knowledge bases, *e. g.* the MySQL/PHP SECO, the closed SECO restricts the access to the ecosystem. For example, Apple controls tightly its iOS SECO and entry of new actors to the marketplace and is therefore an often-used example of a closed ecosystem [Jansen *et al.*, 2009b]. However, the bipartite classification faces problems with, *e. g.*, Google's Android ecosystem.

However, it is often unclear whether 'open ecosystem' refers to an open-source-based ecosystem or, e. g., to an ecosystem that is open for anyone to join.

Google's Android is a somewhat open ecosystem in the sense that everyone can access the source code of the platform as well as publish applications on Google Play marketplace. However, Google has clear control over the other actors in the ecosystem and, as discussed by Spreeuwenberg and Poell [2012], it has adopted some open-source practices while knowingly neglecting others. In the bipartite open vs. closed classification framework, Android is far more open than the iOS SECO while it is clearly more closed than *e. g.* the MySQL/PHP SECO. Thus, as pointed out by Maxwell [2006], the actual question in the openness discussion should be *'How open?'* instead of a binary decision of open or closed.

Cf. Anvaari and Jansen [2013], who studied the openness of mobile platforms from software architectural point of view.

In SECO research, it is not always clear what constitutes an open or closed ecosystem. In comparison, in platform research the definition of open and closed platforms is far more explicit. For example, Eisenmann *et al.* define that a platform is open when [2009, 131]:

1. *"no restrictions are placed on participation in its development, commercialization or use"*; and

2. *"any restrictions—for example, requirements to conform with technical standards or pay licensing fees—are reasonable and non-discriminatory, that is, they are applied uniformly to all potential platform participants"*.

To overcome the black-and-white view of the classification, Eisenmann *et al.* [2009] presented a role-based open vs. closed classification framework for platforms. They identified four roles: *demand-side user* (*i. e.* consumer), *supply-side user* (*i. e.* application developer), *platform provider* (*i. e.* hardware/OS bundle) and *platform sponsor* (*i. e.* IPR holders).

Salminen and Teixeira [2013] used this multidimensional approach to classify the openness of Apple's App Store, Google Play and Windows Phone Store mobile application marketplace platforms. The result of their classification is presented in Table 2.4. According to Salminen and Teixeira [2013], the consumer side is closed for all three as the platforms are mutually exclusive, although Eisenmann *et al.* [2009] used iOS as an example of an open platform from the consumer's side.

However, note that there are several marketplaces for Android apps, e. g. Google Play & Amazon Appstore for Android.

In addition to these ambiguities, this classification framework does not capture the differences between Apple's iOS ecosystem, where applications are screened and selected beforehand, and Google's Android ecosystem, where developers can publish freely but the orchestrator can remove an application after a complaint. Moreover, when the focus is on the SECO, the role of a (hardware/OS) platform provider is not necessarily needed.

Jansen, Brinkkemper, Souer, and Luinenburg [2012] presented The Open Software Enterprise model to study and classify the openness of a software producing company. The model has two main dimensions. The *management dimension* consists of three layers (Strategic, Tactical and Operational) considering management activities. The *practices dimension* includes five openness domains (Governance, Research & development, Software product management, Marketing & sales, and Consulting & support services). While the model focuses on analysing the openness of a software producing enterprise, it also can be used to classify the openness of a SECO and its orchestrator(s).

Table 2.4: A role-based comparison of openness of mobile application marketplace platforms [Salminen and Teixeira, 2013, adapted]

CRITERIA	APPLE APP STORE	GOOGLE PLAY	WINDOWS PHONE STORE
Consumer	Closed	Closed	Closed
Developer	Open	Open	Open
Platform provider	Closed	Open	Open
Platform sponsor	Closed	Open	Closed

Moving towards a more detailed classification of ecosystems, a few alternatives have been presented. For example, Boons and Baas [1997] identified five different types of business ecosystems: product, material, geographical, sectoral and miscellaneous ecosystems. However, in the domain of this thesis, this classification remains far too coarse. For SECOs, Bosch [2009] has presented a software ecosystem taxonomy (Figure 2.2). The taxonomy has two dimensions, where the first describes the abstraction level (*i.e.* OS, application, and end-user programming) of an ecosystem. From these options, the end-user programming abstraction level illustrates ecosystems where domain experts without CS or SE education can still produce content for the ecosystem with domain-specific languages.

The second dimension of the taxonomy captures the type of the platform used (*i.e.* desktop, web or mobile). Bosch [2009] notes that the platform dimension illustrates the evolution of the computing industry; however, it was decided to leave such evolutionary steps as mainframes and newer ubiquitous computing platforms out of the taxonomy as the remarkable majority of present-day development work is done on the mentioned platforms. This, nevertheless, leaves the taxonomy open for future additions in this dimension. Another option to advance this taxonomy is to add an additional dimension, such as the level of openness, to the classification framework.

Bosch's [2009] taxonomy focuses purely on the technical side and does not treat the business side of the SECO. For this kind of analysis, a more fine-grained classification framework was re-

	DESKTOP	WEB	MOBILE
OPERATING SYSTEM	Linux, Windows, OS X	Google AppEngine	Android, Windows Phone, iOS
APPLICATION	MS Office	SalesForce, Amazon	*none so far*⋆
END-USER PROGRAMMING	MS Excel, VHDL	Google's mashup editor†, Microsoft PopFly†	*none so far*

⋆ *E. g.* Facebook's rumoured Project Spartan [Siegler, 2011; Tsotsis, 2011], HTML5-based mobile application platform, could have been a representative of this class.

† Discontinued in 2009

Figure 2.2: Software ecosystem taxonomy according to Bosch [2009, adapted]

cently presented by Jansen and Cusumano [2012, 2013]. Their *Ecosystem Classification Model* has four factors: 1) Base Technology, 2) Coordinators, 3) Extension Markets and 4) Accessibility. The first factor naturally emphasizes the underpinning technology of each ecosystem. Jansen and Cusumano [2012] identified three different types of base technology: a software platform, a software service platform and a software standard. The second factor focuses on the 'owner' of the ecosystem: a SECO is owned either by a community or by a private party.

Jansen and Cusumano [2012] point out that a considerable number of the current SECOs are built around a central marketplace. The type of the extension market works as the fourth factor in their Ecosystem Classification Model. According to Jansen and Cusumano [2012], there are currently five different options: no explicit extension market, only a list of extensions, an explicit extension market, a commercial extension market, and multiple markets. The final factor of the classification model is accessibility to the SECO. They identified three options: open source, screened but free, and paid. In Table 2.5, there are a few

An interesting, though theoretical, discussion of its own would be whether someone can actually own *an ecosystem.*

selected examples in order to illustrate the Ecosystem Classification Model and different factor options.

The two presented classification frameworks differ due to their emphases on business and technical sides of SECO. However, as presented through examples in Figure 2.2 and in Table 2.5, there exist several remarkably different SECOs and they have been assessed by scholars. This naturally sets some limitations on the generalizability of research results from one ecosystem type to others.

2.2.6   *Health of a SECO*

A research line arising in both Business ecosystem and Software ecosystem literature aims to define measures for the healthiness of an ecosystem. Most of these studies are based on the seminal work by Iansiti and Levien [2004a,b]. They stated that, similarly as in a biological ecosystem, the fate of an individual actor in a business ecosystem depends on the whole network instead of the actor's apparent strength. Therefore, assessing the health of the ecosystem is crucial for all actors.

Here, the aim is to show that the ecosystem health concept is ambiguously understood also in ecology.

As a short side-track, it should be noted that there have been long discussions on the use of the 'health' metaphor for the biological ecosystems as well as attempts to define it [see *e. g.* Rapport, 1992, 1998]. Schaeffer *et al.* [1988] have, *e. g.*, noted that human health concepts focus on a single person while ecosystem health treats the whole ecosystem as the unit of analysis. For example, Costanza and Mageau [1999] propose that a biological ecosystem's health should be assessed through its ability to maintain its organization, its function and its ability to face external stresses. These are, to some extent, similar to the measures proposed by Iansiti and Levien [2004a] for a business ecosystem. There are, however, arguments for and against the metaphor [see *e. g.* the debate by Rapport *et al.*, 1998; Wilkins, 1999; Rapport *et al.*, 1999].

However, as Hearnshaw *et al.* [2005] note, despite its popularity, the concept of ecosystem health remains poorly defined and understood. Furthermore, Hearnshaw *et al.* [2005] argue that no single health state is 'better' for a natural ecosystem than some other state. Therefore an ecosystem's health should be evalu-

Table 2.5: SECOs studied in this thesis as well as a few illustrating examples in the Ecosystem Classification Model [Jansen and Cusumano, 2012, adapted].

NAME	BASE TECHNOLOGY	COORDINATORS	EXTENSION MARKET	ACCESSIBILITY
Android	software platform	privately owned	a commercial market	screened*
iOS	software platform	privately owned	a commercial market	paid
Windows Phone†	software platform	privately owned	a commercial market	paid
AutoCAD plug-ins	software platform	privately owned	a list of extensions	paid
Ubuntu	software platform	consortium	multiple extension markets	free
Eclipse	software platform	consortium	an extension market	screened
WordPress	service platform	consortium	an extension market	screened
SalesForce	service platform	privately owned	a commercial market	screened
World of Warcraft	service platform	privately owned	multiple extension markets	free
Open Design Alliance	software standard	consortium	a list of extensions	paid

* Although Google Play screens applications afterwards, a developer is required to register with the service and currently the one-time registration fee is $25. Therefore, the value of this factor should most likely be 'paid' instead of 'screened.' For further details, see Android Developer Help – Developer Registration (https://support.google.com/googleplay/android-developer/answer/113468), accessed on January 13th, 2014.

† Added by the author.

ated according to the society's preferences, *i.e.* they state that the concept can be determined by economic means.

Nonetheless, Iansiti and Levien [2004a] defined three critical measures for the health of business, as well as biological, ecosystems: *Productivity*, *Robustness* and *Niche Creation*. Their work created a base for further work in this topic. For example, Iansiti and Richards [2006]; den Hartigh *et al.* [2006, 2013] and Li *et al.* [2013b] have presented an operationalization for evaluation of health of a business ecosystem. In more detail, the three critical measures are:

PRODUCTIVITY. Iansiti and Levien argue that the most important measure of the biological ecosystem is its productivity, *i.e.* its ability to turn non-biological inputs into living outputs. Productivity's equivalent for the business ecosystem is defined as *"network's ability to consistently transform technology and other raw materials of innovation into lower costs and new products"* [Iansiti and Levien, 2004a, 3]. According to them, return on invested capital is a useful metric for productivity.

ROBUSTNESS. For a biological ecosystem, it is important that it can survive changes in the environment. Iansiti and Levien [2004a] argue that similarly the business ecosystem should be capable of surviving disruptions such as new technological innovations. They propose the survival rate of an ecosystem's members as a robustness measure of the ecosystem.

NICHE CREATION. Iansiti and Levien [2004a] note that it is important for a biological system to support diversity of species. Similarly, a business ecosystem should support different niches in order to be able to absorb external shocks as well as produce new innovations. They note that one way to assess this measure is to study which emerging technologies are applied to support the variety of new products in an ecosystem.

In addition to defining measures for the health of an ecosystem, Iansiti and Levien [2004a] discussed that the orchestrator should aim to improve the overall health of an ecosystem. They state

that effective keystone strategy consists of two parts: *creating value* and *sharing value*. If the value creation fails, the ecosystem will not attract nor retain members. Similarly, the orchestrator is needed to share the value to keep the actors of an ecosystem satisfied.

Iansiti and Levien [2004a] further warn that the orchestrator could take the roles of a *physical dominator* or a *value dominator*. The first one aims to manage a large portion of the network directly and thus suppresses the ecosystem. The second one extracts as much value as it can from the ecosystem and therefore leaves too little to sustain it.

In the more narrow field of SECOs, ecosystem health is seen as an important part of, *e. g.*, SECO strategy [van den Berk *et al.*, 2010] and one of the aims of SECO governance actions [Baars and Jansen, 2012]. For example, Jansen and Cusumano [2012], building on the work by Iansiti and Levien [2004a], presented a governance model for ecosystem health preservation and improvement.

Recently Jansen [2014] presented a measurement model for health of an open-source software ecosystem based on its productivity, robustness and niche creation. The assessment, in his model, is performed in two layers: network and project levels. In addition to these two, Jansen [2014] defines a theoretical level that illustrates the theoretical work done in development of ecosystem health measures. In addition to theoretically driven research, the health of different SECOs has been assessed empirically in literature [see *e. g.* van Angeren *et al.*, 2011, 2013; Goeminne and Mens, 2013; Hoving *et al.*, 2013; Lucassen *et al.*, 2013; van Lingen *et al.*, 2013].

The aforementioned works, however, often focus on analysing the ecosystem's health as a whole and thus represent the orchestrator's viewpoint. While this view is holistic, it does not capture the business ecosystem as a whole. One of the main differences between artificial and biological ecosystems is that a single ant or jaguar does not, most likely, know that it is, and has not have chosen to be, a part of an ecosystem; meanwhile, all ISVs and orchestrators are more or less aware of the ecosystem around them and are capable of doing conscious acts against or for the ecosystem. Therefore, defining the health of an artificial ecosystem differs from defining the health of a biological ecosystem.

Moore [1996] posited that consciousness differentiates business and natural ecosystems.

One issue worth further elaboration is the meaning of the term 'health'. Here I will examine this metaphor from its origin in medicine. For example, Schaeffer *et al.* [1988] noted that medicine has defined a 'standard' human, and a person can be judged to be healthy when his or her, *e. g.*, blood panel results are inside a range of good values. That is, health is thus the absence of diseases. However, as pointed out by Koskinen [2010], most human beings can be classified as either ill or 'not in perfect shape' according to modern medicine. Therefore, defining healthiness as an opposite of illness is a challenging approach.

Koskinen [2010] adopted the work of Fredrik Svenaeus and suggests defining healthiness as one's personal view of *homelike being-in-the-world*. Thus, illness could be defined as a violation of one's feeling of his or her *homelikeness*. As an example, a blind person would be, according to this definition, healthy if he or she is pleased with his or her condition despite the impairment.

This approach might also be useful for the discussion of health of an ecosystem. In addition to looking at the results of quantitative measures that focus on the competitiveness of an ecosystem against others, attention should also be paid to the actors' satisfaction. That is, if actors of a SECO do not feel homelike in the ecosystem, they are more prone to leave the ecosystem—unlike the unconscious actors of a biological ecosystem.

However, often it is not practical nor possible to pursue a situation where all actors in an ecosystem are satisfied. Thus, the distribution of actors' satisfaction is more interesting. Most likely, there is no optimal distribution for all SECOs. Figure 2.3 presents two kinds of extreme satisfaction distributions of a population, *e. g.* satisfaction levels among individual developers of a SECO. For instance, one can argue that the plot on the left represents the current situation in any of the Big Three mobile application ecosystems, as among the hundreds of thousands of developers only a few are monetarily successful [see *e. g.* Hyrynsalmi *et al.*, 2012d; Zhong and Michahelles, 2012a,b]. While this can be argued to be unfair for participants, it presents a classic *Winner-takes-it-all* dynamic often seen in software markets [Buxmann *et al.*, 2013, Ch. 2]. Furthermore, an aim to maximize one's own satisfaction might be a good motivator for new innovations.

In contrast, the plot on the right in Figure 2.3 presents an equilibrium where all participants of an ecosystem are equally satis-
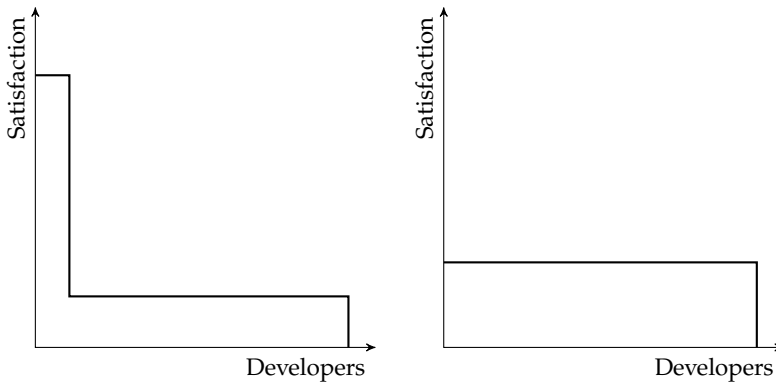
Figure 2.3: Two possible distributions of satisfaction in a population, *e. g.* in a set of developers joined in an ecosystem [Kimppa, 2007, adapted].

fied. This kind of distribution can be, for example, a goal for an open-source SECO while it might not be a desirable outcome for a commercial SECO. Nonetheless, these examples aim to show that evaluating the health of a SECO is not unambiguous and new approaches are needed.

This approach is inspired by a traditional utilitarian discussion of maximizing good [see Feldman, 1978, i. a.].

This kind of a wider definition of ecosystem health is presented in work by, *e. g.*, Ben Hadj Salem Mhamdia [2013] and Manikas and Hansen [2013b]. For instance, a recent work by Ben Hadj Salem Mhamdia [2013] defined a framework for SECO health. She extended Iansiti and Levien's [2004a] measures by adding two dimensions: *stakeholder satisfaction* and *interoperability*. She argued that the stakeholders', *i. e.* customers' and partners', satisfaction or a lack of it can influence the performance of the whole ecosystem. Interoperability, instead, refers to a company's ability to form new relationships in an ecosystem.

Manikas and Hansen [2013b] reviewed the ecosystem health literature from natural, business and Software ecosystem points of view as well as the health of open-source software projects. According to them, there are two SECO specific features that should be taken into account when analysing the health. First, a business ecosystem and a SECO perceive products differently. Second, a SECO has an orchestrator who is running the platform and creating rules which, according to Manikas and Hansen [2013b], are lacking in business ecosystem literature. As a result

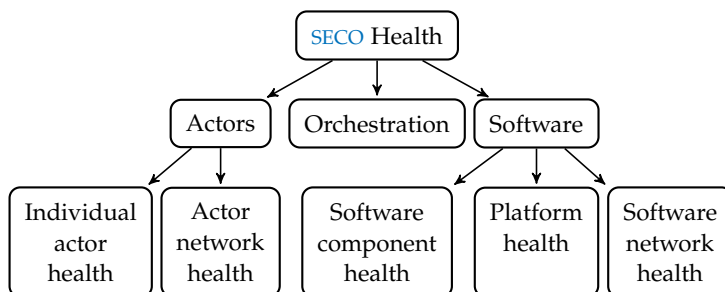*On the other hand, in discount retail ecosystems there are platform owners, i. e. the stores who orchestrate the network.*

Figure 2.4: A breakdown of the SECO health framework [Manikas and Hansen, 2013b, adapted].

of their initial study, they presented a proposal for a SECO health framework, which is illustrated in Figure 2.4, that takes into account these specific features. While the work is in progress at the time of writing of this thesis, it is a promising starting point for new kinds of ecosystem health measures.

Summarizing, although the ecosystem health metaphor is not completely agreed in ecology, the metaphor has been adopted in business ecosystem research. A business ecosystem's, and its derivatives', health is seen to represent its competitiveness abilities against changes and competitors; or, as Manikas and Hansen [2013b, 33] put it, *"an indication how well the ecosystem is functioning"*. A majority of ecosystem health measurement work is based on nature-inspired characteristics by Iansiti and Levien [2004a]. In this thesis, I have argued that the satisfaction of actors involved in an ecosystem should be included in health measures of an ecosystem; as the ecosystems differ, similarly, the satisfaction measure should adapt to the type of an ecosystem. Nevertheless, new promising approaches to assess the health of a SECO have been presented recently, *e. g.* the initial framework by Manikas and Hansen [2013b].

Finally, as pointed out by Jansen [2014], one of the central challenges in the ecosystem health research line is the lack of historical data. First, the picture drawn only with successful projects is most likely biased. Second, an analysis using time lines and historical data would produce more fruitful results for the industry than analysis based on just a point of time. Thus, in addition to developing new metrics for health assessment, fo-

cus should also be moved towards collecting data from different SECOs during their lifetime.

2.3 APP ECONOMY

Shortly after the launch of the App Store by Apple, media named the new phenomenon as the *App economy* [see Jeffries, 2009; MacMillan *et al.*, 2009; Rowan and Cheshire, 2009]. While the term is loosely defined, it is often used to refer generally to all economic activities relating to mobile applications [see Lampathaki, 2013]. Every so often, in public and academic discussion, it includes also, *e. g.*, the mobile devices [see *i. a.* Karla and Bröker, 2011]. In the academic literature, there are a few studies addressing mobile ecosystems with the name App economy [*e. g.* Basole and Karla, 2011, 2012; Karla and Bröker, 2011], studies seeing the concept as a part of a larger social system [Cheng, 2012], and studies seeing it as a synonym for a mobile application market [Amundsen, 2012]. For example, Figure 2.5 depicts value creation in the App economy according to Basole and Karla [2012]. The figure shows that the term can be used to capture several actors and activities intertwined in the mobile business.

Therefore, due to ambiguousness of the term, I will mainly use the term 'mobile application ecosystem', that was defined previously in Subsection 1.2.3. However, I will use the term 'App economy' to refer to (1) all economic activities focusing on the different sides of new smart phones, mobile application marketplaces and ecosystems; and to (2) research activities of (1). That is, as the term 'mobile application ecosystem' limits the study to defined actors and their interactions, the term 'App economy' is here used as an umbrella for all economic activities and studies concerning the new phenomenon. To clarify more, in this thesis, mobile application marketplaces are seen as only a part of the App economy.

Also called touch-screen phones *[see* e. g. *Tracy, 2012].*

Despite the terminological inexactness, the App economy is seen as the major new source of innovation and growth [OECD, 2013]. As often argued, the whole App economy was virtually nonexistent with tens of thousands of applications from a few thousand developers a few years ago [*e. g.* Boudreau, 2007], while nowadays the applications are counted in millions and ISVs in hundreds of thousands.
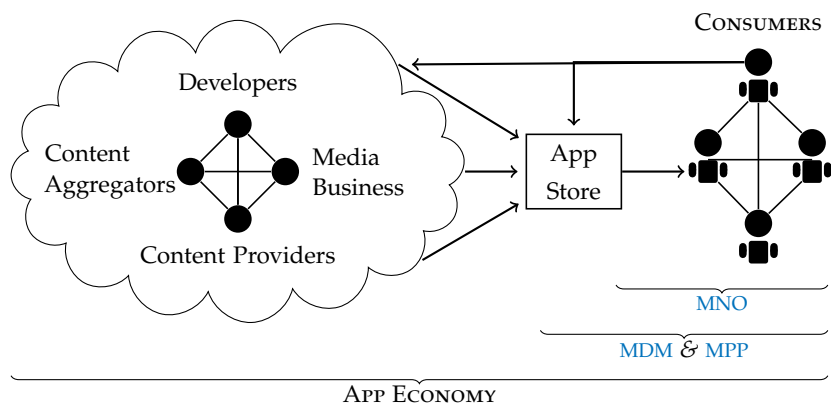
Figure 2.5: Value creation in the App Economy according to Basole and Karla [2012, adapted]. MNO stands for Mobile Network Operator, MDM for Mobile Device Manufacturer and MPP for Mobile Platform Provider.

In the following, I will first briefly explain a few economic theories that are relevant to understand the App economy. To be more exact, I will discuss the Two-sided market theory, by Rochet and Tirole [2003] *i. a.*, and Network effect theory, by Katz and Shapiro [1985] *i. a.* These are certainly not the only economic theories that are relevant for the App economy; *e. g.* Basole and Karla [2012] noted that the Long-tail theory (see *e. g.* Anderson [2008]) is important for the new industry. Furthermore, the Allon *et al.* [2012] study's results of large-scale service marketplaces could also be used to explain application markets. However, the presented theories are central for this thesis. After discussing the economic background, I will briefly review existing research on the App economy.

2.3.1 *Two-sided markets*

Research on two-sided markets started in the beginning of the 21th century when the seminal paper by Rochet and Tirole [2003] was published. The theory has been since advanced by, *e. g.*, Caillaud and Jullien [2003]; Evans [2003b]; Parker and Van Alstyne [2005]; Armstrong [2006]; Hagiu [2006] and Weyl [2010]. Since the introduction, works considering the topic have been published in a broad area from business and economics to law

[Evans, 2011]. Although most of the work in this topic is driven by mathematical analysis, I will present the theory on a more general level.

A two-sided market can, in its simplest form, be defined as a business platform that attracts two kinds of users: those who produce content and those who use the offered content. However, as the original approach could be used to define every market as two-sided, Rochet and Tirole narrowed the definition [2006, 664–665]:

> "– a market is two-sided if the [business] *platform can affect the volume of transactions by charging more to one side of the market and reducing the price paid by the other side by an equal amount; in other words, the price structure matters, and* [business] *platforms must design it so as to bring both sides on board."*

In addition to this, Evans and Schmalensee [2007b] have proposed a definition although, at this time, they were using the term *'economic catalyst'*. A market is two-sided if it has [Evans and Schmalensee, 2007b, 3]:

> "– (a) two or more groups of customers; (b) who need each other in some way; (c) but who cannot capture the value from their mutual attraction on their own; and (d) rely on the catalyst [i. e. a business platform] to facilitate value creating interactions between them."

While the former definition, by Rochet and Tirole [2006], is more exact, it has some limitations as discussed by Evans and Schmalensee [2013]. The latter definition, by Evans and Schmalensee [2007b], is clearer; however, if we follow this classification we could end up in a situation in which all markets are classified as two-sided.

Perhaps due to the original, broad, definition, the terminology of two-sided markets is not stabilized. As it was briefly mentioned already in Subsection 2.2.2, the term 'platform' and its variants are every now and then used as synonyms for two-sided markets. Evans and Schmalensee [2007a], for example, preferred the term 'multi-sided platforms' instead of the original one and Eisenmann *et al.* [2006] used the term 'two-sided networks' as a synonym.

. . . or as Evans [2011, vi] put it, "The mill of articles and dissertations has flourished ever since."

I will use the term 'business platform' instead of a 'platform' to separate this concept from the software platforms. As shown in Table 2.6, no software is needed, while it is a quite common characteristic, in two-sided markets.

A recent survey on two-sided markets literature is presented by Evans and Schmalensee [2013].

Table 2.6: Examples of two-sided markets, both of the sides and platform providers [Eisenmann *et al.*, 2006, adapted].

MARKET	SIDES	PROVIDERS
Operating systems	Consumers & ISVs[★]	Windows, Macintosh
Online recruitment	Job seekers[★] & Employers	Monster, CareerBuilder
Yellow Pages	Consumers[★] & Advertisers	BellSouth, Verizon
Web search	Searchers[★] & Advertisers	Google, Yahoo
Shopping malls	Shoppers[★] & Retailers	Mall of America, *etc.*
Gasoline-powered engines	Car owners & Fueling stations	GM, Toyota, Exxon, Shell

[★] Denotes market's subsidy side

Furthermore, the term 'multi-sided markets' has been used to describe a generalized version of two-sided markets, *i.e.* a market with more than two sides [Rochet and Tirole, 2006]. In this work, I will use the term 'two-sided markets' to refer this theory because, as noted by Evans [2011], the term has already stuck in the literature.

Two-sided markets can be seen everywhere. Worn-out examples of this kind of market included, *e.g.*, video game consoles (players and game makers are the two sides), TV networks (viewers and advertisers), newspapers (advertisers and readers) and payment card systems (merchants and cardholders) [Rochet and Tirole, 2006]. The theory has been even applied in the analyses of the academic journal publication markets [Jeon and Rochet, 2010]. Kouris [2011]; Heitkötter *et al.* [2012] and Unno and Xu [2013] have used the theory in explaining the mobile application marketplaces. In addition to these, Table 2.6 presents more examples of two-sided markets, both the sides involved and the business platform providers.

The key to the success of the business platform is to get users for both sides of the market [Rochet and Tirole, 2003]. Often, as noted by Rochet and Tirole [2003], the platform providers

treat one side of the market as a *"profit center"* while the other is a *"loss leader"*. They used video game consoles as an example: The platform providers might sell the console below actual cost for the consumers and gather the revenue from game royalties and development platforms. Here, the consumers represent the loss leader, or subsidized, side while software developers are the profit-making, or subsidizing, side. However, the roles are market dependent; Rochet and Tirole [2003] argue that in OSs, Microsoft is making money from the consumers' side while it does not make nor lose on the software developer side.

In the case of mobile application marketplaces, ISVs are often the subsidized side.

Pricing is seen as one of the most important strategic choices of the business platform [Rysman, 2009]. *E.g.*, Evans [2003b] stated that an important issue of a platform provider of two-sided markets is to set their pricing structure and level so that it gets both sides on board. Similarly, Eisenmann *et al.* [2006] argue that the crucial question is *"Which side should you subsidize, and for how long?"*

Interestingly two-sided markets seem to be popular research subjects in antitrust economics.

In addition to pricing, Rysman [2009] notes that the openness of the market is an important strategic choice. According to him, there are two factors in openness: number of sides involved in the market, and compatibility towards rival platforms. As an example of the first-named, Rysman [2009] uses Apple's OS, where Apple also produces the computer hardware, and Microsoft's Windows OS, where the platform provider produces only the software platform. In this sense, Microsoft's OS is more open than Apple's because it actually serves three sides. The last-named, compatibility towards rivals, considers the business platform's compatibility and inclusiveness with other platforms.

Eisenmann *et al.* [2006] notes that there is a threat of *'envelopment'* in two-sided markets, especially in the areas where technology is developing rapidly. As the business platforms often have overlapping user bases, a rival business platform provider might envelop a business platform when the rival platform offers its functionality as a part of a bundle of multiple platforms.[2] As an example, mobile phones currently contain functionality of, *e.g.*, radio and music players, which has substituted for separate portable music players.

See Eisenmann et al. [2011] for further discussion about envelopment.

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2 For example, Facebook's rumored Project Spartan, see Siegler [2011], could have theoretically enveloped Apple's App Store.
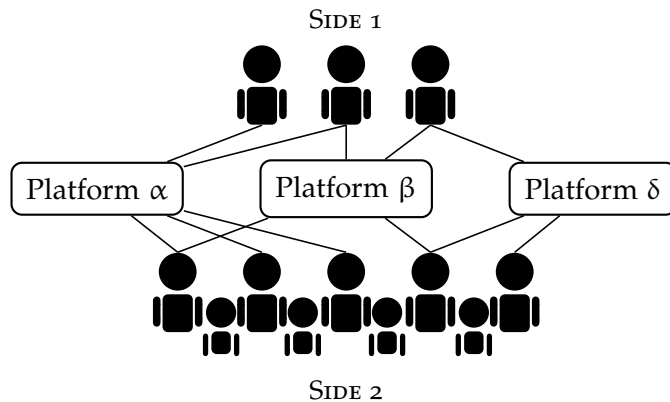
Figure 2.6: Three competitive business platforms (α, β, and δ) and two sides of markets are presented. In this example, both sides are actively multi-homing; *i. e.* several actors are connected to at least two platforms.

In the following, I will shortly discuss more on two issues of two-sided markets competition: Multi-homing and Sun and Tse's [2009] theory on the business platform competition. Later in this article-based dissertation I will rely on these concepts.

MULTI-HOMING.   In a case of competition between manifold business platforms, users from one or both sides can connect to several platforms. For example, retail stores often accept many different credit cards, and similarly some cardholders have more than one payment card. Rochet and Tirole [2003] called this *multi-homing*, *i. e.* a situation when an actor has joined two or more business platforms. The opposing approach is called *single-homing*, *i. e.* a situation in which an end user of a platform is participating only on one platform. These options are illustrated in Figure 2.6. In the figure, there are three competitive business platforms and two sides. Some of the end users of the platforms multi-home while others are single-homing.

There exists several studies on multi-homing in adjacent two-sided markets. Rochet and Tirole [2003, 2006] discussed that multi-homing is a key competitive aspect in two-sided markets and Armstrong [2006] showed its importance mathematically. Theoretical work on multi-homing has been advanced by, *e. g.*, Caillaud and Jullien [2003]; Gabszewicz and Wauthy [2004]; Choi

[2010]; Dou and Ye [2011] and Hagiu and Spulber [2013]. In addition, multi-homing has been studied empirically by, *e. g.*, Rysman [2009] in payment cards, Landsman and Stremersch [2011] in the video game console industry, Idu *et al.* [2011] in Apple's application ecosystems, and Burkard *et al.* [2011, 2012] in Business-to-Business CRM markets.

COMPETITION IN TWO-SIDED MARKETS.   Eisenmann *et al.* [2006] note that competition in two-sided markets might lead to winner-takes-it-all battles where, finally, only one business platform will serve all users. For example, so-called 'standard' or 'format wars'—*e. g.*, Betamax vs. VHS and Blu-ray Disc vs. HD DVD—are often these kinds of battles. Eisenmann *et al.* [2006] argue that this winner-takes-it-all dynamic is likely when three conditions apply: 1) Multi-homing costs are high for, at least, one side; 2) Network effects are positive and strong; and 3) Neither side has a strong preference for special features. I will focus on the first of these in the following.

Network effect theory is discussed in the following subsection.

Single- and multi-homing are an individual user's concept. While end users in the payment card markets are prone to multi-home, there are still consumers with only one credit card. Similarly, although acquiring several computers, OSs and application software licenses for different OSs is expensive, there are consumers using OS X and Windows systems in parallel. To tackle this, Rochet and Tirole [2003] defined single-homing and multi-homing indexes to depict the business platform characteristics. Based on this kind of an index, a market can be defined as either a 'multi-homing market' or a 'single-homing market'.

Sun and Tse [2007, 2009], *i. a.*, have studied Winner-takes-it-all competition in two-sided markets. They showed, that if the single-homing index is high, *i. e.* a market's participants tend to single-home, it is likely that one business platform will dominate the market. In a multi-homing market, smaller markets are more likely to survive and coexist with the dominant market.

Following the classification of Stremersch *et al.* [2007], we divide multi-homing into two levels. *Seller-level multi-homing* indicates the number of actors participating in more than one ecosystem. *Platform-level multi-homing*, instead, focuses on the products that are available from several ecosystems. Note that while there is often a correlation between these two, it is not required. In

other words, the same ISV can publish different products for different ecosystems, and the same product can be offered by different ISVs for different platforms.

In mobile application ecosystems, it is unlikely that consumers have several mobile phones; therefore, it can be seen as a single-homing market from that side. On the developer's side, there are no complete analyses on multi-homing; for instance, Boudreau [2007] notes that there were few multi-homers in mobile application ecosystems a decade ago. Therefore, this side also seems to be a single-homing market.

Furthermore, Kouris and Kleer [2012] used the three "winner-takes-it-all" attributes of Eisenmann *et al.* [2006] and the fourth attribute — the offered goods are homogeneous and there is no demand for differentiation — to evaluate the mobile application ecosystems. They argued that the market has a high tendency towards one platform. Kouris and Kleer [2012] noted that the multi-homing is costly due to the different programming languages and environments used in development.

In contrast to the other two-sided markets, software can be, however, rather easily transformed from one platform to another, although it needs time and work. The applications, furthermore, can be quite cheaply offered for several marketplaces as a reasonable number of applications can be published with a one-time payment. In addition, there are cross-platform development tools that aim to allow developing the application once and porting it to several software platforms. There has also been lots of academic work done to understand and improve cross-platform development tools. For instance, Ohrt and Turau [2012]; Palmieri *et al.* [2012]; Ribeiro and da Silva [2012]; Humayoun *et al.* [2013]; Heitkötter *et al.* [2013] and Xanthopoulos and Xinogalos [2013], to name a few, have evaluated cross-platform development tools for mobile applications. As a summary, Heitkötter *et al.* [2013] stated that native development is not necessary anymore and Humayoun *et al.* [2013] noted that there are reasonable alternatives with better cost-efficiency.

Note also 'web apps' i. e. products built with standardized web development tools such as HTML, CSS and JavaScript [see Charland and Leroux, 2011].

2.3.2 *Network effect and virtuous cycle*

Rochet and Tirole [2006] note that the theory of two-sided markets is related to network effects and multi-product pricing. Here,
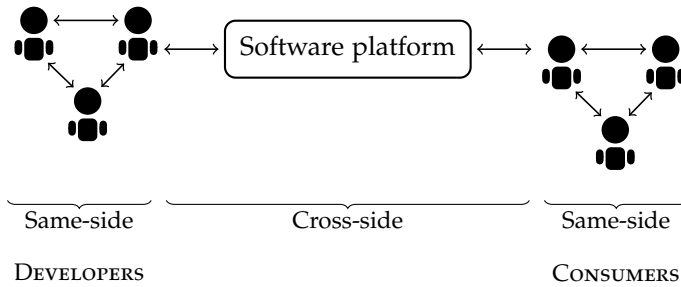
Figure 2.7: The same-side (direct) and cross-side (indirect) network effects in a SECO. [Burkard *et al.*, 2012, adapted]

I will discuss more on the *network effect theory*, which was notably advanced by the work of Katz and Shapiro [1985, 1986] and Farrell and Saloner [1985, 1986]. In the network effect theory, the value of a product or a service depends on the number of users it has. A classic example of a network effect is a telephone: a phone is more useful when more users own telephones [Katz and Shapiro, 1985; Farrell and Saloner, 1986].

Also called 'network externalities'

Katz and Shapiro [1985] identified two types of network effects: direct and indirect. In *direct network effect*, an increase of users leads to direct increase of value to other users. An example is the aforementioned telephone network or social network sites—more users in the consumer side allow existing users to connect and follow a larger number of people. In two-sided markets literature, this effect is called as a *'same-side effect'* [Eisenmann *et al.*, 2006].

In *indirect network effect*, an increase of users of a product might lead to increase of complementary products which can, in turn, increase the value of the original product. For example, a higher number of game consoles and gamers attracts the content producers to publish more for these platforms. Eisenmann *et al.* [2006] call this as a *'cross-side effect'* in the case of the two-sided markets.

See Stremersch et al. [2007] for a recent literature summary on indirect network effect.

These two network effects in a SECO are illustrated in Figure 2.7. In mobile application ecosystems, the same-side effect can be seen, *e. g.* when consumers can play games against each other. The cross-side effect is clearer: an increase in users attracts more ISVs to the ecosystem to produce content, which again increases the value of the platform.

While the above examples are positive network effects, the effect can also be negative. For example, Eisenmann *et al.* [2006]
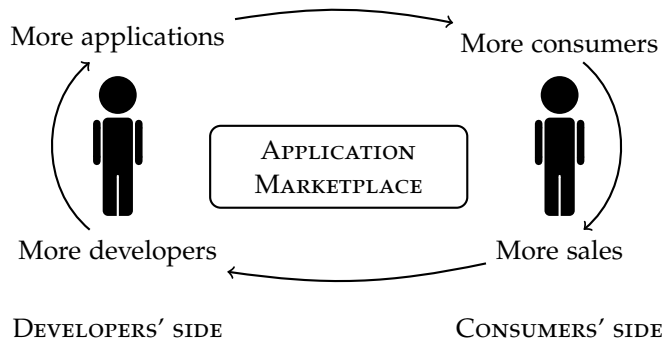
Figure 2.8: The positive feedback loop, or virtuous cycle, in the two-sided mobile application market [Holzer and Ondrus, 2011, adapted]

note that a negative cross-side effect would be an increase in the number of advertisements on TV. Similarly the same-side effect can be negative when *e.g.* sellers prefer fewer rivals in a platform. Regarding two-sided markets in general, Eisenmann *et al.* [2006] note that often the same-side effect is negative while the cross-side effect is positive.

Continuing positive network effects can create a critical mass needed for both sides to ignite a *positive feedback loop* [Evans, 2013], also often called a *virtuous cycle*. Figure 2.8 illustrates a positive loop in the context of mobile application ecosystems. As depicted by Holzer and Ondrus [2011], a virtuous cycle in this domain can be characterized by the following loop: more users means more sales in an application store, which in turn will entice more developers to join in the ecosystem and, thus, produce more applications. This loop turns up often in literature, for example by Katz and Shapiro [1985]; Eisenmann *et al.* [2006]; Holzer and Ondrus [2011]; and Evans and Schmalensee [2013] to name a few.

Parker and Van Alstyne [2005] call this the 'two-sided network effect'.

An opposite phenomenon is called a *vicious cycle* or a *negative feedback loop* [Shapiro and Varian, 1999]; however, it has been addressed, in the two-sided markets literature, considerably less than the vicious cycle. In this death spiral, a decrease in consumers will alienate developers, thus reducing the number of new applications.

Did Symbian hit the vicious cycle?

Although there are a few studies [*e.g.* Boudreau, 2007, 2012; Tåg, 2009; Parker and Van Alstyne, 2013], the limits of the vir-

tuous cycle are clearly less frequently addressed. While, for example, in telephone networks there seems not to be an upper limit for the network effect—every new user is a potential contact point for an existing user—the value created by it can diminish or even turn to negative with time. For example, Evans [2013] discussed that a negative network effect can arise, at some point, when the competition with other members, of that side, outweighs the value created to the competitors by attracting members to the other side. In the context of mobile applications, developers have for years complained that making money has become harder due to the large number of free applications [*e.g.* Rowan and Cheshire, 2009; Burrows, 2010].

Stremersch *et al.* [2007] studied the limits of network effects. To be more specific, they addressed the cross-side effect in several markets from televisions and DVDs to handheld game consoles. The study showed that while hardware sales lead to an increase in software offerings, *vice versa* was rarely true. Furthermore, they stated that the network effect was less pervasive than the prior literature was expecting.

In addition, Boudreau [2007, 2012] assessed in his work the limits of ever-increasing numbers of sellers of complementary goods in two-sided software markets. He noted that growing competition in previous-generation mobile application ecosystems, during 1999–2004, led to slower overall development rates. Boudreau [2012] showed that a larger number of application producers leads to an increasing variety in offerings; however, the large number of developers also leads to a decrease in innovation incentives, which was measured by the rate of new versions of existing products. He also noted that an increase in producers of different kinds of applications increased the innovation incentives. The latter observation is in line with the virtuous cycle theory. However, Boudreau [2007] noted, in the original manuscript, *"[r]estricting entry to just several hundred developers software firms* [sic] *would have led to more active software development."*

Boudreau's [2007] extensive dataset illustrates well the volume difference before and after the launch of the App Store. His dataset consists of 56,760 distinctive products from eight platforms. In P-IV, our datasets contain over 800,000 applications from one platform.

2.3.3   *Word-of-mouth*

While the network effect theory focuses on the value added by a network and its participants, there are more straightforward ways for consumers in a two-sided market to contribute to the

success or failure of products they like or hate: ratings and reviews left in the marketplace on the Internet. In this study, consumers are included in the ecosystem definition as discussed earlier in Subsection 2.2.3. One of their mightiest tools to add value to the ecosystem is a direct feedback—often called Word-of-Mouth (WOM). In all Big Three mobile application ecosystems, consumers are able to rate and review applications that they have downloaded. The verbal reviews and averages of ratings are then shown to the potential buyers.

Network effects and WOM are intertwined by their natures. As discussed by, *e.g.*, Oetting [2009, Ch. 3], when a consumer could benefit from the same-side network effect she might recruit her friends to join the network. Examples of this kind of WOM marketing can be seen in several markets, from Skype and fax machines to Facebook. As Oetting [2009] notes, network effects can be identified as one of the drivers of WOM.

Modern research in marketing on WOM, according to Buttle [1998], started in the 1940s. In the field of marketing, WOM was historically seen as information passed between relatives and non-commercial acquaintances [Dichter, 1966], or it was studied as an oral communication from person to person regarding a brand, product or service [*e.g.* Arndt, 1967]. However, Buttle [1998] notes that, due to the Internet, WOM has transformed; it might apply to organizations in addition to products or services, and it does not need to be face to face or direct communication any more.

At its simplest, eWOM can be defined as a WOM communication occurring in an electronic format. However, eWOM extends the borders of WOM communication remarkably—feedback, by an unknown commentator, can reach a large number of potential customers, and the feedback is often stored for a practically unlimited time. Similarly, the communication channels of eWOM vary widely. Recently, Cheung and Thadani [2012] classified five different 'types' of eWOMs that have appeared in the literature: 1) Online consumer review sites; 2) Online shopping sites; 3) Blogs; 4) Online discussion forums; and 5) Social networking sites. From these, the two first-named have attracted the largest amount of studies.

In this work, I have adopted the definition by Kietzmann and Canhoto [2013], who adapted and extended the original defin-

ition by Hennig-Thurau *et al.* [2004]. According to Kietzmann and Canhoto [2013, 147–148]:

> "*eWOM refers to any statement based on positive, neutral, or negative experiences made by potential, actual, or former consumers about a product, service, brand, or company, which is made available to a multitude of people and institutions via the Internet (through web sites, social networks, instant messages, news feeds...).*"

While this definition is rather broad, consisting of a myriad of different existing and forthcoming communication channels, it depicts well the variety of eWOM available in current electronic business. Unsurprisingly, a remarkable part of today's merchants are offering eWOM systems in their websites [see *e. g.* Dellarocas, 2003; Aarikka-Stenroos and Järveläinen, 2013], and similarly eWOM has also raised a considerable amount of research interest by academics.

A plethora of research focusing on eWOM and its mechanisms from different viewpoints can be seen in the recently published literature reviews by Cheng and Zhou [2010]; Cheung and Thadani [2010, 2012]; De Maeyer [2012]; Aarikka-Stenroos and Järveläinen [2013] and Colvin [2013]. For example, De Maeyer [2012] identified eWOM studies from marketing and management to psychology, IS, and CS disciplines. In WOM research, the most often addressed areas are motives behind communication [*e. g.* Dichter, 1966; Berger and Schwartz, 2011; Khammash and Griffiths, 2011; Cheung and Lee, 2012] and eWOM's effects on the sales of goods [*e. g.* Arndt, 1967; Chevalier and Mayzlin, 2006; Dellarocas *et al.*, 2007]. As a part of this work, we aim to contribute mainly to the latter; our focus is on eWOM appearing in online shopping sites where the feedback is, to some extent, moderated by the orchestrator or the seller.

Chan and Ngai [2011] identified 94 journal articles in their SLR.

Dellarocas *et al.* [2007] have pointed out that there are different dimensions of eWOM that should be equally assessed in the research of eWOM's effects. In his literature review, De Maeyer [2012] identified five most often reoccurring dimensions that have been argued to affect sales. These five are: 1) *Verbal*, 2) *Valence*, 3) *Variance* of reviews, 4) *Volume* of reviews, and 5) *Helpfulness* of a review. In our studies, we have mainly omitted the verbal and helpfulness dimensions of eWOM. The latter due to,

Valence refers to a numeric value such as, e. g., star ratings left by reviewers.

at that time, the lack of a helpfulness rating feature in the Big Three mobile application marketplaces, and the former due to our quantitative research approach.

There are inconsistent findings in previous studies concerning the valence dimension having a greater impact on sales than volume (see Table 2.7). For example, Chen *et al.* [2004] and Chevalier and Mayzlin [2006] finds that eWOM improves sales, while there are also conflicting results [Liu, 2006; Hyrynsalmi *et al.*, 2012d]. Table 2.7 presents selected empirical studies on the effectiveness of these eWOM's dimensions. As the table emphasizes, the findings may differ also inside the same product domain—however, it should be noted that the studies contained more observations and results than those presented in the table. For example, Zhu and Zhang [2010] found that eWOM has a greater impact on less popular games than on popular ones. Furthermore, they theorized that eWOM would have a greater impact on products purchased and used online, *i. e.* software, than those used offline.

Lang and Hyde [2013] raised volume vs. valence as one of the key questions for future studies.

Although volume and valence are seen as the most important dimensions [Liu, 2006], there are certain limitations related to these. While valence represents the nature of the communication (either positive or negative), most of the eWOM are overly positive when simple star ratings are used [*e. g.* Hu *et al.*, 2009]. In Figure 2.9 this *'J-shaped'*, as described by Hu *et al.* [2009], distribution of given stars, *i. e.* valence, in Google Play is shown. As can be seen from the figure, over 67% of star ratings left by consumer are the highest one. In addition, Figure 2.10 shows the distribution of average star ratings of applications in Google Play; a similar 'J-shape' can be identified here too.

Although the volume of eWOM can be seen to measure the total amount of interest awoken by a good—and thus the future popularity in sales—it is actually often only a measure of the previous popularity of a product. In other words, the volume might only reflect the number of consumers who have already bought the product and, thus, be a proxy of the number of previous sales. As eWOM has been suggested to be used as a predictor of future sales [*e. g.* Dellarocas *et al.*, 2007], this correlation might be problematic.

Sun [2012] recently stated that the variance of ratings can be used to explain eWOM's impacts. According to her theorem, a

Table 2.7: Selected studies on eWOM's impact on the sales of different products.

STUDY	DOMAIN	RESULTS
Chen *et al.* [2004]	Books	Volume has a positive impact while valence is not related.
Godes and Mayzlin [2004]	TV shows	Dispersion of eWOM is more important than valence or volume.
Chevalier and Mayzlin [2006]	Books	A higher valence leads to higher sales although negative reviews have greater impact than positive. Verbal dimension has impact beyond numbers.
Clemons *et al.* [2006]	Beers	Variance and valence are positively associated with sales growth; volume is not.
Liu [2006]	Films	Volume over valence in predicting future box office revenues.
Dellarocas *et al.* [2007]	Films	Early volume can be used as a proxy of early sales; valence and dispersion have positive relationships with future sales.
Duan *et al.* [2008]	Films	Valence has significant impact on film's box office revenues but volume does not.
Chintagunta *et al.* [2010]	Films	Valence seems to matter; volume and variance not.
Zhu and Zhang [2010]	Games	Volume seems to correlate better than valence.
Amblee and Bui [2011]	eBooks	Valence does not correlate while volume correlates well with the sales.
Cui *et al.* [2012]	Various	Valence has impact on search goods (consumer electronics) while volume affects experience products (games).[†] Negative reviews have greater impact than positives.
Colvin [2013]	eBooks	Volume and valence have positive effects on sales; however, the effect of volume was consistent while valence's effect was not.
Zhang *et al.* [2013]	Cameras	Both valence and volume affect sales; a negative review has higher impact than positive.
Chen and Liu [2011]	Mobile apps	The top ranked paid applications do not correlate with high valence.
Liu *et al.* [2012]	Mobile apps	User reviews are not significant when a free-to-try version is offered.

[†] Search goods are characterized by attributes that can be known prior to purchase (*e.g.* TV) and experience goods by attributes that cannot be known prior to use (*e.g.* coffee beans) [see *e.g.* Park and Lee, 2009].
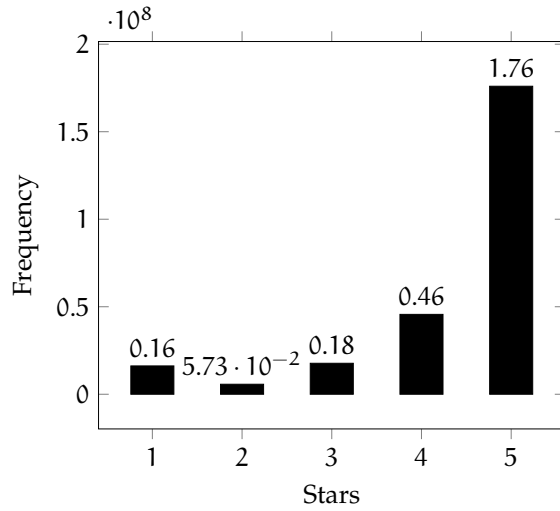
Figure 2.9: Distributions of votes given for all mobile applications in Google Play (May 2013).

high valence indicates a high-quality product and a high variance implies a niche product, *i.e.* a product that some hate and others love. When these two axes are combined, a high valence and a small variance imply a mainstream product of good quality; a 'lowish' valence and a high variance indicate a niche product that a well-matched consumer would value; and a high valence and a highish variance would drive away marginal consumers. Sun [2012] found support for her theorem from an empirical study of Amazon.com and Barnesandnoble.com and stated that a higher standard deviation would benefit a product's sales when the average of star ratings is lower than 4.1 stars.

In the App economy, eWOM has been argued to be important for the ISVs. For example, Edwards [2009] reports on a developer whose application sold hundreds of thousands due to the successful WOM, and Apple Inc.'s [2013] iOS developer guidelines state that *"[c]ustomer ratings and reviews on the App Store can have a big effect on the success of your app –"*. Similarly, Hao *et al.* [2011a,b] have argued the importance of consumer reviews and ratings in the App economy on their econometrical analysis.

Amblee and Bui [2011] addressed eWOM's effect on the sales of *digital microproducts*, *i.e.* digital products whose selling price is low and fixed; often price is identical for all products and there
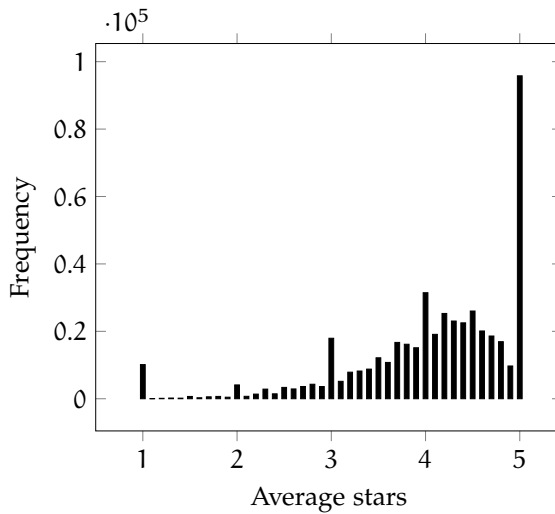
Figure 2.10: Frequencies of average ratings of mobile applications in Google Play (May 2013).

are no delivery costs. They showed that the volume of eWOM correlates well with the sales of Amazon Shorts (*i.e.* short books). As Amblee and Bui [2011] noted, mobile applications can also be seen as a kind of digital microproduct; however, the price of mobile applications varies wildly from less than 1 € to tens and even hundreds of euros. Nevertheless, the other characteristics fit.

There are a few mobile application ecosystem specific eWOM studies. Carare [2012] showed that bestseller rank in Apple's App Store has impact on future demand; although the study did not explicitly address eWOM, the results indicate that the previous popularity might have more impact than the reviews and ratings. Chen and Liu [2011] also studied the App Store and found that, on average, the top-ranked paid applications do not seem to correlate well with customer ratings.

In addition to these, there has been work to develop a better approach for application recommendation. For example, Yan and Chen [2011] remark that application rating requires laborious handwork. This would ultimately lead to sparse reviews, and therefore they introduced their own method. Furthermore, an ever-increasing application offering has caused researchers to propose new eWOM or recommendation systems, as the current

The point of discontinuity in Fig. 2.10 is likely due to the fact that most of those with high averages are only reviewed a few times.

system is felt not to be working well enough. This stream of research seems to be popular [*i.a.* Girardello and Michahelles, 2010a,b,c; Mahmoud and Popowicz, 2010; Lim *et al.*, 2011; Davidsson and Moritz, 2011; Karatzoglou *et al.*, 2012; Böhmer *et al.*, 2013].

Summarizing, eWOM and WOM have been studied extensively in several different markets; however, further work to validate empirical experiments and to create in-depth understanding of the concepts and phenomena related to eWOM is required [*e.g.* Hennig-Thurau *et al.*, 2004; De Maeyer, 2012]. Only a handful of studies have focused on the mobile application ecosystems. Nonetheless, micropricing together with instant delivery, exponentially growing offering and the ubiquitous nature of smart phones should make the mobile application ecosystem an interesting subject of eWOM study.

2.3.4 *Existing research*

In this subsection, I will briefly review a vast amount of research focused on different aspects and phenomena in the App economy. A variety of research addressing different aspects of the App economy can be seen from the fields of sciences interested in the phenomenon.

For example, Daly [2011] and Síthigh [2013] have discussed regulation in the new application era, and blatant copyright violations have generated research in law [Castree III, 2012; Tonner, 2013]. Also there has been a discussion about whether the orchestrators restrict developers' freedom of expression [Hestres, 2013]—that is, in the mobile application ecosystems the orchestrators are more or less unchallenged dictators that can choose what content they publish and what not. For example, the Wikileaks application was censored [Kiss, 2010], a political cartoon was removed although it was later returned [Stelter, 2010], and a serious game about sweatshops was dismissed [Parkin, 2013] by Apple. However, the orchestrating companies actually own the distribution channels—*i.e.* the stores—and they can, therefore, decide rather independently what they wish to publish and support.

Eaton et al. *[2011a,b] used narrative analysis to study these cases.*

In addition to law and ethics, medical sciences have been interested in the app phenomenon. For example, Breton *et al.* [2011]

and Abroms *et al.* [2011] studied health applications—weight loss and smoking cessation, respectively—available at the App Store and noted that they sparsely covered well-known practices. In addition, Donker *et al.* [2013] presented a SLR of mental health applications. While these examples are far out of the scope of this thesis, they illustrate both the ubiquitousness of the App economy in modern society and the interest attracted by the phenomenon.

"Where there is an app, there is a way" [Backinger and Augustson, 2011].

The ubiquitousness of mobile applications and smart phones has also raised worries on privacy and security of applications [see *e. g.* Shabtai *et al.*, 2010; Chin *et al.*, 2012; Fledel *et al.*, 2012]. Ha and Wagner [2013] studied the reviews in Google Play and found that only a small minority of commentators and comments consider applications' permissions. In other words, a majority of the users, according to the comment density, were not interested on the privacy and security issues. However, there are a considerable number of publications aiming to propose improvements to the security mechanisms of smart phones [*e. g.* Ongtang, 2010; Barrera and Van Oorschot, 2011; Enck, 2011; Desnos, 2012; Gibler *et al.*, 2012; Zhou *et al.*, 2013].

Similarly Grubert et al. *[2011] analysed the content of the reviews of augmented reality apps.*

Due to the large number of ISVs and consumers in the mobile application ecosystems, the App economy has been addressed also from the business perspective. For example, there have been studies focusing on explaining the success of the iPhone and Apple [*e. g.* West and Mace, 2010; Laugesen and Yuan, 2010]. West and Mace [2010] argue that the mobile Internet was the killer application of the new generation smart phones. While they mention the popularity of application marketplaces, they are not argued to be the key. Furthermore, the business model of Apple, the ecosystem orchestrator, has been analysed [Bergvall-Kåreborn and Howcroft, 2013; Montgomerie and Roscoe, 2013]. Bergvall-Kåreborn and Howcroft even argue that Apple's, and other orchestrators', model in the App economy is basically a form of crowdsourcing as they are *"able to harness creative labour at little or no cost while minimizing risk"* [Bergvall-Kåreborn and Howcroft, 2013, 288].

From the developers' perspective, there are analyses of differences of mobile application ecosystems [*e. g.* Hammershøj *et al.*, 2010; Hilkert and Benlian, 2011; Holzer and Ondrus, 2011], business models [*e. g.* Bernardos and Casar, 2011; Xia *et al.*, 2010; Van-

nieuwenborg *et al.*, 2012] and revenue streams [Roma *et al.*, 2013; Liu *et al.*, 2012] and even discussion on their roles in an ecosystem [Kimbler, 2010; Schultz *et al.*, 2011]. Henze and Boll [2011] showed that the best time to launch an application in Google Play is Sunday evening. Holzer and Ondrus [2011] analysed how mobile application ecosystems are evolving from the developer's point of view. They argued, *e. g.*, that the industry is converging towards centralized marketplaces. Roma *et al.* [2013] assessed free vs. paid application publishing models and argued that paid applications can overcome free applications in revenue gathering; however, their data was only from the top 200 application listings. Liu *et al.* [2012] showed, with a dataset of 1,597 applications, that the freemium publishing strategy leads to an increase in sales.

Song *et al.* [2013a,b] studied, with interviews, the reasons why developers adopt software platforms. They used the Big Three mobile application ecosystems as study subjects and found that market potential and network effects were among the most often occurring reasons. Li *et al.* [2013a] analysed portfolio management of ISVs in the App Store with a dataset of 11,579 applications that they followed for a time period of 14 months. They showed that the diversity of an application portfolio is negatively associated with the performance of an ISV. However, after a critical point, diversifying its portfolio starts to benefit the developer. Their results are contradictory to Lee and Raghu [2011], who also studied portfolio management in the App Store.

Qiu *et al.* [2011] interviewed developers in order to study how they solve the logic tension of the application market. They found that the developers tend to focus on engineering quality and generate ideas from their personal needs and passion while they only adopt passive marketing techniques of the ecosystem. Bergvall-Kåreborn and Howcroft [2011] found that the motivation of application developers, among their sample, was *e. g.* fun, the feeling of being on the edge of development and extra income. Kim *et al.* [2010] studied ISVs' intentions to develop applications for a mobile application ecosystem; they found that market demand and perceived usefulness of development tools were among the most important factors.

From consumers' perspective, there are a few studies. For example, Amberg *et al.* [2010] interviewed young mobile smart

phone users. Among the respondents, the willingness to pay for applications was very low, while mobile games were among the most frequently searched applications behind the basic features (*e.g.* camera, calendar, SMS). Ahmet and Väänänen-Vainio Mattila [2012] found that their respondents most often recommended mobile applications to others via a face-to-face communication. This implies that the marketplace's eWOM systems are not as important as direct communication. In Ahmet and Väänänen-Vainio Mattila's [2012] study, games were the most often recommended applications.

Suominen *et al.* [2014] studied change of attitudes by university students towards mobile devices since the launch of smart devices. They found little if any changes. Suominen *et al.* [2014] showed that while iPhone users are more willing to pay for applications, in general young users were not willing to spend money on them. Kim *et al.* [2011] showed that WOM was the most important purchase determinant in application purchases. Karhu *et al.* [2011] studied business co-creation between companies and consumers in the application ecosystems. They noted that, among other factors, a vivid application marketplace is essential for co-creation to succeed.

Contemporary large-scale measurements of mobile application ecosystems, similar to our work, exist. Their results are in line with ours. For example, d'Heureuse *et al.* [2012] studied Google Play, App Store, BlackBerry App World and Windows Phone Marketplace with web crawling. In addition, Zhong and Michahelles [2012a,b, 2013] analysed Google Play and the Long-tail theorem with a dataset gathered from the users of Appaware. They showed that the mobile application ecosystem is a super-star market although it has some characteristics of a long-tail market. They argue that an improved application recommendation system, *i.e.* a replacement of a current eWOM platform, would benefit the market. Suh *et al.* [2012] crawled data of 6,270 applications from the App Store to identify representative services offered by the products.

There are also rather theoretical approaches to the App economy phenomenon, in contrast to the empirical evaluations. For example, Lim and Bentley [2012] artificially simulated the App economy to study successful strategies for application developers. Garg and Telang [2013] developed a method to infer applic-

Economides and Grousopoulou [2009]; Bouwman et al. [2010]; and Suominen et al. [2014] found a lack of interest towards mobile games while they, however, are among the most installed content.

Frank et al. [2012a,b] mined permission data from Google Play and showed the request permission patterns of low-reputation applications differs from high-reputation applications.

ation sales from the relative ranks in application marketplaces. Garg and Telang's [2013] results show that the top-ranked application collects 150 times more installations than the 200th-ranked application. Furthermore, Neelakanta and Yassin [2011] simulated competition between the mobile application ecosystems.

In addition to the developer's and consumer's perspectives, there are general analyses on the differences and similarities of the ecosystems [Lin and Ye, 2009; Schlagwein *et al.*, 2010; Campbell and Ahmed, 2011; Kenney and Pon, 2011; Müller *et al.*, 2011; Tuunainen *et al.*, 2011; Cuadrado and Dueñas, 2012, *i.a.*] and the differences of ecosystems' software platforms [*e.g.* Lettner *et al.*, 2012; Anvaari and Jansen, 2013]. Tilson *et al.* [2012] studied the change and control paradoxes of digital infrastructures by using Apple's iOS and Google's Android ecosystem as case study subjects. They showed that their model can be used, to some extent, to explain the evolution of the mobile application ecosystems.

Ghazawneh and Henfridsson [2010, 2013] studied platform governance and control in Apple's App Store through boundary resources. They discussed how boundary resources—*e.g.* Application Programming Interface (API)—are underestimated resources between the ecosystem orchestrator and ISVs. Ghazawneh and Henfridsson [2011] studied key APIs of the iOS software platform. They stated that boundary resources, such as the in-app purchase API, can be and are used to guide viability and value creation of the ecosystem.

Finally, *e.g.* Sangani [2010] noted that the change brought by the App economy and mobile application stores is also reaching other sectors of the software business. Therefore, Jansen and Bloemendal proposed a definition [Jansen and Bloemendal, 2013, 195]:

> "APP STORE: *An online curated marketplace that allows developers to sell and distribute their products to actors within one or more multi-sided software platform ecosystems.*"

Similarly as in this thesis, they see application stores as the centres of ecosystems. However, they distinguish that an application store, such as BinPress[3], can serve several ecosystems. There are several examples—such as the Windows Store, with

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3 http://www.binpress.com/ Accessed February 4th, 2014.

approximately 142,000 applications [Popa, 2013]—of growing application marketplaces in other domains [see *e.g.* Jansen and Cusumano, 2012].

2.4 SUMMARY

This chapter reviewed the background of this thesis, from business ecosystems to the App economy. Section 2.1 presented Moore's business ecosystem and its evolutionary stages, which can be easily used to illustrate both the whole mobile industry and mobile application marketplaces. However, as discussed, while metaphors are powerful ways to communicate complex ideas, the overuse of them might lead research onto sidetracks.

In Section 2.2, SECO was specified through three characteristics: 1) a common technological, *i.e.* software, platform; 2) actors and their interests regarding the ecosystem; and 3) the connecting relationships between the actors. The intertwined nature of platform research and ecosystem research were then discussed. In this thesis, I use three different roles of SECO participants: Ecosystem orchestrator, ISV and Consumer. The relationship forms between these actors were presented in order to show the variety and complexity of possible connections in addition to the collaboration and no relationship options.

Together these reviews aimed to concretize the SECO concept and thus they were followed by several examples of SECOs given when different taxonomies of ecosystem were presented. The objective was to show that, *e.g.*, open source SECO and mobile application ecosystem cannot be directly compared—the specific characteristics of the ecosystems have to be noted beforehand.

Section 2.3 focused on the new phenomenon called the App economy. The section started with some classic economic theories—*i.e.* network effects and WOM—and with a newer one, two-sided markets. In the section, the economic theories were used to explain and characterize the mobile application ecosystem. Finally, a swift review on the myriad of research focusing on the App economy was given.

RESEARCH APPROACH AND PROCEDURE

> *Facts, data, and probabilities can have a way of removing the ego, politics, and hand-waving from a conversation.*
> — CEO Thomas Thurston, Growth Science, 2013

In an interview by Venturebeat

This chapter reviews research methods used in this thesis. In addition, it presents the data acquisition platforms used in the research.

3.1 METHODOLOGY

The objective of this thesis is to advance our understanding of the changes caused by mobile application ecosystems (and application stores) from the perspective of an ISV. The focus of this thesis is on the issues which challenge the developers and developing companies. The research questions address the revenue streams, the impact of eWOM and multi-homing, as these themes have been influenced remarkably by the new digital distribution channel innovation. The new marketplaces offer new usable revenue models and a direct contact point with a customer; furthermore, due to explosion in the number of offered applications, the impact of WOM is becoming crucial. Similarly, before the new marketplaces, the multi-homing publication strategy of mobile applications was rarely studied and used, as discussed in the previous chapter.

In the following, I will first discuss about research methodology tradition in SE and present a few of the research approach classifications specifically presented for and used in SE. These classifications, however, remain scarce for the needs of this dissertation, as is shown later. Therefore, in this work, I have adopted the research approach classification by Järvinen [2004a]. The classification taxonomy was first presented for IS; nevertheless, it is useful for the whole computing discipline. Furthermore, the classification is chosen as it guides and clarifies the limitations of the work.

In IS, there is a richer discussion of paradigms and methods—and even so-called 'paradigm war' [see e. g. Islam, 2012].

Decades ago, Basili [1993] identified four types of research methods suitable for use in the SE domain. 1) *The scientific method* consists of observing the world, proposing a theory or a model, collecting data and validating the hypotheses. 2) *The engineering method* aims to improve existing solutions. 3) In *the empirical method*, a model is proposed, applied in a case study setting and validated. Basili [1993] also calls this an inductive method. 4) *The mathematical method* is a deductive analytical model that is based on deriving a theory from a set of axioms and comparing this to the empirical observations. Recently, Mäkilä [2012] argued that there are similarities in the empirical and the engineering methods and, therefore, he proposed combining these two.

Lately, there have been attempts to extend the toolbox of research methods used with SE—and the focus is on the empirical research methods in contrast to the formal mathematical and constructive engineering methods. For example, Seaman [1999]; Hazzan and Dubinsky [2007] and Dybå *et al.* [2011] have argued on behalf of the use of qualitative methods in the SE discipline. Easterbrook *et al.* [2008], instead, viewed the philosophical standpoints of science and discussed their relations to the empirical research methods of SE. They emphasized the importance of human activities in SE and ended up suggesting five classes of the most relevant research methods: Controlled experiments, Case studies, Survey research, Ethnographies and Action research [Easterbrook *et al.*, 2008].

However, in the empirical studies of SE the division is often seen only between the quantitative and qualitative research paradigms. As defined by Wohlin *et al.* [2003], the former aims to identify a cause-effect relationship and the latter attempts to interpret a phenomenon. While they also note that a research approach, such as a case study, can be used in both paradigmatic approaches, this study, among others, would be classified as a mixed-methods study [see *e. g.* Creswell, 1994]. In this thesis, quantitative and qualitative approaches are used in separate studies—what Yin [2009, 63] calls a conventional situation of mixed-methods study. The articles, included in this thesis, represent different methods and approaches of research. By combining different approaches, new information from the domain is produced.
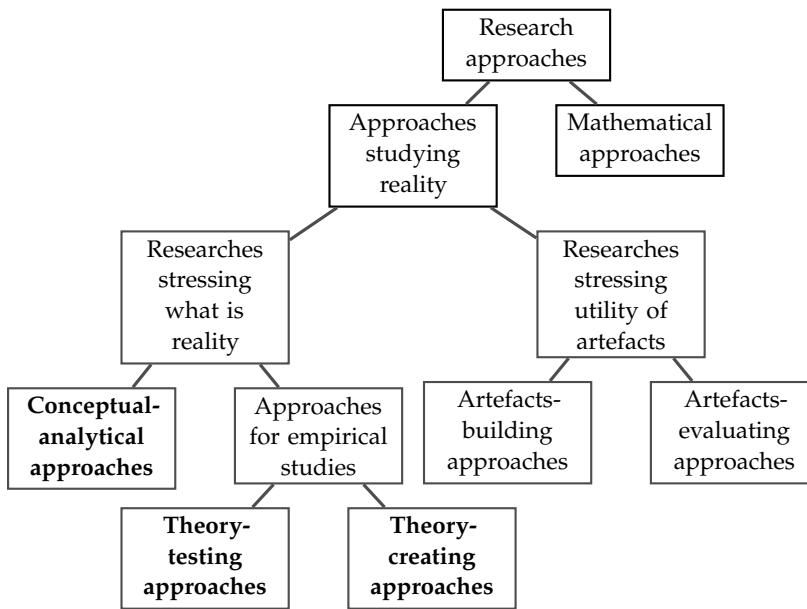
Figure 3.1: Järvinen's classification of research approaches and methods. The approaches used in this dissertation are emphasized. [Järvinen, 2004a, adapted]

The previously described research method classifications of SE, to either the empirical-engineering method or mathematical method, is rather broad for this work. Similarly, classification either to quantitative, qualitative or mixed-method remains too coarse. This thesis contributes mainly to the multi-disciplinary field of software business and is, thus, a multi-disciplinary study by its nature. Therefore, I have adopted Järvinen's [2004a] taxonomy of IS research approaches (Figure 3.1), although here it is seen more as a taxonomy for the whole computing discipline instead of only IS.

Defined as a business of selling software and services related to development of and deployment activities of it.

By following Järvinen's [2004a; 2004b] taxonomy, this study can be classified as belonging in the group of *Reality-stressing researches*. There are a few clear advantages of choosing the Reality-stressing category. First, assessing mobile application ecosystems in a controlled experiment is a hard if not impossible task. That is, the ecosystems are huge self-organizing systems that cannot be controlled in or built for an experiment. In addition, the focus of this thesis is on the ISVs involved in the

As prof. Christer Carlsson has often noted, an ecosystem emerges—it can't be forced to be born.

ecosystems (the developers and developing companies producing content to the ecosystems)—and not in the ecosystem *per se*. However, these ISVs cannot be studied without the surrounding ecosystem. Thus, reality-stressing methods have been chosen for this thesis.

According to Järvinen [2004a], there are two different research approaches for stressing the reality: *Conceptual-analytical* and *Empirical studies*. For the first-named, there are two typical approaches that can be identified from literature [Järvinen, 2004a]. In the first, a theory, model or framework is derived from the assumptions, premises and axioms. In the second, theories, models and frameworks used in the previous studies are identified and logical reasoning is used to integrate them.

For the other category of reality-stressing studies, *i.e.* empirical studies, there are again two types available for research in the computing discipline: *theory-testing* and *theory-creating* [Järvinen, 2004a]. In theory-testing studies, either a theory, framework or model is taken from the existing literature or a new one is proposed in the study. Then the construction is addressed, verified or falsified with an applicable research method. In theory-creating approaches, a study aims to develop a new framework, model or theory based on the collected raw data according to Järvinen [2004a]. For this approach, several research methods, from grounded theory to case studies, can be used.

Theory-testing and -creating are rather specific names for these broad categories.

In this article-based dissertation, both reality-stressing approaches are used. Although I will mainly rely on the theory-testing approach, a conceptual-analytical study is also included in the thesis. Table 3.1 shows individual publications included and research approaches used as well as data types. As shown by the table, we relied often on the observation data gathered from the marketplaces of the Big Three mobile application ecosystems. Furthermore, frequently the used data was collected automatically as discussed in the following section.

In P-I, existing assumptions, or models, extracted from the literature and public discussion were stressed with an automatically crawled dataset. In terms of Chua [1986]; Orlikowski and Baroudi [1991]; and Walsham [1995], the study can be classified as interpretive research. While interpretive studies are often case studies, also quantitative studies can be used [Walsham, 2006]. The research approach was selected in order to create more un-

Table 3.1: The research approaches and datasets, either automatically crawled or manually collected, used in the publications included in this thesis.

	RESEARCH APPROACH	DATA TYPE
P-I	Theory-testing	Observation data (crawled)
P-II	Theory-creating	Observation data (collected)
P-III	Theory-testing	Observation data (collected)
P-IV	Theory-testing	Observation data (crawled)
P-V	Theory-testing	Observation data (crawled)
P-VI	Conceptual-analytical	–

derstanding and insight into the phenomenon under study. In this study, the effect of eWOM was tested quantitatively in a correlation study.

In P-II, we collected data from a set of applications and used the data to create a framework of different business strategies used by companies in a mobile application ecosystem. P-III addresses the value creation framework by Amit and Zott [2001] with a set of data collected from mobile applications and their developers.

P-IV assesses theories of eWOM, taken from the existing literature, in the context of a mobile application ecosystem. The study focuses on addressing, *e. g.,* Sun's [2012] variance theory. However, support for this theory was not found. Publication P-V uses Sun and Tse's [2009] theory of multi-homing to study mobile application ecosystems and their dynamics. The results support their construction.

P-VI is a conceptual-analytical study that focuses on the developing-country application vendors. While it also studies the locations of the headquarters of the 400 application vendors, the study draws from the existing literature of digital divide and bottom of the pyramid to propose a conceptual framework. The framework is intended to be used to research and address issues hindering developing-country software developers from entering application markets.

Table 3.2 summarizes the research methods used for each research question and goal. To research RG1, a set of different

Table 3.2: Research questions and used research methods

	RQS	METHODS
RG1	RQ1.1	Interpretive analysis (P-II), Constructive (P-III), Quantitative analysis (P-VI)
	RQ1.2	Interpretive analysis (P-I), Quantitative analysis (P-II), Qualitative analysis (P-III)
RG2	RQ2.1	Correlation study (P-I, P-IV)
	RQ2.2	Correlation study (P-IV)
RG3	RQ3.1	Quantitative analysis (P-V)
	RQ3.2	Interpretive analysis (P-III, P-V)

methods were used to study what kinds of ISVs there are and how they create value and monetize it. To research RG2, quantitative data was collected and analysed in correlation studies. Similarly, in order to answer RG3, collected data and a quantitative method were used in addition to an interpretive study.

3.2 DATA COLLECTION

Also known as 'Web scraping'. The data used in most of the publications included in this thesis was collected with a web crawling technique directly from the marketplaces of the Big Three mobile application ecosystems. The same technique is used by, *e. g.*, the web search engines in indexing web pages [Brin and Page, 1998a,b]. In the following, I will briefly review literature and architectures of the web crawlers used and then present the typical data processing activities used in these studies.

In publications P-II, P-III and P-VI, we also used manually collected data, from various sources, in addition to automatically gathered. These data collection procedures are described in detail in the respective papers.

3.2.1   *Web crawlers*

At the simplest, a web crawler can be seen as an algorithm that [Olston and Najork, 2010]: 1) Starts from given Uniform Resource Locator (URL) addresses and 2) visits a web page selected from these addresses. 3) It then extracts data from the page and 4) identifies all URL addresses available at the page. 5) Finally, it iteratively repeats the previously described steps until all web pages in the queue of URL addresses have been examined and extracted. That is, at the simplest, it is a kind of a breadth-first search algorithm [see *e. g.* Cormen *et al.*, 2001]. However, there are scale issues that make the web crawlers and search engines interesting research targets for researchers and practitioners [Thelwall, 2002; Patterson, 2004].

E. g., *practically infinite web.*

Web crawling has been studied a lot. In addition to the algorithmic or technical approaches [see *e. g.* Chakrabarti, 2003; Castillo, 2004; Ceri *et al.*, 2013], there have been discussions on ethical issues of crawling [Thelwall and Stuart, 2006] as well as social concerns of web search engines [Van Couvering, 2004]. However, here the focus is purely on the technical implementation. Figure 3.2 presents a high-level reference architecture of a web crawler program and illustrates the overall simplicity of the web crawlers.

A typical web crawling program consists of a *scheduler*, a *downloader* module and two data structures: the *queue* for visited and non-visited URLs and the *storage* for extracted data [Castillo, 2004]. The multi-threaded downloader is responsible for downloading a web page and extracting the data and URLs from the page. Furthermore, it stores the new URLs to the queue and the extracted data to the storage. In order to achieve better performance, multiple threads are usually used in the implementation. The scheduler module decides, according to pre-defined criteria, efficient crawling order and tells the downloader which page to crawl next.

In this study, we have utilized two different web crawling programs implemented by the author and his colleagues. The first one was programmed with the Java language and taken into use at the end of 2011. It was used until the summer of 2012, when the first crawler was superseded by a data acquisition platform implemented with the Python programming language.
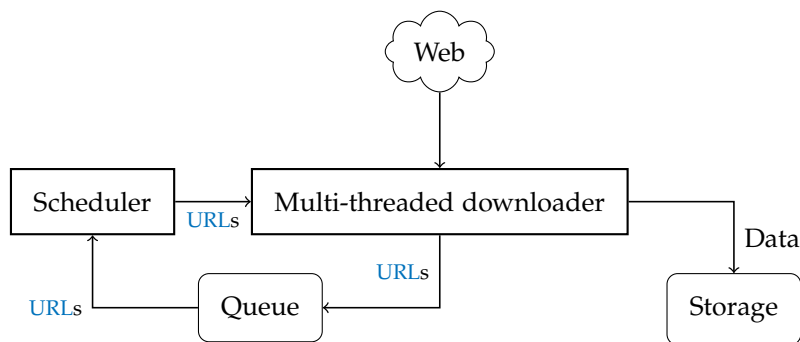
Figure 3.2: A high-level reference architecture of a web crawler program [Castillo, 2004, adapted].

The second web crawler utilizes a third-party's library Scrapy[1], a screen scraping and web crawling framework. The new one was developed in order to create a more general data acquisition platform that could be easily modified and extended.

The first web crawling program worked in two phases. In the first phase, it collected unique application identifiers either from a third party's service[2,3] or from an application listing available at the marketplace. However, from the marketplace all available top listings were read in order to ensure that the most sought content would be included in the datasets. The aim of using the third parties' listings is that not all applications available could be reached through collecting URLs from the pages and using an external listing helps to cover a larger share.

E. g. *Apple's App Store offers an easily readable list.*

In the second phase, the crawler used the collected list of identifies, *i. e.* the output of the first phase, as an input and downloaded an application's page from the marketplace, extracted the data from it and stored the data to text files in a `.csv` format. In addition, the crawler wrote a log file of unexpected encounters, warnings, *etc.* from each running cycle.

The scheduler implemented for the first version followed the '*First in, First out*' principle while it removed duplicates from the application identifier listings. A multi-threaded downloader was used; however, the aim was to minimize the traffic caused, and

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1 Scrapy — http://www.scrapy.org/

2 Usually AndroidPIT (http://www.androidpit.com) for Android Applications

3 Usually Windows Phone Applist (http://www.windowsphoneapplist.com) for Windows Phone applications

thus there were considerable intervals between downloads and only a few threads were used. Therefore, the web crawling took a few days to finish. The data gathered by the first crawler was used in the publication P-I and partially in P-II and P-IV.

The second built web crawling program removed the unnecessary phase where the unique application identifiers were collected separately. The aim was to reduce dependency on the correctness of third-party listings and improve the efficiency of the crawling. This time, the crawler started from the front page of the marketplace and went through all pages and URLs it could reach. It then continued by using a search functionality of the marketplace in order to reach reasonable coverage of the application offering. In contrast to the previous one, this crawler stored the data in a database.

The second crawler was implemented by Miika Oja-Nisula under loose supervision by Tuomas Mäkilä and the author.

Although the crawler is able to reach a considerable amount of applications from the marketplace, it most likely does not reach all applications. However, we have paid attention to ensure that the most important applications are included through different top applications listings and by utilizing *e. g.* 'users have downloaded also these' features in this crawler. The data gathered by the second crawler were used in publications P-IV and P-V.

3.2.2 *Data processing*

In order to use the crawled data in a statistical analysis, several preparation steps were needed. In the following, I will describe a typical process used to prepare the data for the analysis (Figure 3.3). The process might have been a bit different for different studies; however, these deviations, when they exist, are described in the articles.

The initial web crawler stores the data to `.csv` formatted text files while the superseding crawler uses a database. Nevertheless, the data from the storage was transformed to a text file (`.xml` or `.csv`). These files were in Microsoft Excel 2010 spreadsheet software as it offers a relatively good view of the data and allows a user to skim through the file. In the software, missing fields and duplicate entries were searched. In the cases of problems with the data, the files and crawler were studied and when needed the data was recollected. Appendix A shows examples
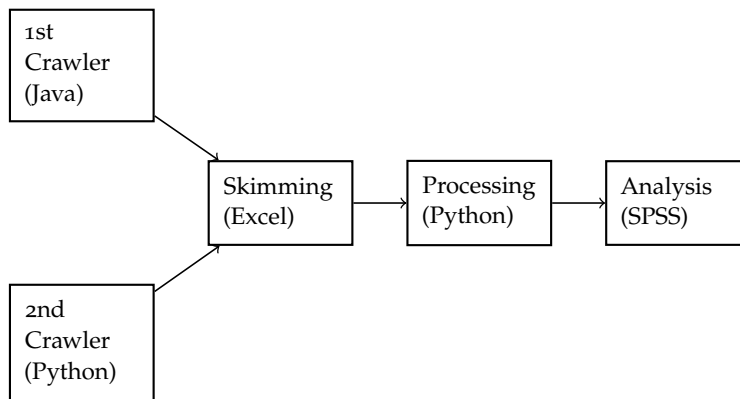
Figure 3.3: An example of the typical data processing process used.

of the raw data crawled from the three mobile application ecosystems.

In the second phase of the data processing, a data transformation, coding and selection were done. When needed, we utilized custom-made Python scripts that went through the data mass and included those applications in a further study that fulfilled pre-set criteria. For example, in P-V we studied applications and developers that are present at least in two of the Big Three mobile application ecosystems. In that study, we used Levenshtein distance to measure the similarity of two names [see Levenshtein, 1966]. If the pre-defined similarity index was exceeded, two names were paired. An example of frequent data transformation, instead, is a coding of textual installation classes (*e. g.* '1–5', '5–10', '10-50' *etc.*) to numerical ones ('1', '2', '3' respectively).

An approximate string matching is needed as the names often differ in ecosystems, e. g. 'Rovio' and 'Rovio Mobile Inc.'

The results of the second phase are saved in a new .csv file that is then given as an input for IBM SPSS Statistics statistical software for statistical calculations. In the studies, we utilized versions 19 and 21 of the core software as well as the SPSS Modeler 14.2 extension. We also often utilized Python scripts to calculate frequencies due to a large number of data points and the slowness of the statistical software to calculate operations for the dataset.

3.2.3 *Limitations of web crawling*

Using web crawling in data collection raises some concerns for the validity and reliability of the study. The main concerns are the reliability of the data and the coverage of the collected sample. In the following, I will discuss the limitations of using web crawling as a data collection method specifically in this domain.

Foremost, it should be noted that the crawling was done in a server located in Finland and therefore applications might have been filtered out due to the location. Therefore datasets might be biased by only containing applications offered for that location. *E. g.*, for eWOM studies this might cause a bias due to the Finnish culture. This is noted in the interpretation of the results, *e. g.*, in P-IV.

Second, in this domain, the data offered by the marketplace is provided by the orchestrator and it is valuable for their marketing purposes. There is little to no way to guarantee that there were no manipulations. Therefore, special care is needed in interpreting the results of the data analysis.

Besides these reliability issues, it should be noted that collecting all applications from the marketplace is a hard task, as often there is no central listing of all products. Therefore, we have relied on different techniques to ensure that a reasonable number of applications will be included in the sample. Furthermore, the data collection techniques most likely overemphasize popular applications and underemphasize unpopular ones, *i. e.* those that have been installed only a few times. *I. e.*, in this study, the used sample might be biased towards popular applications at the cost of less-popular ones.

Fourth, a flaw in the implementation of a web crawler might affect the selected sample. To tackle this, we have carefully tested the developed data collection platforms before use. In addition, we monitored the crawlers' reports during the collection phase and when needed, we stopped crawling to improve the programme. For the second crawler, we relied on well-known and used open-source components to minimize flaws caused by the third parties' components.

"Reliability is the degree to which the finding is independent of accidental circumstances of the research, and validity is the degree to which the finding is interpreted in a correct way."
[Kirk and Miller, 1986, 20]

4

EMPIRICAL STUDIES AND FINDINGS

Because the people who are crazy enough to think they can change the world are the ones who do.

—Apple's "Think Different" commercial, 1997

"Here's to the crazy ones. The misfits. The rebels. The trouble-makers."

This chapter presents briefly the original publications included in this thesis. It also discusses the research objectives and questions set for the dissertation.

4.1 INDIVIDUAL PUBLICATIONS

In the following, I will present the six individual studies that compose this thesis. For each publication, I will briefly discuss on their objectives, research method used, results achieved and their contribution to this thesis. In addition, I will state the author's contribution to each of the studies.

4.1.1 *Publication I*

The publication titled *The Emerging Application Ecosystems: an Introductory Analysis of Android Ecosystem*, by Hyrynsalmi, Suominen, Mäkilä and Knuutila [2014c], presents the data acquisition platform used in the studies and some initial results from the analysis. The purpose of the study was to analyse the emerged Google Play (then Android Market) mobile application ecosystem.

In the study, we collected data from Google Play with a web crawling platform. The dataset was collected twice for this study, first in December 2011 (339,861 applications) and again in June 2012 (366,938 applications). The aim of repetitive data acquisition was to validate gathered data so that a single measurement point would not mix the results.

The study first presents the data acquisition platform and lays cornerstones of this thesis. Descriptive statistics show that a ma-
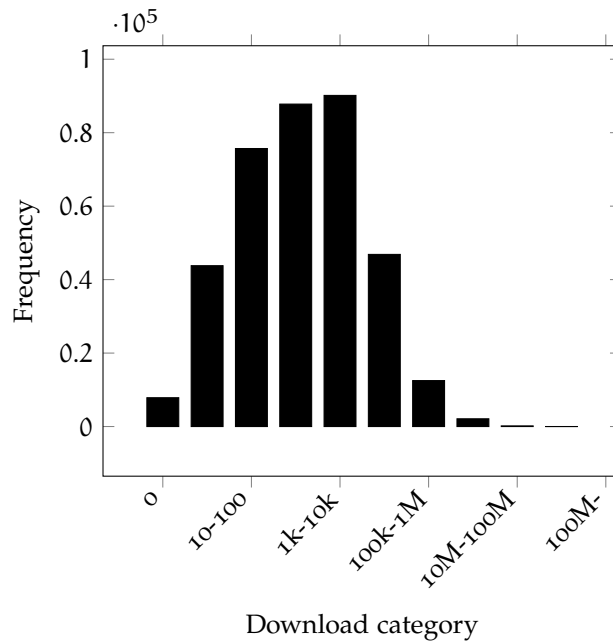
Figure 4.1: Distribution of mobile applications' installation categories of Google Play in a logarithmic scale (June, 2012). In the figure, half-logarithmic steps (*e.g.* '10–50', '50–100') are combined into main steps (*e.g.* '10–100') in order to create a more coherent picture.

jority of applications have been downloaded only a few thousand times (Figure 4.1)—while, at the same time, Google announced that 1.3 million devices are activated daily and the total number of devices reached 500 million in September 2012 [Shankland, 2012]. Only a mere 4% of applications were installed over a million times. In the article, we studied four common assumptions linked to the emerging mobile application ecosystems: 1) direct software sale, 2) the free trial publishing model, 3) personalization of phones, and 4) the correlation of eWOM's valence dimension to the number of installations in the ecosystem.

The study contributes to RQ1.2 by showing that a majority of the applications subject to charge have generated considerably small incomes from the marketplace. Even though the marketplace supports the Long-tail effect, the revenues generated during the lifetime of these applications remain small. Connecting

to RQ2.1, the study shows that there were no positive correlations between the applications' popularity, measured by installations, and valence.

The author is the primary contributor of this article. He developed independently the data acquisition platform used in this study, and later he independently recreated the matching scripts used to identify free trial applications. The author of this thesis was responsible for designing, analysing and reporting the study together with other contributors.

4.1.2 *Publication II*

The publication titled *Revenue Models of Application Developers in*
Android Market Ecosystem, by Hyrynsalmi, Suominen, Mäkilä, Järvi and Knuutila [2012b], focuses on the revenue models utilized by the ISVs in the mobile application ecosystem. The purpose of the study is to determine how ISVs monetize their products as P-I shows that only a fraction generate considerable income from the direct sales.

In the study, we used a random sample of one hundred applications. To omit hobby applications and those too young for stabilized income, a sample was selected among the applications that have more than 1,000 installations (34.5% of all). The selected applications were studied by three researchers. We installed the applications for several Android devices, studied the webpages of developers and gathered information to study the applications.

Our work presents the results of revenue stream and business rationale analysis to understand Google Play beyond the number of applications. Based on the comments and questions received after the presentation of the article, the author reviewed the collected datasets and found one application that uses a donation revenue stream that was not present in the framework of Coursaris and Hassanein [2002]. Table 4.1 presents updated results of revenue streams studied.

The study contributes to RQ1.1 by showing the first categorization of ISVs enticed to the marketplace. As we noted during the analysis of P-I and P-II, treating developers as one homogeneous group confuses the results. This work was continued in P-III. The study also contributes to RQ1.2 by investigating how

Table 4.1: The frequencies of the revenue models in the 100 studied applications and an example of an application utilizing the respective revenue stream. Note that one application can utilize multiple revenue streams. [Hyrynsalmi *et al.*, 2012b, adapted]

REVENUE MODEL	EXAMPLE	FREQ.
Paid download	Cut the Rope	4
Part of Free-Trial model	Fruit Ninja HD	18
Advertising	Angry Birds	37
Subscription	Spotify	10
In-application purchase	Smurf's Village	1
Hosting	101 ESPN by AirKast Inc.	5
Donation	Minimalistic Text (donate)	1
None[†]	Ajax Clock Widget	47

[†] No evident revenue stream was found.

ISVs monetize their products. We studied also some alternative new approaches, *e. g.*, applications' connections to cloud services and revenues gathered through these services. Nevertheless, the results show that, among the selected cases, there were a considerable amount of applications—and developers—without a clear monetization plan.

The author is the main contributor of this article. He, together with other authors, was responsible for and participated in designing the study, collecting the data and analysing and reporting the research.

4.1.3   *Publication III*

The publication titled *Sources of Value in Application Ecosystems*, by Hyrynsalmi, Seppänen and Suominen [2014b], studies value creation in mobile application ecosystems. The purpose is to further understand what kinds of ISVs are within the ecosystem and what their businesses are.

To assess value creation, we operationalize Amit and Zott's [2001] framework. We classify the application developers of the Big Three ecosystems that have an application in the top listings
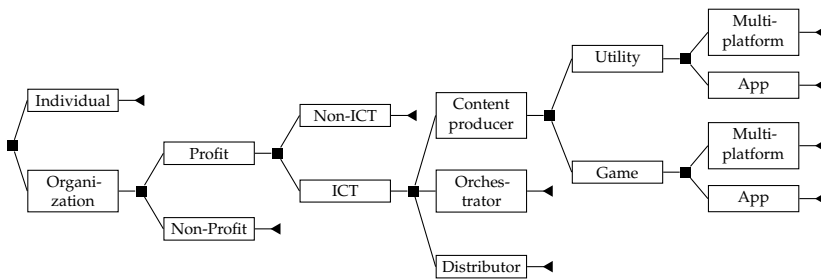
Figure 4.2: A decision tree used to categorize the top ISVs of mobile application ecosystems [Hyrynsalmi *et al.*, 2014b, adapted]

with the decision tree presented in Figure 4.2. With this classification, we selected three case study companies from each group that were assessed by the researchers.

Our study shows that the value creation mechanisms used by the ISVs vary among the groups as well as between individual ISVs. The study also shows gaps in value creation mechanisms found and suggests that there might be room for new innovation in applications.

The study contributes to RQ1.1 by presenting a fine-grained classification of ISVs connected to a mobile application ecosystem. The framework is then applied to select companies for in-depth study. Related to RQ1.2, the study shows the different value creation mechanisms used by the ISVs.

The article is a result of equal contributions of all three authors, while the author of this thesis was responsible for most of the paper. The author of this thesis participated in the designing, data collection, analysing and reporting the study together with the other authors.

4.1.4   *Publication IV*

The publication titled *Busting Myths of eWOM: The Relationship of Customer Ratings and the Sales of Mobile Applications*, by Hyrynsalmi, Seppänen, Aarikka-Stenroos, Suominen, Järveläinen and Harkke [2014a], analyses the impact of consumers' feedback on the sales of applications in Google Play. The aim is to investigate whether eWOM works as an indicator of future sales or not. In other words, the article aims to study whether eWOM optimization is worth the effort.

Table 4.2: Results of eWOM's correlation with sales in short and long timespans [Hyrynsalmi *et al.*, 2014a, adapted]

HYPOTHESIS	SHORT	LONG
Valence correlates positively with sales	True	True
Volume of ratings correlates positively with sales	False	True
Number of installations correlates positively with sales	False	True
Variance together with high average of ratings correlates with sales	True	N/A
Valence of ratings correlates better with sales when the price of the product grows	False	True

In the study, we used three datasets that were crawled in December 2011, February 2013, and May 2013. By using these three points, we studied eWOM's effect on sales in short and long timespans. The correlation between initial eWOM values and advancements in the rank of installation is studied.

The results are shown in Table 4.2. Our study found support that valence correlates with the sales in both the short and long timespans while volume of ratings and previous number of installations correlated positively only in the long timespan. We find support for Sun's [2012] theorem; however, the correlation coefficients are small and near zero although the results are statistically significant. Nevertheless, we show that the valence of ratings seems to correlate better with the sales when the price of products grows. In other words, eWOM seems not to be as important for the cheap applications as for the high-priced. However, the finding was supported only with a longer timespan.

The study contributes to RQ2.1 by showing that eWOM's effect seems to be greater for costly applications than for cheap ones. Furthermore, it showed that the valence, *i. e.* the average of ratings, is the most stable indicator. For RQ2.2, the study finds only weak statistical support. However, in the manual inspection of comments, it seems that the studied applications with high variance and valence were, indeed, products that some loved and others hated.

The article is a theoretically extended, re-analysed and rewritten version of Hyrynsalmi *et al.* [2013] with a newer dataset. The

author of this thesis is the primary contributor of the study. He was responsible for the data collection and design of the study. Together with the other authors, he contributed to the analysis and reporting of the research.

4.1.5 *Publication V*

The publication titled *The Influence of Application Developer Multi-Homing and Keystone Developers on the Competition between Mobile Application Ecosystems*, by Hyrynsalmi, Suominen and Mäntymäki [2014d], focuses on platform competition and multi-homing in the mobile application ecosystems. The objective is to assess the theory of Sun and Tse [2009] in this context.

In the study, we used the data gathered from the Big Three mobile application ecosystems. We implemented a script that matches applications and their developers from different ecosystems. The result of this script is used to analyse the seller-level and platform-level multi-homing rates of mobile application markets.

The study shows that when we focus on all applications and developers involved in the ecosystems, the App economy seems to be a single-homing market. From all, only 1.7%—3.2% of applications and 5.8%—7.2% of developers were multi-homing. According to Sun and Tse [2009], this indicates that one platform will finally rule all users. However, when we study the keystone developers and superstar applications, we note that a remarkable portion of them are multi-homing: 39.2% of applications and 42.7% of developers. This, according to Sun and Tse [2009], suggests that the market can support several competitive ecosystems.

The study contributes to RQ3.1 by developing means to estimate seller-level and platform-level multi-homing. Figure 4.3 illustrates seller-level multi-homing among Apple App Store, Google Play and Windows Phone Store developers. The study, furthermore, shows that while the market as a whole seems to be a single-homing market, the producers of the mobile content used are more important. Figure 4.4 shows the relative amount of top developers' shares of total installation counts in Google Play, *i. e.* a rather small amount of developers produce most of the installations.
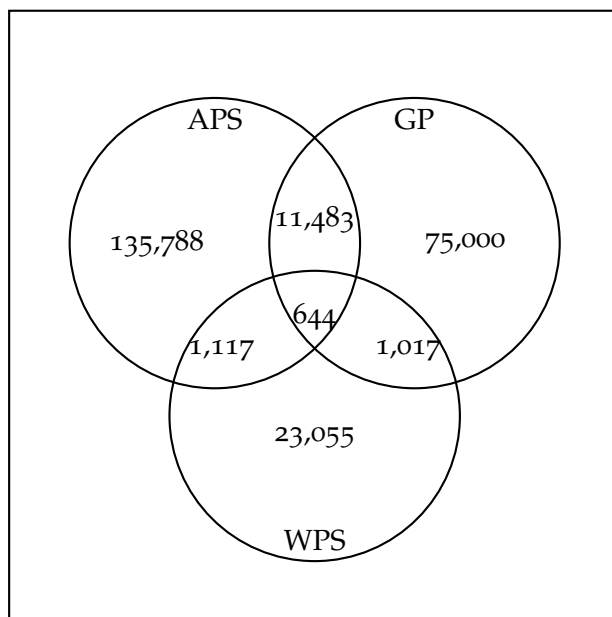
Figure 4.3: Seller-level multi-homing in Apple's App Store (APS), Google Play (GP) and Windows Phone Store (WPS) [Hyrynsalmi *et al.*, 2014d, adapted].

Related to RQ3.2, the study analyses the competition dynamics of mobile application ecosystems. The result from the market analysis indicates that the mobile application ecosystems can be considered both a single-homing and a multi-homing market. According to Sun and Tse [2009], the first-named forecasts that the market would saturate on a single dominant ecosystem. The same theory also predicts that a multi-homing market can sustain several ecosystems. When the keystone developers' importance is noted, the mobile application ecosystems seem to be a multi-homing market. This would explain why today's market seems to be able to support more than one ecosystem.

In addition, the study briefly discussed on the evolution of relative bargaining powers in the mobile ecosystem. By using Moore's [1993] evolution of business ecosystem as a starting point, a struggle for leadership would be expected. The results of the study imply that the bargaining power of the keystone developers over the ecosystem orchestrators will increase as their presence is increasingly important for the ecosystem.
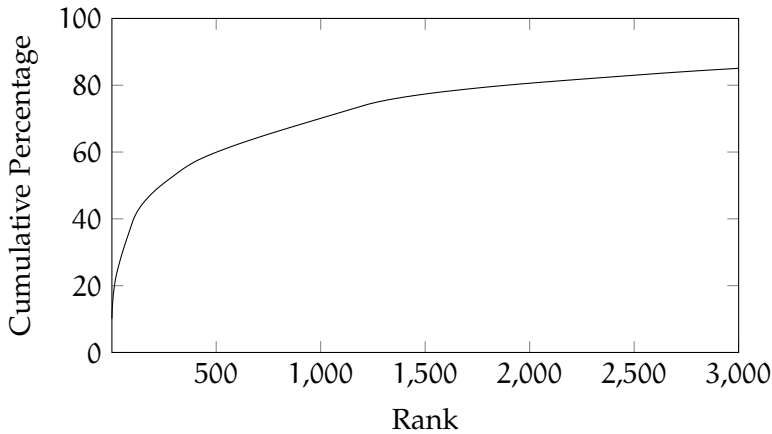
Figure 4.4: The cumulative percentages of the developers' sum of numbers of installations for each of his or her applications in descending order in Google Play [Hyrynsalmi *et al.*, 2014d, adapted]. Only the first 3,000 developers, out of nearly a hundred thousand, are shown.

The author of this thesis is the primary contributor of the study. He was responsible for data gathering and analysis. In addition, he contributed to the design and reporting of the study.

4.1.6 *Publication VI*

The publication titled *Challenges in Entering Application Markets among Software Producers in Developing Countries*, by Tuikka, Hyrynsalmi, Kimppa and Suominen [2013], discusses the impact of the App economy on software developers of developing countries. The article aims to assess the notion made in P-I—that while the average revenues from direct application sales are low for a western developer, they should be highly lucrative for a developing-country software developer.

Thus, the paper studies locations of the 426 most successful application developers, whose applications were among the top listings in the beginning of 2013, and shows that a majority of the applications are developed in western countries (Table 4.3). The data was manually collected from, *e. g.*, the companies' web pages, their Twitter accounts, and public services such as company databases. Nevertheless, among the tops there are developers from BRICS countries as well as from Thailand and

Although the method is the same in P-V, the dataset used is newer.

BRICS = Brazil, Russia, India, China, and South Africa.

Indonesia. The study, in addition, presents a conceptual framework for addressing issues hampering developing-country ISVs from entering mobile application markets.

Table 4.3 also shows the number of the most successful mobile application developers per one million citizens per home country. The products of Finnish mobile companies are occupying the top ranks of application listings and there have been analyses on the reasons [see *e. g.* Kuittinen, 2013]; the table confirms that only Luxembourg, Cyprus and Sweden perform better than Finland in this measure.

The population data of 2013 is from United Nations [2013].

The study contributes to RQ1.1 by analysing more the ISVs that participated in the App economy. It, furthermore, answers the question asked in the earlier papers and states that developing-country application developers are a promising group for further work. In addition, the study aimed to underline that a small change in one part of the system has an impact also on other parts. In other words, while the new centralized application distribution channels might, in a naïve view, have added new revenue streams and tighter competition for a western-world software developer, they hopefully open new worlds for developers with more limited resources.

Cf. *Systems thinking*

The author is the second main contributor of this article together with M. Sc. Tuikka. The author was mainly responsible for collecting the data and analysing it in addition to participating in the design and reporting of the study. Furthermore, the initial idea was presented by the author.

4.2 RESEARCH OBJECTIVES AND RESULTS

The aim of this work is to study companies selling software or services in mobile application marketplaces and, thus, advance our understanding of the mobile application ecosystems. To reach this aim, three research goals and six, a bit more concrete, research questions were set. In the following, I will discuss the questions and then the limitations of the study.

Table 4.3: Countries hosting the most successful mobile application developers [Tuikka *et al.*, 2013, adapted and fixed].

	COUNTRY	ALL	APS	GP	WPS	ISV/1M
1.	United States of America	186	97	86	57	0.59
2.	United Kingdom	25	12	8	7	0.40
3.	China	18	3	6	10	0.01
4.	Canada	12	7	7	4	0.35
–	Sweden	12	8	6	1	1.27
6.	Russian Federation	10	1	4	7	0.07
7.	France	9	3	5	3	0.14
8.	Japan	7	3	7	2	0.06
–	Australia	7	4	2	3	0.31
10.	Switzerland	6	0	4	3	0.76
11.	Germany	5	2	0	3	0.06
–	Austria	5	2	1	2	0.60
–	Finland	5	4	2	3	0.93
–	Republic of Korea	5	1	5	0	0.10
15.	New Zealand	4	2	1	2	0.90
–	Spain	4	1	2	1	0.09
–	Brazil	4	1	1	3	0.02
–	Norway	4	1	2	2	0.81
19.	Poland	3	0	1	2	0.08
–	Israel	3	1	3	0	0.39
–	Italy	3	0	1	2	0.05
–	India	3	0	0	3	0.00
23.	Netherlands	2	0	1	1	0.12
–	Denmark	2	1	2	0	0.36
–	Cyprus	2	2	1	0	1.78
–	Thailand	2	0	2	0	0.03
–	Singapore	2	1	0	1	0.39
–	Ukraine	2	1	1	1	0.04
29.	China, Hong Kong SAR	1	0	1	0	0.14
–	Indonesia	1	1	0	0	0.00
–	Belarus	1	1	0	0	0.11
–	Taiwan	1	1	0	0	
–	Bahrain	1	0	1	0	0.76
–	Estonia	1	0	1	0	0.78
–	Czech Republic	1	0	0	1	0.09
–	Hungary	1	1	0	0	0.10
–	Bulgaria	1	0	1	0	0.14
–	Serbia	1	0	1	0	0.10
–	Kuwait	1	1	0	0	0.31
–	South Africa	1	0	0	1	0.02
–	Luxembourg	1	1	1	0	1.95
	Not known	61	11	25	26	

APS = Apple's App Store, GP = Google Play, WPS = Windows Phone Store

4.2.1   *Results*

The discussion of results is divided according to the set research goals. Thus, RG1, RG2, and RG3 are discussed in the subsections 4.2.1.1, 4.2.1.2, and 4.2.1.3, respectively.

4.2.1.1   *First research goal*

RG1   *Finding out who the software producers are and how they are creating value and monetizing it in the mobile application ecosystems.*

    RQ1.1   What are the different kinds of ISVs that produce mobile applications, and what countries do they come from?

    RQ1.2   How do application vendors create value and monetize their products?

P-I showed that capturing value with paid installations seems not to pay off for the majority of ISVs; however, we also noted that there is a need not to treat all developers as a homogeneous group. As discussed in Chapter 2, there have been studies to identify and classify the actors of an ecosystem. For SECOs, the most comprehensive work was done by Manikas and Hansen [2013b]. However, this classification remained a bit too scarce for ISVs participating in the mobile application ecosystems. Therefore, in the publications P-II and P-III we have aimed to divide ISVs into more fine-grained groups.

RQ1.1   In P-II, we studied revenue streams used in Google Play. Furthermore, we categorized the developers by the business strategy identified and studied the connections between the strategies and revenue streams. From these, it seems that paid applications are used often only by individual application developers. In the study, we noted a large number of developers without clear revenue streams. However, their publishers seem to be professional companies that are using revenue sources that were not present in the framework utilized in the study. In order to understand the ecosystem and its dynamics, the actors need to be further clarified.

Therefore, in P-III we studied the top developers in greater depth. We identified 7 different groups of ISVs: 1) Individual

application developers, 2) Non-profit organizations, 3) Non-ICT companies, 4) Application distributors, 5) Ecosystem orchestrators as application vendors, and 6) Game developers as well as 7) Application developers. The last two were, in P-III, divided into mobile and multi-platform vendors. The classification is not rigid; for example, successful one-man businesses have established companies and recruited more employees to support the growth. However, this classification allows us to study the developers more.

In addition, in P-VI we studied the locations of the developers' headquarters. Not surprisingly, a majority of the companies are located in the highly industrialized western countries such as the United States of America and the United Kingdom. However, among the locations of the developers of the most installed applications there are also countries such as China, Russian Federation and Brazil.

When the classification of the ISVs used in P-III is combined with the location data collected for P-VI, and missing countries are collected similarly as in P-VI, the classification presented in Table 4.4 is the result. Ecosystem orchestrators and non-profit organizations are not listed, as all of the former and a few of the latter are located in the USA. Furthermore, the latter ones were often impossible to assign to one country. As the table shows, there are only a few countries supporting companies that are not mainly working in the software industry. Furthermore, most of the one-man businesses developing mobile applications that reached the top lists are located in the USA. Interestingly, only a handful of them, the one-man businesses, are running their businesses in other countries.

To understand the value creation of ISVs, in P-III we used the framework presented by Amit and Zott [2001] to analyse the value creation by case study subjects in the mobile application ecosystems. We used the presented ISV classification model to identify case study subjects from the developers of the most installed mobile applications. A study of these developers reveals a wide variety of value creation mechanisms used. While we focused on the value creation, and not on the value capture, the study, to some extent, might also explain the lack of revenue streams found in, *e. g.*, P-II as among the top applications there

RQ1.2

Table 4.4: The ISVs producing the most sought applications classified according to the presented application producer classification and the location of headquarters. The types 'Ecosystem orchestrator' and 'Non-profit organization' are not shown as they were either located in the USA or the location could not be detected. Only the first 13 countries are listed.

COUNTRY	GAME DEVELOPER	UTILITY APPLICATION DEVELOPER	SINGLE DEVELOPER	PUBLISHER	NON-SOFTWARE COMPANY	SUM
United States of America	56	73	15	4	31	179†
United Kingdom	9	13	2	1		25
China	5	9	1	1	1	17‡
Canada	7	5				12
Sweden	9	1	1		1	12
Russian Federation	5	3	2			10
France	4	3	2			9
Japan	3	4				7
Australia	4		2	1		7
Switzerland	1	4		1		6
Germany	2	1	1		1	5
Austria	1	2	1		1	5
Finland	4	1				5
Not known	17	30	8			55§

† The Ecosystem orchestrators and a few non-profit organizations—such as LifeChurch.tv, an American evangelical church—are not shown.

‡ A non-profit organization is not shown.

§ Six ISVs could not be classified due to the lack of information.

are clearly complementary applications to the main products that are not available in the App economy.

To conclude, there is a wide variety of ISVs involved in the mobile application ecosystems and some of them are clearly not doing business in the App economy. For example, there are churches spreading their messages and retail stores offering rewards for their loyal customers via mobile media. Furthermore, as discussed in P-II, there are lots of applications in the marketplace that might have been built without clear monetization models. The aim might have been to launch an application and pray for its success. After the masses have found the application, the product will be monetized in one way or another.

4.2.1.2 *Second research goal*

RG2 *Explaining how consumer-generated ratings, such as eWOM mechanisms, affect sales (measured by the number of installations) in a mobile application ecosystem.*

RQ2.1 What kind of effect does a high valence or volume of consumer ratings have on the future sales of a mobile application?

RQ2.2 Can a high valence together with a high variance indicate sales improvement of a niche application?

As De Maeyer [2012] discussed and Table 2.7 shows, the results from the previous studies on eWOM's effect are, to some extent, contradictory to each other. In our studies, we found that the valence correlates the stablest with the sales of applications, measured by installations. While the volume of ratings and previous number of installations also have positive correlations with sales in the long-term study, the correlation coefficients for the short time period were negative. Therefore, in relation to RQ2.1, the answer is positive for the valence dimension but negative for the volume dimension.

In addition, we addressed the variance of eWOM ratings according to the theory by Sun [2012] in P-IV. We found support for the theorem's operationalization ($\rho[224, 178] = 0.014$ ($p < 0.001$)). However, the variance of consumer ratings alone correlates better ($\rho[224, 176] = -0.068$ ($p < 0.001$)) than the theory's operationalization in the study.

To understand the rationalities of the theory, we studied a dozen applications, which had a high valence and variance, and their comments by hand. It seems that these applications were niche products based on the comments left by consumers. This in-depth analysis of one application also revealed that while most of the comments left by consumers were negative, the majority of the numeral ratings were positive. However, for RQ2.2, it seems a high valence together with a high variance do not indicate sales improvement well; nevertheless, it seems possible that the variance can be used to identify niche products.

RG2   Based on our results, it seems that consumer-generated eWOM on a mobile marketplace can have a positive effect on the sales in a mobile application ecosystem. Furthermore, our study shows that eWOM seems to be more effective for costly applications than for cheap ones over a long time period. However, the correlation coefficients in the studies remain low, most likely due to E. g. *visibility in* large datasets, and there might be latent variables, that cannot *social media* be directly observed, which would explain the sales better. Nevertheless, the eWOM mechanism in the ecosystems allows direct communication between an ISV and consumers that can be used, in every case, to listen and improve the application.

4.2.1.3   *Third research goal*

RG3   *Clarifying how multi-homing affects the mobile application ecosystems.*

RQ3.1   What are the multi-homing rates at the seller level and at the platform level at this domain?

RQ3.2   How does multi-homing affect the dynamics of a mobile application ecosystem?

Sun and Tse [2009] modelled two-sided markets and argued that there are remarkable differences in the outcome of single-homing and multi-homing markets. However, from the developers' side there was only a little evidence regarding whether the mobile application ecosystems are single- or multi-homing markets [*e. g.* Boudreau, 2007; Idu *et al.*, 2011].

RQ3.1   In P-V we analysed the ISVs of the Big Three mobile application ecosystems and showed that overall platform-level (1.7–3.2%) and seller-level (5.8–7.2%) multi-homings are small. How-

ever, when we focused on the superstar applications (39.2%) and keystone developers (42.7%), the multi-homing rates are considerably higher. While the overall results indicate single-homing markets, a small set of ISVs produce a large set of installed content (see Figure 4.4), and they are heavily multi-homing.

This result, with Sun and Tse's [2009] theory of platform competition, indicates that the market should be able to sustain several parallel ecosystems. In addition to the platform competition, this sets implications for the ISVs developing for the ecosystems. That is, the multiple alternatives give developers options to decide in which and how many ecosystems to join.

Table 4.5 analyses interests, incentives as well as constraints of the mobile application ecosystem actors. It seems that multi-homing is an advantage, regardless of porting costs, for an ISV as it reduces dependency on an ecosystem orchestrator. However, the application market seems to have demand for brand applications and, thus, an ecosystem's future might depend on these products. This creates interesting dynamics for the market, which might give a higher relative bargaining power for the ISVs.

According to the original business ecosystem evolution framework by Moore [1993], companies participating in the business network will eventually start to fight for the leadership of the ecosystem. In P-V, we discussed how multi-homing behaviour of ISVs would impact the struggle. Based on our argumentation and above analysis of interests, incentives and constraints, it seems that multi-homing might strengthen the position of ISVs and weakens the position of the ecosystem orchestrators. However, a shift in the relative bargaining power in the mobile ecosystem has been argued to be seen earlier [see *e. g.* Lemstra *et al.*, 2009].

Multi-homing as a mechanism of two-sided markets has implications for the mobile application ecosystem and its actors. According to the theories of multiple two-sided markets' competition, multi-homing of sides of the market would affect the outcome of the battle. Currently, for the contender ecosystems multi-homing has a positive effect as it may weaken the position of the leading ecosystems. Furthermore, orchestrators' work in luring new and established developers to publish for the ecosystem might strengthen ISVs' position. Nevertheless, these results are only opening a new research avenue on the impacts of multi-

Table 4.5: Interests, incentives, and constraints of participating in a mobile application ecosystem of different actor groups in the mobile ecosystems.

	ECOSYSTEM ORCHESTRATOR	APPLICATION DEVELOPER	MOBILE NETWORK OPERATOR	CUSTOMER
Interests	Gather the largest customer base	A large potential customer base; Sustainable business [Anvaari and Jansen, 2013; Waltl, 2013]	A larger customer base; Strengthen other revenue streams [West and Mace, 2010]	Features important for a customer; Public opinion
Incentives	Support the main business strategies [Schultz et al., 2011]	Expand the market share	Selling more data subscriptions and other services [West and Mace, 2010]	Add value in everyday use
Constraints	Lack of proper mobile content; Lack of proper devices	Development and marketing costs [Holzer and Ondrus, 2011]	Marketing costs; Tie-in sales contracts	The cost of a mobile device; The cost of changing the ecosystem; On average, 1-2 devices per platform per customer

homing in mobile application markets, and further studies will most likely reveal new insights into the dynamics of the markets.

4.2.2 *Limitations*

Naturally, this thesis has its limitations. First and foremost, this thesis relies on the data collected from the marketplaces. This sets some limitations on the reliability of the data as discussed earlier. *I.e.*, the orchestrator has control over the data, and the data can be partial as well as representing only a biased sample of the marketplace. From the reliability of the data it should be noted that the collected data is valuable marketing material for its publisher. Furthermore, there are no means to verify the results outside of the crawled web page as the publisher of an application receives the information from the same source. This sets limitations the reliability of the results and, therefore, further work is needed to verify the results via triangulation.

See Subsection 3.2.3.

In addition to the reliability, there are some limitations to the representativeness of the collected sample. While, as discussed in 3.2.1, we have aimed to include all applications from the marketplace, it is likely that we have collected only a subset of all applications. For example, the location of the web crawling platforms' server can filter out applications that are not meant for this market area. Furthermore, the web crawling favours links that appear often, and URLs that are not reachable through other pages are hard to find. Thus, the collected sample is likely biased towards the popular applications at the cost of less-popular ones. In practice, this would mean applications that have not been installed even once. Nevertheless, we have noted this limitation in the interpretation of the results in the individual articles.

Second, in P-II and P-III we used samples of the population. In P-II we used a random sample among the applications that have been installed over one thousand times. Although the sample selection was randomized, it is possible that there is a bias in the selection due to the low number of cases studied. However, it is believed that one hundred randomly selected applications were enough to represent the population. In P-III, we aimed to select representative cases from the developers of the top applications. The selection was guided by the crafted ISV classification framework.

The third limitation is the chosen research methods. Although in this domain a more qualitative approach could have been used, we justify the selected methods with our focus on a typical ISV participating in the marketplace. For example, interviews and surveys would have limited results only to a reachable set of population. Nevertheless, in further work, a more qualitative research method should be used to study the App economy. *E. g.*, the decision processes in application stores by end-users could be studied with experimentation. Ideas for further work are discussed in Section 2.3.

In a recent article, Lin, Lucas, and Shmueli [2013] discussed the problems of the large datasets in IS studies. With a study population large enough, relying only on the p-value is dangerous as the value will easily be relatively small due to the amount of samples. In other words, the low p-values in this study might be artificial due to tens and hundreds of thousands of applications included in statistical calculations. In the publications included in this dissertation, the researchers have been aware of this limitation and followed the guideline by Chatfield [1995, 70]: *"– the question is not whether differences are 'significant' (they nearly always are in large samples), but whether they are interesting."* That is, the focus has been on the practical significance of the results.

In addition to the limitations, generalization of the results needs to be discussed. According to Lee and Baskerville [2003], generalization refers to the validity of a theory in a different context where it was not empirically tested. Lee and Baskerville [2003] divided it into four parts according *from* where (empirical or theoretical statements) and *to* where (similarly, empirical or theoretical statements) the results are generalized. In the following, I will discuss the generalization of our results.

Concerning the type of *from* empirical statement *to* empirical statement' generalization, Lee and Baskerville [2003] mainly discuss the representativeness of the sample. In the studies, where we used web crawling, the sampling method was to include all products from the population that we could find. Although the sample is not complete, *i. e.* the whole population is not included into it, it certainly contains by far most of the applications available. However, the applications that are not included are most likely those that are installed only a few times and are hard to
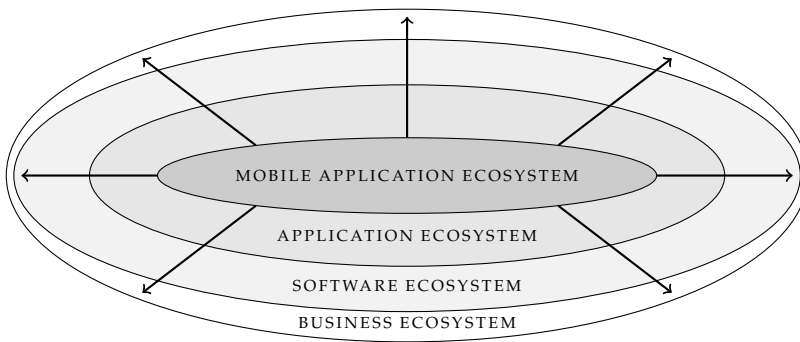
Figure 4.5: This study's sphere of applicability

reach. The lack of them, in the sample, might bias the results towards the better earning applications.

In this type of generalization, there is also another issue worth addressing: to what limits can the results from a mobile application ecosystem be generalized for other types of SECOs. First, as argued in this thesis, the mobile application ecosystems have domain-specific features, *e. g.* high dependency on the physical devices and their success, whereas a pure SECO does not have this kind of millstones. To tackle this issue, I will propose a '*sphere of applicability*' for the results [the approach is adapted from Salminen, 2014]. This is illustrated in Figure 4.5.

The results from a single mobile application ecosystem can, at the easiest, be generalized to the other mobile application ecosystems. The second layer of the sphere is an *application ecosystem*, *i. e.* a SECO that otherwise is similar to the mobile application ecosystem but differs from the type or requirement of a device. Such application ecosystems are, *e. g.*, Apple's Mac App Store and Windows Store. While currently these two marketplaces do not offer the myriad of applications that their smart device counterparts do, the marketplace use rather identical logic. However, a generalization of the results for these requires the study of the differences in the domain-specific characteristics.

An interesting study of its own would be to address why these marketplaces haven't grown as exponentially as the mobile ones.

The second layer of the sphere of applicability is a SECO. As the usable revenue streams, the roles of actors and even the concept of a product can more or less differ from the mobile application ecosystems, using the results in this context needs careful analysis. Finally, the outmost layer is the business eco-

system, where the result of, *e. g.*, multi-homing might be applied. However, again, a careful consideration is needed.

IMPLICATIONS AND CONCLUSIONS

> *'Gee, what have I done—have I done enough for the world*
> *to justify having been here?*
>
> — Dr. Maurice R. Hilleman, a vaccine developer, who saved
> more lives than any other scientist in the 20th century

. . . and still counting.

This chapter will discuss the practical implications of this thesis. In addition, some implications for the theories are reviewed and ideas for further work are discussed.

5.1 PRACTICAL IMPLICATIONS

The hype of the App economy is built upon a handful of success stories. These are, *e. g.*, game developers such as Rovio Entertainment and SuperCell with hundreds of millions in revenue gathered and superstar applications launched by individual developers such as 'Flappy Birds' from Vietnam or 'Hill Climb Racing' from Finland. Furthermore, there are also a few success stories of utility applications (*e. g.* WhatsApp). However, although these given examples have earned fortunes for their establishers, it is good to remember that these companies are literally a few from hundreds of thousands.

While this study did not aim to find a formula for success in the App economy, it, hopefully, is able to give some practical implications. First, among other studies, we showed that direct sale of applications seems not to work for the majority of applications in the mobile application ecosystem. As Rovio Entertainment's Mighty Eagle Peter Vesterbacka said: *"Nobody pays on Android"* [Chen, 2011]. However, certain niche applications, such as road maps, have been able to gather considerable revenue from application sales. In contrast to these, there are hundreds of applications without any sales.

See also Vannieuwenborg et al. [2012] for some guidelines.

In addition to the clearly commercial freemium applications or complementary applications to the main products and services, there are lots of cost-free applications. There are some

reasons why there are many free cases in the ecosystem. They can be easily divided into the following two general classes: 1) There were never intentions to earn. The application is a niche product meant for a small set of people, or it might have been just built to improve the developer's CV, as a commercial of the developer's abilities, to gather fame or just to improve the developer's skills or even to spread an ideological message. 2) There were intentions to earn; however, the business case was missing and when the application failed, it was just launched free for everyone. That is, when an application did not succeed commercially, it might have been offered free to reach some of the advantages listed in the first part.

However, note the difference from, e. g., banking applications that do not generate revenue per se but support other revenue mechanisms.

For game developers, it seems that different freemium monetization strategies are the most useful—at least for the superstars. However, there is only scarce, to the author's knowledge, information about how well the in-application payments produce for the ISVs, on average, if the application does not reach the top lists. For the developers of utility applications, monetization might be even harder as often the ideas are reproduced, with only a modest amount of work, when the value proposition is not unique enough. For utility application developers, building a brand or a network that cannot be copied, *cf.* Instagram and WhatsApp, might be the key for surviving.

Perhaps due to the issues just discussed, lots of developers seems to use, to borrow a term from football, the 'Long ball' tactic: They publish an application, or a dozen, and pray for a success. This was rather visible in applications studied for P-II where lots of products were without a clear monetization plan. In addition, this publishing strategy seems to be used by many mobile game developers. Furthermore, the previously mentioned examples of success stories have used this kind of publishing strategy and produced superstars. However, as it currently seems that Google Play marketplace is not a Long-tail market but a Superstar market [Zhong and Michahelles, 2013], this publishing strategy might be the best one from the alternatives.

Also known as 'kick and rush' tactic.

Second, for ISVs, multi-homing *i. e.* publishing products for several platforms is advisable. This reduces the dependency

on one ecosystem orchestrator[1] and might widen the revenue streams. In addition, multi-homing strengthens developers' position in the ecosystem where currently the orchestrators are indisputable dictators. However, the multi-homing publishing strategy always causes additional costs despite available technical support by cross-platform development tools. The balance between potential incomes and risks have to be weighted independently in every case.

Third, our study has some practical implication for the use of eWOM in the mobile application ecosystem. In the following, I will discuss these from two perspectives. For a practitioner, eWOM ratings given in the marketplace seem to work in a bit more complex way than it first seems. For example, highly popular applications have a lower valence value than less popular ones. Furthermore, the ratings mechanisms are not completely open as the marketplace rarely asks for reviews. Therefore, the developer can build a feature that forwards bad ratings to her own system and good ones to the marketplace. Even more, the developer can recruit his friends and relatives to rate the application—or buy ratings and reviews from online. As a general guideline, it might be a good idea to focus on your product and users, not on ratings or the optimization of them. However, it is good to emphasize that the eWOM mechanism implemented in the marketplace allows gathering direct feedback from the consumers, which can be used to improve an application.

In 'traditional' application publishing stores such channels have been missing.

For the ecosystem orchestrator, there are some implications. First, although the star rating is so often used in e-commerce systems that it has almost became *de facto* standard, the star-based rating seems not to be the best one as a remarkably majority of the ratings belong to the highest category. This hinders the usefulness of ratings in a marketplace. Second, the marketplace asks ratings only when a user is removing an application in contrast to, *e. g.*, Amazon's approach to actively seek feedback. This has also led to questionable features that prompt a review ques-

In Hyrynsalmi et al. [2013], we presented that there are better ways to organize the reviews and ratings in Google Play. The store and the eWOM platform were renewed later that year. A coincidence? Yes, most likely.

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1 In 2012, there was an online petition for monetary support to an individual developer whose applications were removed from the App Store due to Apple's technical problem. As he noted, the orchestrator, Apple, was not responsible for income losses caused by the removal. Originally available at http://www.savemyhousefromapple.com/. Last accessed March 3rd, 2012; not available any more.

tion inside an application to the user and redirect the negative feedbacks to the ISV's own system while positives are directed to the marketplace. Third, perhaps due to laboriousness of commenting, the verbal reviews are sparse and uninformative with only a few words. However, the recent reform in Google Play might change eWOM writing behaviour as well as the impact of eWOM.

5.2   THEORETICAL CONTRIBUTIONS

In the following, I will discuss the theoretical implications of this thesis. The discussion is divided into three parts according to those previous studies used in this thesis to address the mobile application ecosystems.

SOFTWARE ECOSYSTEMS.   This study addressed empirically one kind of a SECO and the focus, in our publications, has been to study the ecosystem from the ISV's point of view. The study contributes to the SECO literature by empirically assessing value creation, monetization and multi-homing of one ecosystem actor group: the ISVs. In the discussion of theorizing SECOs, we have used the theory of two-sided markets to explain the markets and network theory to explain and understand the value of a multitude of offerings.

However, the major limitation is restricting to a special kind of a SECO: the mobile application ecosystem. As argued through this thesis, the impact of mobile devices, the ubiquitous nature of smart devices as well as hundreds of thousands of ISVs and millions of users differentiate the mobile application ecosystems from more traditional SECOs. Nevertheless, this study and our articles have, among others, opened research avenues for studying ISVs connected to the ecosystem.

TWO-SIDED MARKETS.   To the ever-increasing literature of the two-sided markets, we have contributed by empirically addressing multi-homing rates in one industry domain. In addition, we have discussed the effects of multi-homing on relative bargaining powers of an ecosystem. While there are works combining bargaining powers and the two-sided markets [*e. g.* Bolt and

Soramäki, 2008; Vannini, 2008], our work takes the orchestrator of the market into account.

Furthermore, we have shown that there are remarkable difference to the market analysis when addressing superstars and nonentities in this particular domain. The results contribute to the theoretical works, *e. g.* Sun and Tse [2009], on two-sided markets by emphasizing the differences of importance between the actors.

ELECTRONIC WORD-OF-MOUTH.   To the best of the author's knowledge, our work is among the first to empirically address Sun's [2012] variance of eWOM theory. Our results in P-IV do support the theory: the product of standard deviation and valence, as suggested by the theorem, is positively correlated with the sales. However, the correlation coefficient is extremely small. Furthermore, the variance alone correlated better with sales, although its correlation coefficient value is negative. Therefore, the study implies that the variance is a promising target for further work in this domain. This result is naturally limited by our focus to a single mobile application ecosystem and its eWOM mechanisms.

Nevertheless, our results show that the traditional dimensions of eWOM can be used to explain future sales, to some extent, in the marketplace. However, the correlation coefficients are low and a more sophisticated model could work better. Thus, more work is needed. Furthermore, P-IV shows that the price of the products, at least in mobile applications, seems to affect the effectiveness of eWOM. In a short time period, we could not confirm this result, but with a longer time period it is supported. In other words, it seems that consumers are willing to take a risk instead of reading the reviews when the price is low enough— as discussed by, *e. g.,* prospect theory [Kahneman and Tversky, 1979], consumers might spend their money without expectation of return when the price is low enough.

5.3   FUTURE WORK

This study presented some initial work aimed at understanding the emerged mobile application ecosystems. Nonetheless, the work is far from complete and further work is needed. Espe-

cially, utilizing qualitative research methods could produce useful information for this domain. In the following, I will discuss a few ideas for future researches. The discussion is divided into categories by using the central themes of this dissertation.

Mobile application ecosystems

The mobile application ecosystem is the central concept of this thesis. While this dissertation advances our understanding of the new phenomenon in certain areas, it opens several new questions and topics for further work. *E. g.,* the following areas should be addressed in future:

VALUE CREATION AND CAPTURE. Although this work presented results of an analysis of value creation and monetization in mobile application ecosystems, the ecosystems are evolving rapidly, as are the value creation and capture mechanisms. Since then, new revenue streams and models have been presented. Follow-up research is needed to further understand value creation and, especially, value capture in the mobile application ecosystems.

APPLICATION SELECTION BY CONSUMERS. In this work, we used a quantitative approach to study whether eWOM affects the sales of an application in the mobile application ecosystems. While we found a positive correlation between positive customer feedback and higher sales, the correlation coefficients are low. Thus, qualitative work is needed to understand consumers' decision process when selecting and buying a mobile application.

GOVERNANCE OF AN ECOSYSTEM. This work focused on the content-producing ISVs woven into a mobile application ecosystem. While these ISVs' 'homelike being-in-the-world' is argued to be an important aspect of the health of an ecosystem, this work did not address how an ecosystem orchestrator should guarantee an individual ISV's well-being or govern the whole ecosystem. Some initial work for an ecosystem governance model is presented by Jansen and Cusumano [2012]; however, further work in this domain is needed to better understand different governance mechanisms.

Software ecosystems

This research has raised some questions regarding the SECO research. Further work is needed in, *e. g.,* the following areas:

ECOSYSTEM TAXONOMY. Through this thesis I have argued all SECOs are not equal—some are more equal than others. Comparing an open-source SECO and a SECO built upon a commercial off-the-shelf software platform is hard; furthermore, generalizing guidelines for *e. g.* health governance for these kinds of ecosystems differ. Thus, a proper SECO taxonomy, which is based on an analysis of SECOs' similarities and differences, would be helpful in the further research and the generalization of results.

HEALTH MEASUREMENT. Manikas and Hansen [2013b] and we have presented that ISVs' health, or homelikeness, should be noted when evaluating the overall well-being of an ecosystem as they are conscious actors that are able to perform actions against and for the ecosystem. Relating to the ecosystem taxonomy, I have also argued that the health measurement should note the characteristics of an ecosystem. For example, an open-source SECO should reach a maximal satisfaction for as many as possible while a commercial one might settle for a maximal satisfaction of a few. Figure 5.1 uses the relative share of Google Play installations for each ISV as an indicator of their satisfaction. This is calculated similarly as in Fig. 4.4 on page 105. While the figure shows only 180 ISVs, out of nearly one hundred thousand, it illustrates what the satisfaction distribution might be like for a commercial ecosystem. If all ISVs had been included into the figure, it would have been really long-tailed.

RELATIONSHIPS BETWEEN ACTORS. While there is extant literature on, *e. g.,* a SECO's value chain modeling [Boucharas *et al.*, 2009; Handoyo *et al.*, 2013b] and adaptation, from biology, of relationship forms between actors of an ecosystem [Yu *et al.*, 2008], the relationship between actors in a SECO are infrequently studied. Future work could investigate more the relationships between ISVs in an ecosystem and whether these relationship forms benefit or hamper the ecosystem.
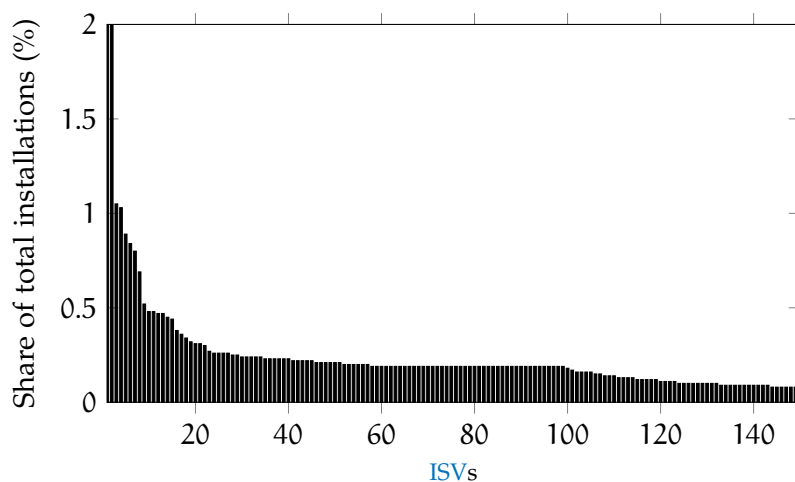
Figure 5.1: An example of addressing Google Play's ISVs' health through the share of the total installations.

Two-sided markets

Regarding the field of two-sided markets, this study raises a few issues needing further work. First, the study done in P-V focuses only on one industry domain, and replication analyses from different industries are needed to form a theory of multi-homing's effect on the competition in two-sided markets. Second, the two-sided markets theory is built upon, *i. a.*, the network theory and, thus, the virtuous cycle is seen as an effective mechanism. However, this thesis questions the limits of the virtuous cycle of network effects. Further work is needed in, *e. g.*, the following areas:

LIMITS OF VIRTUOUS CYCLE. As discussed in Subsection 2.3.2, there is little work on the limits of the virtuous cycle. While ever-increasing numbers of offered products might lure more consumers, the search costs will rise. Furthermore, a large number of competitors in the same marketplace would ultimately lead to cannibalization of other developers and products. Further work is needed to understand the limits of the virtuous cycle and whether limiting the number of developers and products—as *e. g.* Apple is doing—would serve the ecosystem better.

EVOLUTION OF MULTI-HOMING. A potentially interesting issue to address in the future work is to follow two-sided markets and how actors' multi-homing behaviour changes during that time. That is, will the actors start to multi-home in increasing amounts over time or will the platform- and seller-level multi-homing rates remain the same? This would have an impact on the competition theories, that note multi-homing, of two-sided markets.

THE ROLES OF KEYSTONES AND SUPERSTARS. In the dissertation, the influence of multi-homing of keystone developers and superstar applications on the competition between mobile application ecosystems was discussed. As stated, further work is needed to verify our results from different domains and to better understand multi-homing's influence on the competition dynamics. In addition, future studies should focus on analysing the value of keystones and superstars on a two-sided market. While, *e.g.,* Binken and Stremersch [2009]; Landsman and Stremersch [2011] have analysed the impact of superstars to a two-sided market, the domain of their studies, the video game console industry, has a remarkably higher entry barrier to the market than, for instance, the mobile application industry. This might change the impact of superstars as reproducing content or a value proposition of an application is easier.

Electronic Word-of-Mouth

eWOM has become a popular research topic in several disciplines from CS to marketing. In this study, we addressed eWOM from the ISV's viewpoint; however, the achieved results suggest ideas for further work in this topic.

MICRO-PRICING. Our study, P-IV, showed that the price of a product or a service might affect the effectiveness of eWOM. In other words, it seems that eWOM is not as important for the cheap products as it is for the costly ones. However, the result was not stable as there was a pattern only in the long-time-period dataset. Further work is also needed to replicate results in other domains.

LIFE-CYCLE OF REVIEWS. Our study showed that selecting the time span in an eWOM study can affect the results. However, we can also ask whether there is a life-cycle for eWOM reviews and how that affects the sales of a product over a long time. Sun [2012], in her work, theorized how the valence value changes over time when the niche lovers and haters review the product. With automated data collection on a large number of products, this can be studied further and theorized in the future.

TEXTUAL ANALYSIS. An eWOM analysis based on the numerical values, *e.g.* valence, has offered an alluring option for research to study the impact of consumer feedback; however, in this approach, most of the information given by a consumer is compressed to a single value. Web crawling and textual analysis would enable researchers to study the effect of eWOM's verbal dimension in a large-scale experiment.

The recent change of Google Play's eWOM system also allows us, in future, to compare the two types of systems and their impacts on the effectiveness of eWOM. This kind of work might, in future, help us to give guidelines for marketplace owners for building an effective eWOM system.

Nevertheless, this thesis shows that web crawling is a useful technique for data gathering as long as the researchers are aware of its limitations. Furthermore, we, in our publications, have started research for the emerged App economy. As the whole application store phenomenon is still in its starting blocks, the domain will most likely remain an interesting topic for further research in the following years.

That's All, Folks!   ∎

BIBLIOGRAPHY

Aarikka-Stenroos, Leena and Järveläinen, Jonna. Examining the variations of eWOM in e-commerce – focus on mechanisms and types of conveying customer experiences. In *The Proceedings of the 22nd Nordic Academy of Management Conference*, Reykjavík, Iceland, August 2013. Nordic Academy of Management. (Cited on page 73.)

ABI Research. Tablets will generate 35% of this year's $25 billion app revenue; expected to surpass smartphones by 2018. Press release, March 2013. URL http://www.abiresearch.com/press/tablets-will-generate-35-of-this-years-25-billion-. Last Accessed on 18th July, 2013. (Cited on page 4.)

Abroms, Lorien C.; Padmanabhan, Nalini; Thaweethai, Lalida, and Phillips, Todd. iPhone apps for smoking cessation: A content analysis. *American Journal of Preventive Medicine*, 40(3):279–285, March 2011. doi:10.1016/j.amepre.2010.10.032. (Cited on page 79.)

Activision Blizzard. Annual report 2012. Press release, 2013. (Cited on page 5.)

Adner, Ron. Match your innovation strategy to your innovation ecosystem. *Harvard Business Review*, 84(4):98–107, April 2006. (Cited on page 30.)

Adner, Ron and Kapoor, Rahul. Innovation ecosystems and the pace of substitution: Re-examining technology s-curves. Forthcoming, December 2011. (Cited on page 30.)

Ahmet, Zeynep and Väänänen-Vainio Mattila, Kaisa. Mobile service distribution from the end-user perspective: The survey study on recommendation practices. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '12, pages 573–588, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1016-1. doi:10.1145/2212776.2212831. (Cited on page 81.)

Allon, Gad; Bassamboo, Achal, and Çil, Eren B. Large-scale service marketplaces: The role of the moderating firm. *Management Science*, 58(10):1854–1872, October 2012. ISSN 1526-5501. doi:10.1287/mnsc.1120.1533. (Cited on page 62.)

Amberg, Michael; Thiessen, Inka; Lang, Michael, and Belkius, Bartosch. Mobile application marketplaces — an investigation from customers' perspective. In Schumann, Matthias; Kolbe, Lutz M.; Breitner, Michael H., and Frerichs, Arne, editors, *Tagungsband der Multikonferenz Wirtschaftsinformatik*, MKWI'2010, pages 541–554, Göttingen, Germany, 2010. ISBN 978-3-941875-31-9. (Cited on page 80.)

Amblee, Naveen and Bui, Tung. Harnessing the influence of social proof in online shopping: The effect of electronic word of mouth on sales of digital microproducts. *International Journal of Electronic Commerce*, 16(2):91–114, January 2011. ISSN 1086-4415. doi:10.2753/JEC1086-4415160205. (Cited on pages 75, 76, and 77.)

Amit, Raphael and Zott, Christoph. Value creation in e-business. *Strategic Management Journal*, 22(6–7):493–520, 2001. doi:10.1002/smj.187. (Cited on pages 26, 89, 100, and 109.)

Amoroso, Donald L. and Ogawa, Mikako. Japan's model of mobile ecosystem success: The case of NTT DoCoMo. *Journal of Emerging Knowledge on Emerging Markets*, 3(1):473–488, November 2011. doi:10.7885/1946-651X.1064. Article 27. (Cited on page 36.)

Amundsen, Mike. From APIs to affordances: A new paradigm for web services. In *Proceedings of the Third International Workshop on RESTful Design*, WS-REST '12, pages 53–60, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1190-8. doi:10.1145/2307819.2307832. (Cited on page 61.)

Anderson, Chris. *The Long Tail: Why the Future of Business is Selling Less of More*. Hyperion, New York, NY, USA, revised edition, 2008. ISBN 978-1-4013-8725-9. (Cited on page 62.)

Anderson, Chris. *Free: The Future of a Radical Innovation*. Hyperion, New York, NY, USA, 1st edition, 2009. (Cited on page 5.)

Anthes, Gary. Invasion of the mobile apps. *Communications of the ACM*, 54 (9):16–18, September 2011. ISSN 0001-0782. doi:10.1145/1995376.1995383. (Cited on page 3.)

Anvaari, Mohsen and Jansen, Slinger. Architectural openness: comparing five mobile platform architectures. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 8, pages 138–158. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00016. (Cited on pages 50, 82, and 114.)

AppNation. State of the App Economy report forecasts App Economy to reach $151B by 2017. Press release, July 2013. (Cited on page 4.)

Apple Inc. *App Store Submission Tutorial*, 2013. URL http://developer.apple.com/library/ios/#documentation/General/Conceptual/ApplicationDevelopmentOverview/DeliverYourAppontheAppStore/DeliverYourAppontheAppStore.html. Accessed on June 14, 2013. (Cited on page 76.)

Armstrong, Mark. Competition in two-sided markets. *The RAND Journal of Economics*, 37(3):668–691, September 2006. doi:10.1111/j.1756-2171.2006.tb00037.x. (Cited on pages 14, 62, and 66.)

Arndt, Johan. Role of product-related conversations in the diffusion of a new product. *Journal of Marketing Research*, 4(3):291–295, August 1967. ISSN 0022-2437. URL http://www.jstor.org/stable/3149462. (Cited on pages 72 and 73.)

B Baars, Alfred and Jansen, Slinger. A framework for software ecosystem governance. In Cusumano, Michael A.; Iyer, Bala, and Venkatraman, N., editors, *Software Business*, volume 114 of *Lecture Notes in Business Information Processing*, pages 168–180, Berlin, Germany, 2012. Springer Berlin Heidel-

berg. ISBN 978-3-642-30745-4. doi:10.1007/978-3-642-30746-1_14. (Cited on page 57.)

Backinger, Cathy L. and Augustson, Erik M. Where there's an app, there's a way? *American Journal of Preventive Medicine*, 40(3):390–391, March 2011. ISSN 0749-3797. doi:10.1016/j.amepre.2010.11.014. (Cited on page 79.)

Baghbadorani, Milad Fathi and Harandi, Amirpouyan. A conceptual model for business ecosystem and implications for future research. In *International Proceedings of Economics Development and Research*, volume 52 of *ICEME2012*, pages 82–86, Hong Kong, 2012. International Association of Computer Science and Information Technology Press (IACSIT Press). ISBN 978-981-07-4086-3. doi:10.7763/IPEDR.2012.V52.17. (Cited on page 43.)

Barbosa, Olavo and Alves, Carina. A systematic mapping study on software ecosystems. In Jansen, Slinger; Bosch, Jan; Campell, Piers, and Ahmed, Faheem, editors, *Proceedings of the Workshop on Software Ecosystems 2011*, volume 746 of *CEUR Workshop Proceedings*, pages 15–26. CEUR-WS, June 2011. URL http://ceur-ws.org/Vol-746/IWSECO2011-2-BarbosaAlves.pdf. (Cited on pages 38, 41, and 47.)

Barbosa, Olavo; dos Santos, Rodrigo Pereira; Alves, Carina; Werner, Claudia, and Jansen, Slinger. A systematic mapping study on software ecosystems from a three-dimensional perspective. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 4, pages 59–81. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 978-1781955628. doi:10.4337/9781781955635.00011. (Cited on pages 13 and 38.)

Barrera, David and Van Oorschot, Paul. Secure software installation on smartphones. *IEEE Security Privacy*, 9(3):42–48, May/June 2011. ISSN 1540-7993. doi:10.1109/MSP.2010.202. (Cited on page 79.)

Basili, Victor R. The experimental paradigm in software engineering. In *Proceedings of the International Workshop on Experimental Software Engineering Issues: Critical Assessment and Future Directions*, volume 706 of *Lecture Notes in Computer Science*, pages 3–12, London, UK, 1993. Springer-Verlag. ISBN 78-3-540-57092-9. doi:10.1007/3-540-57092-6_91. (Cited on pages 22 and 86.)

Basili, Victor R.; Caldiera, Gianluigi, and Rombach, H. Dieter. Goal question metric paradigm. In Marciniak, John J., editor, *Encyclopedia of Software Engineering*, pages 528–532. John Wiley & Sons — Interscience, New York, NY, USA, 1994. ISBN 0-471-54004-8. doi:10.1002/0471028959.sof142. (Cited on page 20.)

Basili, Victor R.; Heidrich, Jens; Lindvall, Mikael; Münch, Jürgen; Seaman, Carolyn; Regardie, Myrna, and Trendowicz, Adam. Determining the impact of business strategies using principles from goal-oriented measurement. In *Wirtschaftinformatik Proceedings 2009*, 2009. Paper 43. (Cited on page 20.)

Basole, Rahul C. Visualization of interfirm relations in a converging mobile ecosystem. *Journal of Information Technology*, 24(2):144–159, 2009. doi:10.1057/jit.2008.34. (Cited on pages 10, 35, and 36.)

Basole, Rahul C. and Karla, Jürgen. On the evolution of mobile platform ecosystem structure and strategy. *Business & Information Systems Engineering*,

3:313–322, 2011. doi:10.1007/s12599-011-0174-4. (Cited on pages 3, 18, 37, and 61.)

Basole, Rahul C. and Karla, Jürgen. Value transformation in the mobile service ecosystem: A study of App Store emergence and growth. *Service Science*, 4 (1):24–41, 2012. doi:10.1287/serv.1120.0004. (Cited on pages xxv, 37, 61, and 62.)

Basole, Rahul C. and Putrevu, Jagannath. Venture financing in the mobile ecosystem. In *Proceedings of the 2013 International Conference on Mobile Business*, ICMB'2013, Berlin, Germany, June 2013. AIS. URL http://aisel.aisnet.org/icmb2013/10/. Paper 10. (Cited on page 36.)

Basole, Rahul C. and Rouse, William B. Complexity of service value networks: conceptualization and empirical investigation. *IBM Systems Journal*, 47(1): 53–70, January 2008. ISSN 0018-8670. doi:10.1147/sj.471.0053. (Cited on page 36.)

Basole, Rahul C.; Russel, Martha G.; Huhtamäki, Jukka, and Rubens, Neil. Understanding mobile ecosystem dynamics: A data-driven approach. In *International Conference on Mobile Business*, 2012. URL http://aisel.aisnet.org/icmb2012/15. Paper 15. (Cited on page 36.)

Beinhocker, Eric D. *The Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics*. Harvard Business School Press, Boston, MA, USA, 1st edition, 2006. ISBN 1-57851-777-X. (Cited on pages 31 and 32.)

Ben Hadj Salem Mhamdia, Amel. Performance measurement practices in software ecosystem. *International Journal of Productivity and Performance Management*, 62(5):514–533, 2013. ISSN 1741–0401. doi:10.1108/IJPPM-09-2012-0097. (Cited on page 59.)

Bengtsson, Maria and Kock, Sören. "Coopetition" in business networks – to cooperate and compete simultaneously. *Industrial Marketing Management*, 29(5):411–426, 2000. ISSN 0019-8501. doi:10.1016/S0019-8501(99)00067-X. (Cited on page 49.)

Bergen, Jennifier. Google removes malicious Angry Birds apps from Android Market. Geek.com, June 2011. http://www.geek.com/games/google-removes-malicious-angry-birds-apps-from-android-market-1390545/ Accessed on January 3nd, 2014. (Cited on page 48.)

Berger, Jonah and Schwartz, Eric M. What drives inmmediate and ongoing word of mouth? *Journal of Marketing Research*, 48(5):869–880, October 2011. ISSN 0022-2437. doi:10.1509/jmkr.48.5.869. (Cited on page 73.)

Bergvall-Kåreborn, Birgitta and Howcroft, Debra. Mobile applications development on Apple and Google platforms. *Communications of the Association for Information Systems*, 39(30):565–580, December 2011. URL http://aisel.aisnet.org/cais/vol29/iss1/30. (Cited on pages 43 and 80.)

Bergvall-Kåreborn, Birgitta and Howcroft, Debra. The Apple business model: Crowdsourcing mobile applications. *Accounting Forum*, 37(4):280–289, December 2013. ISSN 0155-9982. doi:10.1016/j.accfor.2013.06.001. The Apple Business Model: Value Capture and Dysfunctional Economic and Social Consequences — special issue. (Cited on page 79.)

Bernardos, Ana M. and Casar, José R. Analyzing business models for mobile augmented reality. In *15th International Conference on Intelligence in Next Generation Networks (ICIN)*, pages 97–102, October 2011. doi:10.1109/ICIN.2011.6081111. (Cited on pages 16, 36, and 79.)

Binken, Jeroen L.G. and Stremersch, Stefan. The effect of superstar software on hardware sales in system markets. *Journal of Marketing*, 73(2):88–104, 2009. doi:10.1509/jmkg.73.2.88. (Cited on pages 46 and 127.)

Boehm, Barry W. Software engineering economics. *IEEE Transactions on Software Engineering*, SE-10(1):4–21, 1984. ISSN 0098-5589. doi:10.1109/TSE.1984.5010193. (Cited on page 9.)

Böhmer, Matthias; Ganev, Lyubomir, and Krüger, Antonio. AppFunnel: A framework for usage-centric evaluation of recommender systems that suggest mobile applications. In *Proceedings of the 2013 International Conference on Intelligent User Interfaces*, IUI '13, pages 267–276, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-1965-2. doi:10.1145/2449396.2449431. (Cited on page 78.)

Bolt, Wilko and Soramäki, Kimmo. Competition, bargaining power and pricing in two-sided markets. DNB Working paper 181, DE Nederlandsche Bank NV, Amsterdam, The Netherlands, September 2008. (Cited on page 122.)

Boons, Frank A.A. and Baas, Leo W. Types of industrial ecology: The problem of coordination. *Journal of Cleaner Production*, 5(1–2):79–86, 1997. ISSN 0959-6526. doi:10.1016/S0959-6526(97)00007-3. Industrial Ecology — special issue. (Cited on page 52.)

Bosch, Jan. Maturity and evolution in software product lines: Approaches, artefacts and organization. In Chastek, Gary J., editor, *Proceedings of the Second International Conference on Software Product Lines (SPLC 2)*, volume 2379 of *Lecture Notes in Computer Science*, pages 257–271, London, UK, 2002. Springer Berlin Heidelberg. ISBN 3-540-43985-4. doi:10.1007/3-540-45652-X_16. (Cited on page 43.)

Bosch, Jan. From software product lines to software ecosystems. In *Proceedings of the 13th International Software Product Line Conference*, SPLC '09, pages 111–119, Pittsburgh, PA, USA, 2009. Carnegie Mellon University. URL http://dl.acm.org/citation.cfm?id=1753235.1753251. (Cited on pages 11, 37, 38, 39, 40, 52, and 53.)

Bosch, Jan and Bosch-Sijtsema, Petra. From integration to composition: On the impact of software product lines, global development and ecosystems. *Journal of Systems and Software*, 83(1):67–76, January 2010. ISSN 0164-1212. doi:10.1016/j.jss.2009.06.051. (Cited on pages 38, 39, 40, and 44.)

Bossavit, Laurent. *The Leprechauns of Software Engineering – How folklore turns into fact and what to do about it*. Lean Publishing, 2013. Version 2013-03-17. (Cited on page 22.)

Boucharas, Vasilis; Jansen, Slinger, and Brinkkemper, Sjaak. Formalizing software ecosystem modeling. In *Proceedings of the 1st International Workshop on Open Component Ecosystems*, IWOCE '09, pages 41–50, New York, NY, USA,

2009. ACM. ISBN 978-1-60558-677-9. doi:10.1145/1595800.1595807. (Cited on page 125.)

Boudreau, Kevin. Too many complementors? Evidence on software developers. Technical report, HEC-Paris School of Management, January 2007. URL http://hal-hec.archives-ouvertes.fr/hal-00597766. Working Paper Series, Social Science Research Network. (Cited on pages 17, 61, 68, 70, 71, and 112.)

Boudreau, Kevin J. Let a thousand flowers bloom? An early look at large numbers of software app developers and patterns of innovation. *Organization Science*, 23(5):1409–1427, September 2012. ISSN 1526-5455. doi:10.1287/orsc.1110.0678. (Cited on pages 17, 70, and 71.)

Bouwman, Harry; Carlsson, Christer; Castillo, Francisco José Molina; Giaglis, George M., and Walden, Pirkko. Factors affecting the present and future use of mobile data services: comparing the Dutch, Finnish and Greek markets. *International Journal of Mobile Communications*, 8(4):430–450, July 2010. ISSN 1470-949X. doi:10.1504/IJMC.2010.033835. (Cited on page 81.)

Brandenburger, Adam M. and Nalebuff, Barry J. *Co-opetition*. Currency Doubleday, New York, NY, USA, 1st edition, 1997. ISBN 0-385-47950-6. (Cited on page 11.)

Breton, Emily R; Fuemmeler, Bernard F, and Abroms, Lorien C. Weight loss—there is an app for that! But does it adhere to evidence-informed practices? *Translational Behavioral Medicine*, 1(4):523–529, 2011. ISSN 1869-6716. doi:10.1007/s13142-011-0076-5. (Cited on page 78.)

Bridgman, Percy W. and Holton, Gerald. Empirical method. AccessScience@McGraw-Hill, April 2000. doi:10.1036/1097-8542.231000. (Cited on page 22.)

Brin, Sergey and Page, Lawrence. The anatomy of a large-scale hypertextual web search engine. In *Proceedings of the Seventh International Conference on World Wide Web 7*, WWW7, page 20, Amsterdam, The Netherlands, The Netherlands, 1998a. Elsevier Science Publishers B. V. (Cited on page 90.)

Brin, Sergey and Page, Lawrence. The anatomy of a large-scale hypertextual web search engine. *Computer Networks and ISDN Systems*, 30(1-7):107–117, April 1998b. ISSN 0169-7552. doi:10.1016/S0169-7552(98)00110-X. (Cited on page 90.)

Bringhurst, Robert. *The Elements of Typographic Style*. Version 3.0. Hartley & Marks Publishers, Point Roberts, WA, USA, 2004. (Cited on pages ix and 296.)

Briscoe, Gerard and De Wilde, Philippe. Digital ecosystems: Evolving service-orientated architectures. In *Proceedings of the 1st International Conference on Bio Inspired Models of Network, Information and Computing Systems*, BIONET-ICS '06, pages 1–6, New York, NY, USA, 2006. ACM. ISBN 1-4244-0463-0. doi:10.1109/BIMNICS.2006.361817. (Cited on page 30.)

Burkard, Christoph; Draisbach, Tobias; Widjaja, Thomas, and Buxmann, Peter. Software ecosystems: Vendor-sided characteristics of online marketplaces.

In *Lecture Notes in Informatics — Informatik 2011*, October 2011. URL http://tubiblio.ulb.tu-darmstadt.de/52025/. (Cited on pages 17 and 67.)

Burkard, Christoph; Widjaja, Thomas, and Buxmann, Peter. Software ecosystems. *Business & Information Systems Engineering*, 4(1):41–44, 2012. doi:10.1007/s12599-011-0199-8. (Cited on pages 17, 67, and 69.)

Burrows, Peter. Apple vs. Google: How the battle between Silicon Valley's superstars will shape the future of mobile computing. Businessweek Magazine, January 2010. http://www.businessweek.com/magazine/content/10_04/b4164028483414.htm Accessed on February 4th, 2014. (Cited on page 71.)

Buttle, Francis A. Word of mouth: understanding and managing referral marketing. *Journal of Strategic Marketing*, 6(3):241–254, September 1998. ISSN 0965254X. doi:10.1080/096525498346658. (Cited on page 72.)

Buxmann, Peter; Diefenbach, Heiner, and Hess, Thomas. *The Software Industry: Economic Principles, Strategies, Perspectives*. Springer Berlin Heidelberg, Berlin, Germany, 2013. ISBN 978-3-642-31509-1. doi:10.1007/978-3-642-31510-7. (Cited on pages 8 and 58.)

Caillaud, Bernard and Jullien, Bruno. Chicken & egg: Competition among intermediation service providers. *The RAND Journal of Economics*, 34(2):309–328, Summer 2003. URL http://www.jstor.org/stable/1593720. (Cited on pages 62 and 66.)

Campbell, Piers R. J. and Ahmed, Faheem. A three-dimensional view of software ecosystems. In *Proceedings of the Fourth European Conference on Software Architecture: Companion Volume*, ECSA '10, pages 81–84, New York, NY, USA, August 2010. ACM. ISBN 978-1-4503-0179-4. doi:10.1145/1842752.1842774. (Cited on page 12.)

Campbell, Piers R. J. and Ahmed, Faheem. An assessment of mobile OS-centric ecosystems. *Journal of Theoretical and Applied Electronic Commerce Research*, 6(2):50–62, August 2011. ISSN 0718-1876. doi:10.4067/S0718-18762011000200006. (Cited on pages 46 and 82.)

Camponovo, Giovanni and Pigneur, Yves. Business model analysis applied to mobile business. In *5th International Conference on Enterprise Information Systems (ICEIS 2003)*, pages 1–11, Angers, France, April 2003. (Cited on page 8.)

Carare, Octavian. The impact of bestseller rank on demand: Evidence from the app market. *International Economic Review*, 53(3):717–742, 2012. ISSN 1468-2354. doi:10.1111/j.1468-2354.2012.00698.x. (Cited on pages 17 and 77.)

Castillo, Carlos. *Effective Web Crawling*. Ph.D. thesis, Department of Computer Science, University of Chile, Santiago, Chile, November 2004. (Cited on pages 23, 91, and 92.)

Castree III, Sam. Cyber-plagiarism for sale!: The growing problem of blatant copyright infringement in online digital media stores. *Texas Review of Entertainment & Sports Law*, 14(1):25–45, September 2012. ISSN 1533-1903. (Cited on page 78.)

C

Ceri, Stefano; Bozzon, Alessandro; Brambilla, Marco; Della Valle, Emanuele; Fraternali, Piero, and Quarteroni, Silvia. *Web Information Retrieval*. Data-Centric Systems and Applications. SpringerSpringer Berlin Heidelberg, Berlin, Germany, 2013. ISBN 978-3-642-39313-6. doi:10.1007/978-3-642-39314-3. (Cited on page 91.)

Chakrabarti, Soumen. *Mining the Web: Discovering Knowledge from Hypertext Data*. The Morgan Kaufmann Series in Data Management Systems. Morgan Kaufmann, San Francisco, CA, USA, 2003. ISBN 978-1-55860-754-5. doi:10.1016/B978-155860754-5/50002-1. (Cited on page 91.)

Chan, Yolanda Y.Y. and Ngai, E.W.T. Conceptualising electronic word of mouth activity: An input-process-output perspective. *Marketing Intelligence & Planning*, 29(5):488–516, 2011. doi:10.1108/02634501111153692. (Cited on page 73.)

Charland, Andre and Leroux, Brian. Mobile application development: Web vs. native. *Communications of the ACM*, 54(5):49–53, May 2011. ISSN 0001-0782. doi:10.1145/1941487.1941504. (Cited on page 68.)

Chatfield, Chris. *Problem Solving: A statistician's guide*. Chapman & Hall/CRC, Boca Raton, Florida, USA, 2nd edition, 1995. ISBN 0-412-60630-5. (Cited on page 116.)

Chen, Brian X. Android in-app payments begin with Angry Birds. Wired.co.uk, February 2011. URL http://www.wired.co.uk/news/archive/2011-02/08/angry-birds-android-one-click-payment. Last accessed June 14, 2013. (Cited on page 119.)

Chen, Brian X. Apple fights app makers who try to game the system. The New York Times, February 2012. Available at http://bits.blogs.nytimes.com/2012/02/07/app-store/ Accessed on March 26th, 2014. (Cited on page 21.)

Chen, Miao and Liu, Xiaozong. Predicting popularity of online distributed applications: iTunes app store case analysis. In *Proceedings of the 2011 iConference*, iConference '11, pages 661–663, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0121-3. doi:10.1145/1940761.1940859. (Cited on pages 16, 75, and 77.)

Chen, Pei-Yu; Wu, Shin-yi, and Yoon, Jungsun. The impact of online recommendations and consumer feedback on sales. In *Proceedings of the Twenty-Fifth International Conference on Information Systems (ICIS 2004)*, pages 711–724, 2004. URL http://aisel.aisnet.org/icis2004/58. Paper 58. (Cited on pages 74 and 75.)

Cheng, Chih-Wen. The system and self-reference of the App economy: The case of Angry Birds. *Westminster Papers in Communication & Culture*, 9(1): 47–66, October 2012. ISSN 1744-6708. (Cited on page 61.)

Cheng, Xiufang and Zhou, Meihua. Study on effect of eWOM: A literature review and suggestions for future research. In *International Conference on Management and Service Science (MASS)*, pages 1–4, 2010. doi:10.1109/ICMSS.2010.5576663. (Cited on page 73.)

Cheon, Myun J.; Grover, Varun, and Sabherwal, Rajiv. The evolution of empirical research in IS: a study in IS maturity. *Information and Management*, 24

(3):107–119, March 1993. ISSN 0378-7206. doi:10.1016/0378-7206(93)90060-7. (Cited on page 22.)

Cheung, Christy M. K. and Thadani, Dimple R. The impact of electronic word-of-mouth communication: A literature analysis and integrative model. *Decision Support Systems*, 54(1):461–470, December 2012. ISSN 0167-9236. doi:10.1016/j.dss.2012.06.008. (Cited on pages 72 and 73.)

Cheung, Christy M.K. and Lee, Matthew K.O. What drives consumers to spread electronic word-of-mouth on online consumer-opinion platforms. *Decision Support Systems*, 53(1):218–225, April 2012. doi:10.1016/j.dss.2012.01.015. (Cited on page 73.)

Cheung, Christy M.K. and Thadani, Dimple R. The effectiveness of electronic word-of-mouth communication: A literature analysis. In *Proceedings of the 23rd Bled eConference eTrust: Implications for the Individual, Enterprises and Society*, pages 329–345, 2010. URL http://aisel.aisnet.org/bled2010/18. Paper 18. (Cited on page 73.)

Chevalier, Judith A. and Mayzlin, Dina. The effect of word of mouth on sales: Online book reviews. *Journal of Marketing Research*, XLIII(3):345–354, August 2006. doi:10.1509/jmkr.43.3.345. (Cited on pages 73, 74, and 75.)

Chin, Erika; Felt, Adrienne Porter; Sekar, Vyas, and Wagner, David. Measuring user confidence in smartphone security and privacy. In *Proceedings of the Eighth Symposium on Usable Privacy and Security*, SOUPS '12, pages 1:1–1:16, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1532-6. doi:10.1145/2335356.2335358. (Cited on page 79.)

Chintagunta, Pradeep K.; Gopinath, Shyam, and Venkataraman, Sriram. The effects of online user reviews on movie box office performance: Accounting for sequential rollout and aggregation across local markets. *Marketing Science*, 29(5):944–957, September 2010. ISSN 1526-548X. doi:10.1287/mksc.1100.0572. (Cited on page 75.)

Choi, Jay Pil. Tying in two-sided markets with multi-homing. *The Journal of Industrial Economics*, 58(3):607–626, September 2010. ISSN 1467-6451. doi:10.1111/j.1467-6451.2010.00426.x. (Cited on page 66.)

Chua, Wai Fong. Radical developments in accounting thought. *The Accounting Review*, 61(4):601–632, October 1986. ISSN 0001-4826. URL http://www.jstor.org/stable/247360. (Cited on page 88.)

Clawson, Trevor. Aiming high in the app economy. Forbes, January 2014. http://www.forbes.com/sites/trevorclawson/2014/01/15/aiming-high-in-the-app-economy/ Accessed on February 7th, 2014. (Cited on page 3.)

Clemons, Eric K.; Gao, Guodong Gordon, and Hitt, Lorin M. When online reviews meet hyperdifferentiation: A study of the craft beer industry. *Journal of Management Information Systems*, 23(2):149–171, Fall 2006. ISSN 0742-1222. doi:10.2753/MIS0742-1222230207. (Cited on page 75.)

Colvin, Deidra A. *Effect of Social Media as Measured by the Dispersion of Electronic Word-of-Mouth on the Sales Success of Experience Goods: An Empirical Study of Kindle Book Sales*. Dissertation, Falls School of Business Administration,

Anderson University, Anderson, IN, USA, March 2013. (Cited on pages 73 and 75.)

Corallo, Angelo; Passiante, Giuseppina, and Prencipe, Andrea, editors. *The Digital Business Ecosystem*. Edward Elgar Publisher Inc., Northampton, MA, USA, 2007. ISBN 9781847200433. doi:10.4337/9781781009925. (Cited on page 35.)

Cormen, Thomas H.; Leiserson, Charles E.; Rivest, Ronald L., and Stein, Clifford. *Introduction to Algorithms*. The MIT Press, Cambridge, MA, USA, 2nd edition, 2001. (Cited on page 91.)

Costanza, Robert and Mageau, Michael. What is a healthy ecosystem? *Aquatic Ecology*, 33(1):105–115, 1999. ISSN 1386-2588. doi:10.1023/A:1009930313242. (Cited on page 54.)

Coursaris, Constantinos and Hassanein, Khaled. Understanding m-commerce: A consumer-centric model. *Quarterly Journal of Electronic Commerce*, 3(3):247–271, 2002. URL http://www.khaledhassanein.ca/wp-content/uploads/2007/04/J5.pdf. (Cited on page 99.)

Coursaris, Constantinos; Hassanein, Khaled, and Head, Milena. Mobile technology and the value chain: Participants, activities and value creation. *International Journal of Business Science and Applied Management*, 3:14–30, 2008. ISSN 1753-0296. (Cited on page 36.)

Creswell, John W. *Research Design: Qualitative & Quantitative Approaches*. Sage Publications, Inc., Thousand Oaks, CA, USA, 1st edition, 1994. ISBN 978-0803952546. (Cited on page 86.)

Cuadrado, F. and Dueñas, J.C. Mobile application stores: success factors, existing approaches, and future developments. *IEEE Communications Magazine*, 50(11):160–167, 2012. ISSN 0163-6804. doi:10.1109/MCOM.2012.6353696. (Cited on page 82.)

Cui, Geng; Lui, Hon-Kwong, and Guo, Xiaoning. The effect of online consumer reviews on new product sales. *International Journal of Electronic Commerce*, 17(1):39–58, October 2012. ISSN 1086-4415. doi:10.2753/JEC1086-4415170102. (Cited on page 75.)

Cusumano, Michael A. *The Business of Software: What Every Manager, Programmer, and Entrepreneur Must Know to Thrive and Survive in Good Times and Bad*. Free Press, New York, NY, USA, 2004. ISBN 978-0743215800. (Cited on page 7.)

Cusumano, Michael A. *Staying Power: Six Enduring Principles for Managing Strategy and Innovation in an Uncertain World (Lessons from Microsoft, Apple, Intel, Google, Toyota and More)*. Oxford University Press, Oxford, UK, 2010. (Cited on pages 43 and 44.)

D   Daly, Angela. Recent issues for competition on the internet: Google's search and advertising, the Apple App Store, and the AOL Huffington Post merger. Working papers series, Swinburne University of Technology, May 2011. (Cited on page 78.)

Davidsson, Christoffer and Moritz, Simon. Utilizing implicit feedback and context to recommend mobile applications from first use. In *Proceedings*

of the 2011 Workshop on Context-awareness in Retrieval and Recommendation, CaRR '11, pages 19–22, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0625-6. doi:10.1145/1961634.1961639. (Cited on page 78.)

De Maeyer, Peter. Impact of online consumer reviews on sales and price strategies: a review and directions for future research. *Journal of Product & Brand Management*, 21(2):132–139, 2012. doi:10.1108/10610421211215599. (Cited on pages 15, 21, 73, 78, and 111.)

Dedrick, Jason; Kraemer, Kenneth L., and Linden, Greg. The distribution of value in the mobile phone supply chain. *Telecommunications Policy*, 35(6): 505–521, July 2011. ISSN 0308-5961. doi:10.1016/j.telpol.2011.04.006. (Cited on page 36.)

Dellarocas, Chrysanthos. The digitization of word of mouth: Promise and challenges of online feedback mechanisms. *Management Science*, 49(10):1407–1424, October 2003. ISSN 0025-1909. doi:10.1287/mnsc.49.10.1407.17308. (Cited on pages 15 and 73.)

Dellarocas, Chrysanthos; Zhang, Xiaoquan (Michael), and Awad, Neveen F. Exploring the value of online product reviews in forecasting sales: The case of motion pictures. *Journal of Interactive Marketing*, 21(4):23–45, 2007. ISSN 1520-6653. doi:10.1002/dir.20087. (Cited on pages 15, 73, 74, and 75.)

den Hartigh, Erik; Tol, Michiel, and Visscher, Wouter. The health measurement of a business ecosystem. In van Eijnatten, Frans M., editor, *Proceedings of the ECCON 2006 Annual Meeting: "Organisations as Chaordic Panarchies" — Towards Self-Transcending Work Holarchies*, pages 1–39, Bergen aan Zee, The Netherlands, October 2006. European Network on Chaos and Complexity Research and Management Practice. (Cited on page 56.)

den Hartigh, Erik; Visscher, Wouter; Tol, Michiel, and Salas, Adolfo Jiménez. Measuring the health of a business ecosystem. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 11, pages 221–246. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00020. (Cited on page 56.)

Desnos, Anthony. Android: Static analysis using similarity distance. In *45th Hawaii International Conference on System Science (HICSS)*, pages 5394–5403, January 2012. doi:10.1109/HICSS.2012.114. (Cited on page 79.)

d'Heureuse, Nico; Huici, Felipe; Arumaithurai, Mayutan; Ahmed, Mohamed; Papagiannaki, Konstantina, and Niccolini, Saverio. What's app?: A wide-scale measurement study of smart phone markets. *ACM SIGMOBILE Mobile Computing and Communications Review*, 16(2):16–27, November 2012. ISSN 1559-1662. doi:10.1145/2396756.2396759. (Cited on page 81.)

Dhungana, Deepak; Groher, Iris; Schludermann, Elisabeth, and Biffl, Stefan. Software ecosystems vs. natural ecosystems: Learning from the ingenious mind of nature. In *Proceedings of the Fourth European Conference on Software Architecture: Companion Volume*, ECSA '10, pages 96–102, New York, NY, USA, August 2010. ACM. ISBN 978-1-4503-0179-4. doi:10.1145/1842752.1842777. (Cited on page 38.)

Dhungana, Deepak; Groher, Iris; Schludermann, Elisabeth, and Biffl, Stefan. Guiding principles of natural ecosystems and their applicability to software ecosystems. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 3, pages 43–58. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00010. (Cited on page 38.)

Dichter, Ernest. How word-of-mouth advertising works. *Harvard Business Review*, 44(6):147–166, November-December 1966. ISSN 0017-8012. (Cited on pages 72 and 73.)

Dini, Paolo; Lombardo, Gabriella; Mansell, Robin; Razavi, Amir Reza; Moschoyiannis, Sotiris; Krause, Paul; Nicolai, Andrea, and León, Lorena Rivera. Beyond interoperability to digital ecosystems: regional innovation and socio-economic development led by SMEs. *International Journal of Technological Learning, Innovation and Development*, 1(3):410–426, 2008. doi:10.1504/IJTLID.2008.019981. (Cited on page 30.)

Donker, Tara; Petrie, Katherine; Proudfoot, Judy; Clarke, Janine; Birch, Mary-Rose, and Christensen, Helen. Smartphones for smarter delivery of mental health programs: A systematic review. *Journal of Medical Internet Research*, 15(11):e247, November 2013. doi:10.2196/jmir.2791. (Cited on page 79.)

Dou, Jiangli and Ye, Bing. Multi-homing, product differentation and competition. Working Paper, November 2011. (Cited on page 67.)

Duan, Wenjing; Gu, Bin, and Whinston, Andrew B. Do online reviews matter? — an empirical investigation of panel data. *Decision Support Systems*, 45(4):1007–1016, November 2008. ISSN 0167-9236. doi:10.1016/j.dss.2008.04.001. (Cited on page 75.)

Dunnewijk, Theo and Hultén, Staffan. A brief history of mobile communication in Europe. *Telematics and Informatics*, 24(3):164–179, August 2007. ISSN 0736-5853. doi:10.1016/j.tele.2007.01.013. Mobile Communications: From Cellular to Ad-hoc and Beyond — special issue. (Cited on page 35.)

Dybå, Tore; Prikladnicki, Rafael; Rönkkö, Kari; Seaman, Carolyn, and Sillito, Jonathan. Qualitative research in software engineering. *Empirical Software Engineering*, 16(4):425–429, 2011. ISSN 1382-3256. doi:10.1007/s10664-011-9163-y. (Cited on page 86.)

E   Easterbrook, Steve; Singer, Janice; Storey, Margaret-Anne, and Damian, Daniela. Selecting empirical methods for software engineering research. In Shull, Forrest; Singer, Janice, and Sjøberg, Dag I. K., editors, *Guide to Advanced Empirical Software Engineering*, pages 285–311. Springer London, London, UK, 2008. ISBN 978-1-84800-043-8. doi:10.1007/978-1-84800-044-5_11. (Cited on page 86.)

Eaton, B. D.; Elaluf-Calderwood, S. M.; Sørensen, C., and Yoo, Y. Structural narrative analysis as a means to unfold the paradox of control and generativity that lies within mobile platforms. In *Proceedings of the 2011 10th International Conference on Mobile Business*, ICMB '11, pages 68–73, Washington, DC, USA, 2011a. IEEE Computer Society. ISBN 978-0-7695-4434-2. doi:10.1109/ICMB.2011.16. (Cited on page 78.)

Eaton, Ben D.; Elaluf-Calderwood, Silvia M.; Sørensen, Carsten, and Yoo, Youngjin. Dynamic structures of control and generativity in digital ecosystem service innovation: The cases of the Apple and Google mobile app stores. Working Paper Series 183, Department of Management, London School of Economics and Political Science, London, UK, April 2011b. (Cited on page 78.)

Economides, Anastasios A. and Grousopoulou, Amalia. Students' thoughts about the importance and costs of their mobile devices' features and services. *Telematics and Informatics*, 26(1):57–84, February 2009. doi:10.1016/j.tele.2008.01.001. (Cited on page 81.)

Eden, Amnon H. Three paradigms of computer science. *Minds and Machines*, 17(2):135–167, July 2007. ISSN 0924-6495. doi:10.1007/s11023-007-9060-8. (Cited on page 22.)

Edwards, Chris. iMgonnagetrich [comms mobile apps]. *Engineering Technology*, 4(16):70–71, September 2009. ISSN 1750-9637. URL http://eandt.theiet.org/magazine/2009/16/imgonnagetrich.cfm. (Cited on pages 3 and 76.)

Eisenhardt, K.M. and Brown, S.L. Patching. Restitching business portfolios in dynamic markets. *Harvard Business Review*, 77(3):72–82, May-June 1999. ISSN 0017-8012. (Cited on page 11.)

Eisenmann, Thomas; Parker, Geoffrey, and Van Alstyne, Marshall W. Strategies for two-sided markets. *Harvard Business Review*, 84(10):92–101, 2006. (Cited on pages 63, 64, 65, 67, 68, 69, and 70.)

Eisenmann, Thomas; Parker, Geoffrey, and Van Alstyne, Marshall. Platform envelopment. *Strategic Management Journal*, 32(12):1270–1285, December 2011. ISSN 1097-0266. doi:10.1002/smj.935. (Cited on page 65.)

Eisenmann, Thomas R.; Parker, Geoffrey, and Van Alstyne, Marshall. Platforms, markets and innovation: How, when and why? In Gawer, Annabelle, editor, *Platforms, Markets and Innovation*, pages 131–162. Edward Elgar Publisher Inc., Cheltenham, UK, 2009. ISBN 978-1-84980-331-1. doi:10.4337/9781849803311.00013. (Cited on pages 50 and 51.)

Electronic Arts. Electronic arts reports Q4 FY12 and FY12 financial results. Press release, May 2012. (Cited on page 5.)

Enck, William. Defending users against smartphone apps: Techniques and future directions. In *Proceedings of the 7th International Conference on Information Systems Security*, ICISS'11, pages 49–70, Berlin, Germany, 2011. Springer Berlin Heidelberg. ISBN 978-3-642-25559-5. doi:10.1007/978-3-642-25560-1_3. (Cited on page 79.)

Evans, David S. Some empirical aspects of multi-sided platform industries. *Review of Network Economics*, 2(3):191–209, September 2003a. doi:10.2202/1446-9022.1026. (Cited on page 42.)

Evans, David S. The antitrust economics of multi-sided platform markets. *Yale Journal on Regulation*, 20(2):352–382, Summer 2003b. doi:10.2139/ssrn.332022. (Cited on pages 62 and 65.)

Evans, David S. *Platform Economics: Essays on Multi-Sided Businesses*. Create-Space Independent Publishing Platform, Charleston, SC, USA, 2011. ISBN 978-1468102727. (Cited on pages 42, 43, 63, and 64.)

Evans, David S. Economics of vertical restraints for multi-sided platforms. Coase-Sandor Institute for Law and Economics: Research Paper 626, The University of Chicago Law School, Chicago, IL, USA, January 2013. doi:10.2139/ssrn.2195778. (Cited on pages 70 and 71.)

Evans, David S. and Schmalensee, Richard. The industrial organization of markets with two-sided platforms. *Competition Policy International*, 3(1):151–179, Spring 2007a. doi:10.3386/w11603. (Cited on pages 42 and 63.)

Evans, David S. and Schmalensee, Richard. *Catalyst Code: The Strategies Behind the World's Most Dynamic Companies*. Harvard Business School Press, Boston, MA, USA, 1st edition, 2007b. ISBN 9781422101995. (Cited on page 63.)

Evans, David S. and Schmalensee, Richard. The antitrust analysis of multi-sided platform businesses. Roger Blair and Daniel Sokol, eds., Oxford Handbook on International Antitrust Economics, Oxford University Press, Forthcoming, January 2013. URL http://ssrn.com/abstract=2185373. (Cited on pages 63 and 70.)

Evans, David S.; Hagiu, Andrei, and Schmalensee, Richard. *Invisible Engines: How Software Platforms Drive Innovation and Transform Industries*. The MIT Press, Cambridge, MA, USA, 2006. ISBN 978-0262550680. (Cited on pages 11, 16, 42, and 43.)

F   Facebook. Facebook to acquire Instagram. Press Release, April 2012. Available at http://newsroom.fb.com/news/2012/04/facebook-to-acquire-instagram// Accessed March 27th, 2014. (Cited on page 6.)

Facebook. Facebook to acquire WhatsApp. Press Release, February 2014. Available at http://newsroom.fb.com/news/2014/02/facebook-to-acquire-whatsapp/ Accessed March 27th, 2014. (Cited on page 6.)

Farrell, Joseph and Saloner, Garth. Standardization, compatibility, and innovation. *The RAND Journal of Economics*, 16(1):70–83, Spring 1985. URL http://www.jstor.org/stable/2555589. (Cited on page 69.)

Farrell, Joseph and Saloner, Garth. Installed base and compatibility: Innovation, product preannouncements, and predation. *The American Economic Review*, 76(5):940–955, December 1986. URL http://www.jstor.org/stable/1816461. (Cited on page 69.)

Feijóo, Claudio; Maghiros, Ioannis; Abadie, Fabienne, and Gómez-Barroso, José-Luis. Exploring a heterogeneous and fragmented digital ecosystem: Mobile content. *Telematics and Informatics*, 26(3):282–292, August 2009a. ISSN 0736-5853. doi:10.1016/j.tele.2008.11.009. (Cited on pages 16 and 36.)

Feijóo, Claudio; Pascu, Corina; Misuraca, Gianluca, and Lusoli, Wainer. The next paradigm shift in the mobile ecosystem: Mobile social computing and the increasing relevance of users. *Communications & Strategies*, 1(75):57–78, 3rd quarter 2009b. URL http://ideas.repec.org/a/idt/journl/cs7503.html. (Cited on page 36.)

Feijóo, Claudio; Gómez-Barroso, José-Luis; Aguado, Juan-Miguel, and Ramos, Sergio. Mobile gaming: Industry challenges and policy implications. *Telecommunications Policy*, 36(3):212–221, April 2012. ISSN 0308-5961. doi:10.1016/j.telpol.2011.12.004. (Cited on page 36.)

Feldman, Fred. *Introductory Ethics*. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 1st edition, 1978. ISBN 0-13-501783-1. (Cited on page 59.)

Fenton, Norman; Pfleeger, Shari Lawrence, and Glass, Robert L. Science and substance: A challenge to software engineers. *IEEE Software*, 11(4):86–95, July 1994. ISSN 0740-7459. doi:10.1109/52.300094. (Cited on page 22.)

Fledel, Yuval; Shabtai, Asaf; Potashnik, Dennis, and Elovici, Yuval. Google Android: An updated security review. In Gris, Martin and Yang, Guang, editors, *Mobile Computing, Applications, and Services*, volume 76 of *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, pages 401–414. Springer Berlin Heidelberg, Berlin, Germany, 2012. ISBN 978-3-642-29335-1. doi:10.1007/978-3-642-29336-8_29. (Cited on page 79.)

Foresman, Chris. PR firm settles with FTC over alleged App Store astroturfing. Arstechnica, August 2010. Available at http://arstechnica.com/tech-policy/2010/08/pr-firm-settles-with-ftc-over-alleged-app-store-astroturfing/ Accessed on March 26th, 2014. (Cited on page 21.)

Frank, Mario; Dong, Ben; Felt, Adrienne Porter, and Song, Dawn. Mining permission request patterns from Android and Facebook applications. In *2012 IEEE 12th International Conference on Data Mining*, pages 870–875. IEEE Computer Society, December 2012a. ISBN 978-1-4673-4649-8. doi:10.1109/ICDM.2012.86. (Cited on page 81.)

Frank, Mario; Dong, Ben; Felt, Adrienne Porter, and Song, Dawn. Mining permission request patterns from Android and Facebook applications (extended author version). Published in arXiv.org on Computing Research Repository (CoRR), October 2012b. URL http://arxiv.org/abs/1210.2429. (Cited on page 81.)

Funk, Jeffrey L. The emerging value network in the mobile phone industry: The case of japan and its implications for the rest of the world. *Telecommunications Policy*, 33(1–2):4–18, 2009. ISSN 0308-5961. doi:10.1016/j.telpol.2008.09.002. (Cited on page 36.)

Gabszewicz, Jean J. and Wauthy, Xavier. Two-sided markets and price competition with multi-homing. CORE Discussion paper 2004/30, Université catholique de Louvain, Center for Operations Research and Econometrics (CORE), Louvain-la-Neuve, Belgium, July 2004. (Cited on page 66.)

Garg, Rajiv and Telang, Rahul. Inferring app demand from publicly available data. *MIS Quarterly*, 37(4):1253–1262, December 2013. doi:10.2139/ssrn.1924044. (Cited on pages 81 and 82.)

Gartner. Gartner's 2012 hype cycle for emerging technologies identifies "tipping point" technologies that will unlock long-awaited technology scenarios. Press Release, August 2012. URL http://www.gartner.com/newsroom/id/2124315. Last accessed March 26st, 2014. (Cited on page 18.)

G

Gartner. Gartner says less than 0.01 percent of consumer mobile apps will be considered a financial success by their developers through 2018. Press Release, January 2014. URL http://www.gartner.com/newsroom/id/2648515. Last accessed March 21st, 2014. (Cited on page 5.)

Gawer, Annabelle and Cusumano, Michael A. Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, 31(3):417–433, May 2013. ISSN 1540-5885. doi:10.1111/jpim.12105. (Cited on pages 41, 42, and 43.)

Ghazawneh, Ahmad and Henfridsson, Ola. Micro-strategizing in platform ecosystems: A multiple case study. In Galletta, Dennis F. and Liang, Ting-Peng, editors, *Proceedings of the International Conference on Information Systems*, ICIS, Shanghai, China, December 2011. Association for Information Systems. ISBN 978-0-615-55907-0. URL http://aisel.aisnet.org/icis2011/proceedings/generaltopics/3. Paper 3. (Cited on page 82.)

Ghazawneh, Ahmad and Henfridsson, Ola. Governing third-party development through platform boundary resources. In Sabherwal, Rajiv and Sumner, Mary, editors, *Proceedings of the Thirty First International Conference on Information Systems*, ICIS'2010, pages 48–64, Saint Louis, MO, USA, December 2010. Association for Information Systems. ISBN 978-0-615-41898-8. URL http://aisel.aisnet.org/icis2010_submissions/48. Paper 48. (Cited on page 82.)

Ghazawneh, Ahmad and Henfridsson, Ola. Balancing platform control and external contribution in third-party development: the boundary resources model. *Information Systems Journal*, 23(2):173–192, March 2013. ISSN 1365-2575. doi:10.1111/j.1365-2575.2012.00406.x. (Cited on page 82.)

Gibler, Clint; Crussell, Jonathan; Erickson, Jeremy, and Chen, Hao. AndroidLeaks: Automatically detecting potential privacy leaks in Android applications on a large scale. In *Proceedings of the 5th International Conference on Trust and Trustworthy Computing*, TRUST'12, pages 291–307, Berlin, Germany, 2012. Springer Berlin Heidelberg. ISBN 978-3-642-30920-5. doi:10.1007/978-3-642-30921-2_17. (Cited on page 79.)

Girardello, Andrea and Michahelles, Florian. Bootstrapping your mobile application on a social market. In *Proceedings of UbiComp'10*. ACM, September 2010a. ISBN 978-1-60558-843-8/10/09. (Cited on page 78.)

Girardello, Andrea and Michahelles, Florian. Explicit and implicit ratings for mobile applications. In Fähnrich, Klaus-Peter and Franczyk, Bogdan, editors, *Informatik 2010: Service Science — Neue Perspektiven für die Informatik, Beiträge der 40. Jahrestagung der Gesellschaft für Informatik e.V. (GI), Band 1, 27.09. — 1.10.2010, Leipzig*, volume 175 of *LNI*, pages 606–612. GI, 2010b. ISBN 978-3-88579-269-7. (Cited on page 78.)

Girardello, Andrea and Michahelles, Florian. AppAware: Which mobile applications are hot? In *Proceedings of the 12th International Conference on Human-Computer Interaction with Mobile Devices and Services*, MobileHCI '10, pages 431–434, New York, NY, USA, 2010c. ACM. ISBN 978-1-60558-835-3. doi:10.1145/1851600.1851698. (Cited on page 78.)

Glass, Robert L. The software-research crisis. *IEEE Software*, 11(6):42–47, November 1994. ISSN 0740-7459. doi:10.1109/52.329400. (Cited on page 22.)

Glass, Robert L. *Facts and Fallacies of Software Engineering*. Pearson Education, Inc., Boston, MA, 2002. ISBN 0-321-11742-5. (Cited on page 22.)

Glass, Robert L.; Vessey, Iris, and Ramesh, V. Research in software engineering: an analysis of the literature. *Information and Software Technology*, 44(8):491–506, 2002. ISSN 0950-5849. doi:10.1016/S0950-5849(02)00049-6. (Cited on pages 8 and 23.)

Glass, Robert L.; Ramesh, V., and Vessey, Iris. An analysis of research in computing disciplines. *Communications of the ACM*, 47(6):89–94, June 2004. ISSN 0001-0782. doi:10.1145/990680.990686. (Cited on page 22.)

Godes, D. and Mayzlin, D. Using online conversations to study word-of-mouth communication. *Marketing Science*, 23(4):545–560, 2004. doi:10.1287/mksc.1040.0071. (Cited on page 75.)

Goeminne, Mathieu and Mens, Tom. Analyzing ecosystems for open source software developer communities. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 12, pages 247–275. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00021. (Cited on page 57.)

Grabham, Dan. Ballmer says Windows Phone now a 'strong third ecosystem'. Techradar.com, January 2012. http://www.techradar.com/news/phone-and-communications/mobile-phones/ballmer-says-windows-phone-now-a-strong-third-ecosystem-1053229 Accessed on December 8th, 2012. (Cited on page 3.)

Grant, Rebecca. 5 data scientists who became CEOs — and are leading thriving companies. Venturebeat, December 2013. http://venturebeat.com/2013/12/03/5-data-scientists-who-became-ceos-and-are-leading-thriving-companies/ Accessed on January 7th, 2014. (Cited on page 85.)

Gregg, Dawn G.; Kulkarni, Uday R., and Vinzé, Ajay S. Understanding the philosophical underpinnings of software engineering research in information systems. *Information Systems Frontiers*, 3(2):169–183, June 2001. ISSN 1387-3326. doi:10.1023/A:1011491322406. (Cited on page 22.)

Grubert, Jens; Langlotz, Tobias, and Grasset, Raphaël. Augmented reality browser survey. Technical Report ICG-TR-101, Institute for Computer Graphics and Vision, Graz University of Technology, Graz, Austria, December 2011. (Cited on page 79.)

Gueguen, Gaël and Isckia, Thierry. The borders of mobile handset ecosystems: Is coopetition inevitable? *Telematics and Informatics*, 28(1):5–11, February 2011. ISSN 0736-5853. doi:10.1016/j.tele.2010.05.007. (Cited on pages 10 and 11.)

Ha, Elizabeth and Wagner, David. Do Android users write about electric sheep? Examining consumer reviews in Google Play. In *Proceedings of the 10th Annual IEEE Consumer Communication & Networking Conference*, CCNC

H

2013. IEEE, 2013. ISBN 978-1-4503-0121-3. doi:10.1109/CCNC.2013.6488439. (Cited on page 79.)

Hagiu, Andrei. Pricing and commitment by two-sided platforms. *The RAND Journal of Economics*, 37(3):720–737, September 2006. ISSN 1756-2171. doi:10.1111/j.1756-2171.2006.tb00039.x. (Cited on page 62.)

Hagiu, Andrei and Spulber, Daniel. First-party content and coordination in two-sided markets. *Management Science*, 59(4):933–949, April 2013. ISSN 0025-1909. doi:10.1287/mnsc.1120.1577. (Cited on page 67.)

Håkansson, Håkon; Ford, David; Gadde, Lars-Erik; Snehota, Ivan, and Waluszewski, Alexandra. *Business in Networks*. John Wiley & Sons Ltd., Chichester, West Sussex, UK, 2009. ISBN 978-0470749630. (Cited on page 29.)

Hammershøj, Allan; Sapuppo, Antonio, and Tadayoni, Reza. Challenges for mobile application development. In *14th International Conference on Intelligence in Next Generation Networks*, ICIN'2010, pages 1–8. IEEE Computer Society, October 2010. doi:10.1109/ICIN.2010.5640893. (Cited on page 79.)

Hamming, Richard Wesley. One man's view of computer science. *Journal of the Association for Computing Machinery*, 16(1):3–12, January 1969. ISSN 0004-5411. doi:10.1145/321495.321497. 1968 ACM Turing Lecture. (Cited on page 29.)

Handoyo, Eko; Jansen, Slinger, and Brinkkemper, Sjaak. Software ecosystem roles classification. In Herzwurm, Georg and Margaria, Tiziana, editors, *Software Business: From Physical Products to Software Services and Solutions*, volume 150 of *Lecture Notes in Business Information Processing*, pages 212–216. Springer Berlin Heidelberg, Berlin, Germany, 2013a. ISBN 978-3-642-39335-8. doi:10.1007/978-3-642-39336-5_21. (Cited on page 45.)

Handoyo, Eko; Jansen, Slinger, and Brinkkemper, Sjaak. Software ecosystem modeling: The value chains. In *Proceedings of the Fifth International Conference on Management of Emergent Digital EcoSystems*, MEDES '13, pages 17–24, New York, NY, USA, 2013b. ACM. ISBN 978-1-4503-2004-7. doi:10.1145/2536146.2536167. (Cited on pages 45 and 125.)

Hanssen, Geir K. A longitudinal case study of an emerging software ecosystem: Implications for practice and theory. *Journal of Systems and Software*, 85(7):1455–1466, July 2012. ISSN 0164-1212. doi:10.1016/j.jss.2011.04.020. (Cited on pages 11 and 13.)

Hanssen, Geir K. and Dybå, Tore. Theoretical foundations of software ecosystems. In Jansen, Slinger; Bosch, Jan, and Alves, Carina F., editors, *Proceedings of the International Workshop on Software Ecosystems*, volume 879 of *CEUR Workshop Proceedings*, pages 2–13, MIT Sloan School of Management, Cambridge, MA, USA, June 2012. CEUR-WS. URL http://ceur-ws.org/Vol-879/paper1.pdf. (Cited on pages 13, 38, 41, and 47.)

Hanssen, Geir Kjetil. *From Agile Software Product Line Engineering Towards Software Ecosystems*. Doctoral thesis, Norwegian University of Science and Technology, Trondheim, Norway, November 2010. (Cited on page 44.)

Hao, Lin; Li, Xiaofei; Tan, Yong, and Xu, Jiuping. The economic value of ratings in app market (July 18, 2011). Available at SSRN: http://ssrn.com/abstract=1892584, 2011a. (Cited on page 76.)

Hao, Lin; Li, Xiaofei; Tan, Yong, and Xu, Jiuping. The economic role of rating behavior in third-party application market. In *Proceedings of Thirty Second International Conference on Information Systems*, ICIS 2011, pages 1–15, December 2011b. URL http://aisel.aisnet.org/icis2011/proceedings/economicvalueIS/26. Paper 26. (Cited on page 76.)

Hazzan, Orit and Dubinsky, Yael. Qualitative research in software engineering. *Frontier Journal — High-tech Think Tank and Action Workbench*, 4(6):6–16, June 2007. Professor Orit Hazzan's Column. (Cited on page 86.)

Hearnshaw, Edward J. S.; Cullen, Ross, and Hughey, Kenneth F. D. Ecosystem health demystified: an ecological concept determined by economic means. Proceedings of the 2nd National Workshop of the Australian National University's Economics and Environment Network, May 2005. URL http://hdl.handle.net/10182/3728. Conference paper presented at the Economics and Environment Network Workshop, held at the Australian National University, Canberra. (Cited on page 54.)

Heitkötter, Henning; Hildebrand, Kay F., and Usener, Claus A. Mobile platforms as two-sided markets. In *Proceedings of the Eighteenth Americas Conference on Information Systems*, AMCIS 2012, pages 1–9, Seattle, Washington, August 2012. Association for Information Systems. URL http://aisel.aisnet.org/amcis2012/proceedings/AdoptionDiffusionIT/11. Paper 11. (Cited on page 64.)

Heitkötter, Henning; Hanschke, Sebastian, and Majchrzak, Tim A. Evaluating cross-platform development approaches for mobile applications. In Cordeiro, José and Krempels, Karl-Heinz, editors, *Web Information Systems and Technologies: 8th International Conference, WEBIST 2012, Porto, Portugal, April 18-21, 2012, Revised Selected Papers*, volume 140 of *Lecture Notes in Business Information Processing*, pages 120–138. Springer Berlin Heidelberg, Berlin, Germany, 2013. ISBN 978-3-642-36607-9. doi:10.1007/978-3-642-36608-6_8. (Cited on page 68.)

Hennig-Thurau, Thorsten; Gwinner, Kevin P.; Walsh, Gianfranco, and Gremler, Dwayne D. Electronic word-of-mouth via consumer-opinion platforms: What motivates consumers to articulate themselves on the internet? *Journal of Interactive Marketing*, 18(1):38–52, 2004. ISSN 1520-6653. doi:10.1002/dir.10073. (Cited on pages 73 and 78.)

Henze, Niels and Boll, Susanne. Release your app on sunday eve: Finding the best time to deploy apps. In *Proceedings of the 13th International Conference on Human-Computer Interaction with Mobile Devices and Services*, MobileHCI '11, pages 581–586, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0541-9. doi:10.1145/2037373.2037464. (Cited on page 80.)

Hestres, Luis E. App neutrality: Apple's App Store and freedom of expression online. *International Journal of Communication*, 7(0):1265–1280, June 2013. ISSN 1932-8036. URL http://ijoc.org/index.php/ijoc/article/view/1904. (Cited on page 78.)

148 BIBLIOGRAPHY

Hilkert, Daniel and Benlian, Alexander amd Hess, Thomas. The openness of smartphone software platforms — A framework and preliminary empirical findings from the developers' perspective. In Heiß, Hans-Ulrich; Pepper, Peter; Schlingloff, Holger, and Schneider, Jörg, editors, *Proceedings of INFORMATIK 2011 — Informatik schafft Communities*, number P-192 in Lecture Notes in Informatics (LNI) — Proceedings, page 422, Bonn, Germany, October 2011. Köllen Druck+Verlag GmbH. ISBN 978-3-88579-286-4. (Cited on page 79.)

Hohmann, Luke. *Beyond Software Architecture: Creating and Sustaining Winning Solutions*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2003. ISBN 0201775948. (Cited on page 7.)

Holzer, Adrian and Ondrus, Jan. Mobile application market: A developer's perspective. *Telematics and Informatics*, 28(1):22–31, February 2011. ISSN 0736-5853. doi:10.1016/j.tele.2010.05.006. (Cited on pages 13, 15, 16, 70, 79, 80, and 114.)

Hoving, Rick; Slot, Gabriel, and Jansen, Slinger. Python: Characteristics identification of a free open source software ecosystem. In *7th IEEE International Conference on Digital Ecosystems and Technologies (DEST)*, pages 13–18. IEEE Computer Society, July 2013. ISBN 978-1-4799-0784-7. doi:10.1109/DEST.2013.6611322. (Cited on page 57.)

Hu, Nan; Zhang, Jie, and Pavlou, Paul A. Overcoming the j-shaped distribution of product reviews. *Communications of the ACM*, 52(10):144–147, October 2009. ISSN 0001-0782. doi:10.1145/1562764.1562800. (Cited on page 74.)

Humayoun, Shah Rukh; Ehrhart, Stefan, and Ebert, Achim. Developing mobile apps using cross-platform frameworks: A case study. In *Proceedings of the 15th International Conference on Human-Computer Interaction, Part I: Human-Centred Design Approaches, Methods, Tools, and Environments — Volume 1*, HCI'13, pages 371–380, Berlin, Germany, 2013. Springer Berlin Heidelberg. ISBN 978-3-642-39231-3. doi:10.1007/978-3-642-39232-0_41. (Cited on page 68.)

Hyrynsalmi, Sami; Suominen, Arho, and Knuutila, Timo. A discussion of software product conceptualizations. In Seppänen, Marko; Mäkinen, Saku; Ortt, Roland J., and Hosni, Yasser, editors, *Proceedings of the 5th European Conference on Management of Technology, EuroMOT2011*, pages 226–240. Tampere University of Technology, 2011.

Hyrynsalmi, Sami; Mäkilä, Tuomas; Järvi, Antero; Suominen, Arho; Seppänen, Marko, and Knuutila, Timo. App Store, Marketplace, Play! An analysis of multi-homing in mobile software ecosystems. In Jansen, Slinger; Bosch, Jan, and Alves, Carina F., editors, *Proceedings of the Fourth International Workshop on Software Ecosystems*, volume 879 of *CEUR Workshop Proceedings*, pages 55–68, MIT Sloan School of Management, Cambridge, MA, USA, June 2012a. CEUR-WS. URL http://ceur-ws.org/Vol-879/paper5.pdf. (Cited on pages 4, 25, and 27.)

Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas; Järvi, Antero, and Knuutila, Timo. Revenue models of application developers in Android Market ecosystem. In Cusumano, M.A.; Iyer, B., and Venkatraman, N.,

editors, *ICSOB 2012*, number 114 in Lecture Notes in Business Information Processing, pages 209–222, Berlin, Germany, 2012b. Springer Berlin Heidelberg. ISBN 978-3-642-30746-1. doi:10.1007/978-3-642-30746-1_17. (Cited on pages 26, 99, and 100.)

Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas, and Järvi, Antero. Analyzing developers' challenges in mobile application marketplaces. In Buxmann, Peter; Jansen, Slinger; Kude, Thomas; Popp, Karl-Michael, and Przewloka, Martin, editors, *Proceedings of the European Workshop on Software Ecosystems 2012*, EWSECO'2012, pages 32–37. Synomic Academy, 2012c.

Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas, and Knuutila, Timo. The emerging mobile ecosystems: An introductory analysis of Android Market. In *Proceedings of the 21st International Conference on Management of Technology*, IAMOT'2012, pages 1–16, Hsinchu, Taiwan, March 2012d. International Association for Management of Technology. (Cited on pages 24, 26, 58, and 74.)

Hyrynsalmi, Sami; Suominen, Arho; Seppänen, Marko, and Mäkilä, Tuomas. The relevance of customer reviews in the mobile application marketplaces. In Zawislak, Paulo A. and Hosni, Yasser, editors, *"Science, Technology and Innovation in the Emerging Markets Economy", Proceedings of the 22nd International Conference on Management of Technology*, IAMOT'2013, pages 1–12, Porto Alegre, Brazil, April 2013. International Association for Management of Technology. ISBN 0-9815817-6-5. Paper no. 1569675819. (Cited on pages 24, 27, 102, and 121.)

Hyrynsalmi, Sami; Seppänen, Marko; Aarikka-Stenroos, Leena; Suominen, Arho; Järveläinen, Jonna, and Harkke, Ville. Busting myths of eWOM: The relationship between customer ratings and the sales of mobile applications. Accepted for publication in the *Journal of Theoretical and Applied Electronic Commerce Research*, October 2014a. (Cited on pages 26, 101, and 102.)

Hyrynsalmi, Sami; Seppänen, Marko, and Suominen, Arho. Sources of value in application ecosystems. *The Journal of Systems and Software*, 96:61–72, October 2014b. ISSN 0164-1212. doi:10.1016/j.jss.2014.05.064. (Cited on pages 26, 100, and 101.)

Hyrynsalmi, Sami; Suominen, Arho; Mäkilä, Tuomas, and Knuutila, Timo. The emerging application ecosystems: An introductory analysis of Android ecosystem. *International Journal of E-Business Research*, 10(2):61–81, April–June 2014c. ISSN 1548-1131. doi:10.4018/ijebr.2014040104. (Cited on pages 25 and 97.)

Hyrynsalmi, Sami; Suominen, Arho, and Mäntymäki, Matti. The influence of application developer multi-homing and keystone developers on competition between mobile application ecosystems. Submitted to review, September 2014d. (Cited on pages 27, 103, 104, and 105.)

Iansiti, Marco and Levien, Roy. Strategy as ecology. *Harvard Business Review*, 82(3):68–78, March 2004a. (Cited on pages 30, 31, 48, 54, 56, 57, 59, and 60.)

Iansiti, Marco and Levien, Roy. *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Harvard Business School Press, Boston, MA, USA, 2004b. ISBN 1-59139-307-8. (Cited on page 54.)

I

Iansiti, Marco and Richards, Gregory L. The information technology ecosystem: Structure, health, and performance. *The Antitrust Bulletin*, 51(1):77–110, Spring 2006. ISSN 0003-603X. (Cited on page 56.)

Idu, Andrei; van de Zande, Tommy, and Jansen, Slinger. Multi-homing in the Apple ecosystem: Why and how developers target multiple Apple App Stores. In *Proceedings of the International Conference on Management of Emergent Digital EcoSystems*, MEDES '11, pages 122–128, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-1047-5. doi:10.1145/2077489.2077511. (Cited on pages 17, 67, and 112.)

Isaacson, Walter. *Steve Jobs*. Simon & Schuster, New York, NY, USA, first edition, October 2011. ISBN 978-1-4516-4855-3. (Cited on page 97.)

Islam, A. K. M. Najmul. *Understanding e-learning system users' post-adoption usage behavior and its outcomes: a study of a learning management system*. Ph.D. dissertation, Turku School of Economics, University of Turku, Turku, Finland, June 2012. URL http://urn.fi/URN:ISBN:978-952-249-202-9. Series A-5:2012. (Cited on page 85.)

Iyer, Bala; Lee, Chi-Hyon, and Venkatraman, N. Managing in a "small world ecosystem": Some lessons from the software sector. *California Management Review*, 48(3):28–47, Spring 2006. ISSN 0008-1256. doi:10.2307/41166348. (Cited on page 45.)

J Jansen, Slinger. Measuring the health of open source software ecosystems: Moving beyond the project scope. *Information and Software Technology*, 56(11): 150–1519, November 2014. ISSN 0950–5849. doi:10.1016/j.infsof.2014.04.006. Special issue on Software Ecosystems. (Cited on pages 57 and 60.)

Jansen, Slinger and Bloemendal, Ewoud. Defining app stores: The role of curated marketplaces in software ecosystems. In Herzwurm, Georg and Margaria, Tiziana, editors, *Software Business. From Physical Products to Software Services and Solutions*, volume 150 of *Lecture Notes in Business Information Processing*, pages 195–206, Berlin, Germany, 2013. Springer Berlin Heidelberg. ISBN 978-3-642-39335-8. doi:10.1007/978-3-642-39336-5_19. (Cited on pages 3, 12, and 82.)

Jansen, Slinger and Cusumano, Michael A. Defining software ecosystems: A survey of software platforms and business network governance. In Jansen, Slinger; Bosch, Jan, and Alves, Carina F., editors, *Proceedings of the Fourth International Workshop on Software Ecosystems*, volume 879 of *CEUR Workshop Proceedings*, pages 41–58, Cambridge, MA, USA, June 2012. IWSECO, CEUR-WS. URL http://ceur-ws.org/Vol-879/paper4.pdf. (Cited on pages 35, 47, 53, 55, 57, 83, and 124.)

Jansen, Slinger and Cusumano, Michael A. Defining software ecosystems: a survey of software platforms and business network governance. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 1, pages 13–28. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00008. (Cited on page 53.)

Jansen, Slinger and van Capelleveen, Guido. Quality review and approval methods for extensions in software ecosystems. In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 10, pages 187–217. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00018. (Cited on page 72.)

Jansen, Slinger; Brinkkemper, Sjaak, and Finkelstein, Anthony. Business network management as a survival strategy: A tale of two software ecosystems. In Jansen, Slinger; Brinkkemper, Sjaak; Finkelstein, Anthony, and Bosch, Jan, editors, *Proceedings of the first International Workshop on Software Ecosystems*, volume 505 of *CEUR Workshop Proceedings*, pages 34–48. CEUR-WS, September 2009a. URL http://ceur-ws.org/Vol-505/iwseco09-5JansenBrinkkemperFinkelstein.pdf. (Cited on page 18.)

Jansen, Slinger; Finkelstein, Anthony, and Brinkkemper, Sjaak. A sense of community: A research agenda for software ecosystems. In *31st International Conference on Software Engineering — Companion Volume, ICSE-Companion 2009*, pages 187–190. IEEE, May 2009b. doi:10.1109/ICSE-COMPANION.2009.5070978. (Cited on pages 11, 12, 13, 38, 39, 40, 44, and 50.)

Jansen, Slinger; Brinkkemper, Sjaak; Souer, Jurriaan, and Luinenburg, Lutzen. Shades of gray: Opening up a software producing organization with the open software enterprise model. *Journal of Systems and Software*, 85(7):1495–1510, July 2012. ISSN 0164-1212. doi:10.1016/j.jss.2011.12.007. Software Ecosystem — special issue. (Cited on pages 47 and 51.)

Jansen, Slinger; Brinkkemper, Sjaak; Souer, Jurriaan, and Luinenburg, Lutzen. The open software enterprise model: how open is my software business? In Jansen, Slinger; Brinkkemper, Sjaak, and Cusumano, Michael A., editors, *Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry*, chapter 9, pages 159–286. Edward Elgar Publisher Inc., Northampton, MA, USA, 2013. ISBN 9781781955628. doi:10.4337/9781781955635.00017. (Cited on page 47.)

Järvinen, Pertti. Research questions guiding selection of an appropriate research method. Series of Publications D – Net Publications D–2004–5, Department of Computer Sciences, University of Tampere, Tampere, Finland, December 2004a. (Cited on pages xxv, 23, 85, 87, and 88.)

Järvinen, Pertti. On a variety of research output types. Series of Publications D – Net Publications D–2004–6, Department of Computer Sciences, University of Tampere, Tampere, Finland, December 2004b. (Cited on pages 23 and 87.)

Jayaraman, Karthik. Making sense of software ecosystems: A critical review. In *Proceedings of the 11th International Conference on Electronic Business*, ICEB 2011, Bangkok, Thailand, November–December 2011. (Cited on page 38.)

Jeffries, Stuart. The app economy. The Guardian, July 2009. URL http://www.theguardian.com/technology/2009/jul/29/iphone-apps. Accessed on January 24th, 2014. (Cited on pages 3 and 61.)

Jeon, Doh-Shin and Rochet, Jean Charles. The pricing of academic journals: A two-sided market perspective. *American Economic Journal: Microeconomics*, 2 (2):222–255, May 2010. doi:10.1257/mic.2.2.222. (Cited on page 64.)

K Kabbedijk, Jaap and Jansen, Slinger. Steering insight: An exploration of the Ruby software ecosystem. In Regnell, Björn; van de Weerd, Inge, and De Troyer, Olga, editors, *Software Business — Second International Conference, ICSOB 2011, Brussels, Belgium, June 8-10, 2011. Proceedings*, volume 80 of *Lecture Notes in Business Information Processing*, pages 44–55, Berlin, Germany, 2011. Springer Berlin Heidelberg. ISBN 978-3-642-21543-8. doi:10.1007/978-3-642-21544-5_5. (Cited on page 13.)

Kahneman, Daniel and Tversky, Amos. Prospect theory: An analysis of decision under risk. *Econometrica*, 47(2):263–291, 1979. (Cited on page 123.)

Karatzoglou, Alexandros; Baltrunas, Linas; Church, Karen, and Böhmer, Matthias. Climbing the app wall: Enabling mobile app discovery through context-aware recommendations. In *Proceedings of the 21st ACM International Conference on Information and Knowledge Management*, CIKM '12, pages 2527–2530, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1156-4. doi:10.1145/2396761.2398683. (Cited on page 78.)

Karhu, Kimmo; Botero, Andrea; Vihavainen, Sami; Tang, Tingan, and Hämäläinen, Matti. A digital ecosystem for co-creating business with people. *Journal of Emerging Technologies in Web Intelligence*, 3(3):197–205, August 2011. doi:10.4304/jetwi.3.3.197-205. (Cited on page 81.)

Karhu, Kimmo; Tang, Tingan, and Hämäläinen, Matti. Analyzing competitive and collaborative differences among mobile ecosystems using abstracted strategy networks. *Telematics and Informatics*, 31(2):319–333, May 2014. ISSN 0736-5853. doi:10.1016/j.tele.2013.09.003. (Cited on page 36.)

Karla, Jürgen and Bröker, Henry. Emergence of the App-Economy: What drives the mobile business industry in Germany? *International Journal of Business Research*, 11(5):67–75, 2011. ISSN 1555-1296. (Cited on page 61.)

Katz, Michael L. and Shapiro, Carl. Network externalities, competition, and compatibility. *The American Economic Review*, 75(3):424–440, June 1985. ISSN 0002-8282. URL http://www.jstor.org/stable/1814809. (Cited on pages 15, 62, 69, and 70.)

Katz, Michael L. and Shapiro, Carl. Technology adoption in the presence of network externalities. *Journal of Political Economy*, 94(4):822–841, August 1986. URL http://www.jstor.org/stable/1833204. (Cited on page 69.)

Kenney, Martin and Pon, Bryan. Structuring the smartphone industry: Is the mobile internet OS platform the key? *Journal of Industry, Competition and Trade*, 11(3):239–261, 2011. doi:10.1007/s10842-011-0105-6. (Cited on page 82.)

Khammash, Marwan and Griffiths, Gareth Havard. Case study: 'Arrivederci CIAO.com, Buongiorno Bing.com' — electronic word-of-mouth (eWOM), antecedences and consequences. *International Journal of Information Management: The Journal for Information Professionals*, 31(1):82–87, February 2011. ISSN 0268-4012. doi:10.1016/j.ijinfomgt.2010.10.005. (Cited on page 73.)

Kietzmann, Jan and Canhoto, Ana. Bittersweet! Understanding and managing electronic word of mouth. *Journal of Public Affairs*, 13(2):146–159, May 2013. ISSN 1479-1854. doi:10.1002/pa.1470. Special Issue: Viral Media & Marketing: Strategy, Policy and Exploitation. (Cited on pages 72 and 73.)

Kim, Hee-Woong; Lee, Hyun Lyung, and Son, Jung Eun. An exploratory study on the determinants of smartphone app purchase. In *The 11th International DSI and the 16th APDSI Joint Meeting*, Taipei, Taiwan, July 2011. (Cited on page 81.)

Kim, Hyung Jin; Kim, Inchan, and Lee, Ho Geun. The success factors for app store-like platform businesses from the perspective of third-party developers: An empirical study based on a dual model framework. In *Pacific Asia Conference on Information Systems*, PACIS, pages 60–72. AISeL, July 2010. (Cited on page 80.)

Kimbler, Kristofer. App store strategies for service providers. In *14th International Conference on Intelligence in Next Generation Networks*, ICIN'2010, pages 1–5, October 2010. ISBN 978-1-4244-7443-1. doi:10.1109/ICIN.2010.5640947. (Cited on page 80.)

Kimppa, Kai K. *Problems with the Justification of Intellectual Property Rights in Relation to Software and Other Digitally Distributable Media*. Ph.D. dissertation, Turku Centre for Computer Science, Turku, Finland, May 2007. (Cited on page 59.)

Kirk, Jerome and Miller, Marc L. *Reliability and Validity in Qualitative Research*. SAGE Publications, Inc., Newbury Park, CA, USA, 1986. ISBN 9781412985659. doi:10.4135/9781412985659. (Cited on page 95.)

Kiss, Jemima. Apple pulls Wikileaks app, but Android apps remain. The Guardian, December 2010. http://www.theguardian.com/media/pda/2010/dec/21/apple-wikileaks-app Accessed January 4th, 2014. (Cited on page 78.)

Kittlaus, Hans-Bernd and Clough, Peter N. *Software Product Management and Pricing: Key Success Factors for Software Organizations*. Springer Berlin Heidelberg, Berlin, Germany, 1st edition, 2009. ISBN 978-3-540-76986-6. doi:10.1007/978-3-540-76987-3. (Cited on pages 38 and 39.)

Knuth, Donald E. Computer Programming as an Art. *Communications of the ACM*, 17(12):667–673, December 1974. ISSN 0001-0782. doi:10.1145/361604.361612. (Cited on page 1.)

Koskinen, Jani. Phenomenological view of health and patient empowerment with personal health record. In Suomi, Reima and Iveskoksi, Ilkka, editors, *Navigating the Fragmented Innovation Landscape: Proceedings of the Third International Conference on Wellbeing in the Information Society (WIS 2010)*, volume 56 of *TUCS General Publications*, pages 111–122, Turku, Finland, August 2010. Turku Centre for Computer Science. (Cited on page 58.)

Kouris, Iana. Unified two-sided market model. Working Draft, September 2011. URL http://www.intertic.org/Conference/Kouris.pdf. (Cited on page 64.)

Kouris, Iana and Kleer, Rob. Business models in two-sided markets: An assessment of strategies for app platforms. In *International Conference on Mobile Business 2012*, ICMB'2012, pages 1–12. Association for Information Systems, January 2012. URL http://aisel.aisnet.org/icmb2012/22. Paper 22. (Cited on page 68.)

Krugman, Paul. The power of biobabble: Pseudo-economics meets pseudo-evolution. Slate, The Dismal Science, October 1997. http://www.slate.com/articles/business/the_dismal_science/1997/10/the_power_of_biobabble.single.html Accessed on January 6th, 2014. (Cited on page 31.)

Kuittinen, Tero. Operation badland — How individualism and government support fuel Finland's App Miracle. Forbes, June 2013. http://www.forbes.com/sites/terokuittinen/2013/06/19/operation-badland-how-individualism-and-government-support-fuel-finlands-app-miracle/ Accessed February 18th, 2013. (Cited on page 106.)

Kumar, Sameer. Mobile communications: Global trends in the 21st century. *International Journal of Mobile Communications*, 2(1):67–86, May 2004. ISSN 1470-949X. doi:10.1504/IJMC.2004.004488. (Cited on page 35.)

L Lampathaki, Fenareti, editor. *Session Proceedings of Boosting the App Economy: What's the role of APIs, Cloudlets & Data Driven Services?*, FIA Dublin Session Proceedings, June 2013. (Cited on page 61.)

Landsman, Vardit and Stremersch, Stefan. Multi-homing in two-sided markets: An empirical inquiry in the video game console industry. *Journal of Marketing*, 75(6):39–54, 2011. doi:10.1509/jm.09.0199. (Cited on pages 17, 67, and 127.)

Lang, Bodo and Hyde, Kenneth F. Word of mouth: What we know and what we have yet to learn. *Journal of Consumer Satisfaction, Dissatisfaction & Complaining Behavior*, 26:1–18, 2013. ISSN 0899–8620. (Cited on page 74.)

Lapointe, Adrian. When good metaphors go bad: The metaphoric "branding" of cyperspace. Technical report of technology & public policy, Center for Strategic & International Studies, September 2011. URL http://csis.org/publication/when-good-metaphors-go-bad-metaphoric-branding-cyberspace. (Cited on page 35.)

Laugesen, John and Yuan, Yufei. What factors contributed to the success of Apple's iPhone? In *Proceedings of the 2010 Ninth International Conference on Mobile Business / 2010 Ninth Global Mobility Roundtable*, ICMB-GMR '10, pages 91–99, Washington, DC, USA, 2010. IEEE Computer Society. ISBN 978-0-7695-4084-9. doi:10.1109/ICMB-GMR.2010.63. (Cited on pages 16 and 79.)

Laurenz Eveleens, Johan and Verhoef, Chris. The rise and fall of the Chaos Report figures. *IEEE Software*, 27(1):30–36, January 2010. ISSN 0740-7459. doi:10.1109/MS.2009.154. (Cited on page 22.)

Lee, Allen S. and Baskerville, Richard L. Generalizing generalizability in information systems research. *Information Systems Research*, 14(3):221–243, September 2003. ISSN 1526-5536. doi:10.1287/isre.14.3.221.16560. (Cited on page 116.)

Lee, Bong Gyou; Lee, Gun Hee; Shim, Yong Ho, and Choi, Ajin. Let developers run into the app store by lowering the barrier-to-entry. *International Journal of Electronic Finance*, 4(3):201–220, 2010. doi:10.1504/IJEF.2010.03403. (Cited on page 16.)

Lee, Gunwoong and Raghu, T. S. Product portfolio and mobile apps success: Evidence from App Store market. In *Proceedings of the Seventeenth Americas Conference on Information Systems*, Detroit, MI, USA, August 2011. URL http://aisel.aisnet.org/amcis2011_submissions/444. Paper 444. (Cited on page 80.)

Lemstra, Wolter; Leeuw, Gerd-Jan; Kar, Els, and Brand, Paul. "Just another distribution channel?". In Hesselman, Cristian and Giannelli, Carlo, editors, *Mobile Wireless Middleware, Operating Systems, and Applications — Workshops*, volume 12 of *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, pages 1–12. Springer Berlin Heidelberg, Berlin, Germany, 2009. ISBN 978-3-642-03569-2. doi:10.1007/978-3-642-03569-2_1. (Cited on page 113.)

Lettner, Michael; Tschernuth, Michael, and Mayrhofer, Rene. Mobile platform architecture review: Android, iPhone, Qt. In *Proceedings of the 13th International Conference on Computer Aided Systems Theory — Part II*, EUROCAST'11, pages 544–551, Berlin, Germany, 2012. Springer Berlin Heidelberg. ISBN 978-3-642-27578-4. doi:10.1007/978-3-642-27579-1_70. (Cited on page 82.)

Levenshtein, Vladimir I. Binary codes capable of correcting deletions, insertions, and reversals. *Soviet Physics–Doklady*, 10(8):707–710, February 1966. (Cited on page 94.)

Li, Feng and Whalley, Jason. Deconstruction of the telecommunications industry: from value chains to value networks. *Telecommunications Policy*, 26 (9–10):451–472, 2002. ISSN 0308-5961. doi:10.1016/S0308-5961(02)00056-3. (Cited on page 35.)

Li, Mei; Goh, Khim Yong, and Cavusoglu, Huseyin. Mobile app portfolio management and developers' performance: An empirical study of the Apple iOS platform. In *Proceedings of the Thirty Fourth International Conference on Information Systems*, pages 1–11, Milan, Italy, December 2013a. AIS Electronic Library. (Cited on page 80.)

Li, Xiaoping; Jie, Xiaowen; Li, Qiang, and Zhang, Qi. Research on the evaluation of business ecosystem health. In Xu, Jiuping; Yasinzai, Masoom, and Lev, Benjamin, editors, *Proceedings of the Sixth International Conference on Management Science and Engineering Management*, volume 185 of *Lecture Notes in Electrical Engineering*, pages 1009–1020, London, UK, 2013b. Springer London. ISBN 978-1-4471-4599-8. doi:10.1007/978-1-4471-4600-1_87. (Cited on page 56.)

Lim, Soo Ling and Bentley, Peter J. How to be a successful app developer: Lessons from the simulation of an app ecosystem. In *Proceedings of the Genetic and Evolutionary Computation Conference*, GECCO '12, pages 129–136, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1177-9. doi:10.1145/2330163.2330182. (Cited on page 81.)

Lim, Yujin; Kim, Hak-Man; Kang, Sanggil, and Kim, Tai-hoon. Recommendation algorithm of the app store by using semantic relations between apps. In Kim, Tai-hoon; Adeli, Hojjat; Robles, Rosslin John, and Balitanas, Maricel, editors, *Ubiquitous Computing and Multimedia Applications*, volume 151 of *Communications in Computer and Information Science*, pages 139–144. Springer Berlin Heidelberg, Berlin, Germany, 2011. ISBN 978-3-642-20997-0. doi:10.1007/978-3-642-20998-7_18. (Cited on page 78.)

Lin, Feida and Ye, Weiguo. Operating system battle in the ecosystem of smartphone industry. In *Proceedings of the 2009 International Symposium on Information Engineering and Electronic Commerce*, IEEC '09, pages 617–621, Washington, DC, USA, 2009. IEEE Computer Society. ISBN 978-0-7695-3686-6. doi:10.1109/IEEC.2009.136. (Cited on page 82.)

Lin, Mingfeng; Lucas, Henry C. Jr., and Shmueli, Galit. Research commentary—too big to fail: Large samples and the p-value problem. *Information Systems Research*, 24(4):906–917, December 2013. doi:10.1287/isre.2013.0480. (Cited on page 116.)

Liu, Charles Zhechao; Au, Yoris A., and Choi, Hoon Seok. An empirical study of the freemium strategy for mobile apps: Evidence from the Google Play market. In Huang, Ming-Hui; Piccoli, Gabe, and Sambamurthy, Vallabh, editors, *Proceedings of the 33rd International Conference on Information Systems (ICIS2012)*, pages 1–17, 2012. (Cited on pages 75 and 80.)

Liu, Yong. Word-of-mouth for movies: Its dynamics and impact on box office revenue. *Journal of Marketing*, 70(3):74–89, July 2006. ISSN 0022-2429. doi:10.1509/jmkg.70.3.74. (Cited on pages 74 and 75.)

Lucassen, Garm; Rooij, Kevin, and Jansen, Slinger. Ecosystem health of cloud PaaS providers. In Herzwurm, Georg and Margaria, Tiziana, editors, *Software Business. From Physical Products to Software Services and Solutions — 4th International Conference, ICSOB 2013, Potsdam, Germany, June 11-14, 2013. Proceedings*, volume 150 of *Lecture Notes in Business Information Processing*, pages 183–194. Springer Berlin Heidelberg, Berlin, Germany, June 2013. ISBN 978-3-642-39335-8. doi:10.1007/978-3-642-39336-5_18. (Cited on page 57.)

Lungu, Mircea; Lanza, Michele; Gîrba, Tudor, and Robbes, Romain. The small project observatory: Visualizing software ecosystems. *Science of Computer Programming*, 75(4):264–275, April 2010. ISSN 0167-6423. doi:10.1016/j.scico.2009.09.004. (Cited on page 38.)

Lungu, Mircea F. *Reverse Engineering Software Ecosystems*. Doctoral dissertation, Faculty of Informatics of the University of Lugano, Lugano, Switzerland, September 2009. (Cited on pages 11, 38, 39, and 41.)

Luo, Yadong. *Coopetition in International Business*. Copenhagen Business School Press, Køge, Denmark, 1st edition, October 2004. ISBN 978-8763001281. (Cited on page 11.)

Luoma, Eetu. *Examining Business Models of Software-as-a-Service Companies*. Ph.D. dissertation, University of Jyväskylä. Jyväskylä studies in computing 188, Jyväskylä, Finland, December 2013. URL http://urn.fi/URN:ISBN:978-951-39-5562-5. (Cited on page 8.)

MacMillan, Douglas; Burrows, Peter, and Ante, Spencer E.   Inside the app economy. Bloomberg Businessweek Magazine, October 2009. Available at http://www.businessweek.com/magazine/content/09_44/b4153044881892.htm Accessed last 16th July, 2013. (Cited on pages 3 and 61.)

Mahmoud, Qusay H. and Popowicz, Pawel. Toward a framework for the discovery and acquisition of mobile applications. In *Proceedings of the 2010 Ninth International Conference on Mobile Business / 2010 Ninth Global Mobility Roundtable*, ICMB-GMR '10, pages 58–65, Washington, DC, USA, 2010. IEEE Computer Society. ISBN 978-0-7695-4084-9. doi:10.1109/ICMB-GMR.2010.75. (Cited on page 78.)

Maitland, Carleen F; Bauer, Johannes M., and Westerveld, Rudi. The European market for mobile data: Evolving value chains and industry structures. *Telecommunications Policy*, 26(9–10):485–504, October–November 2002. ISSN 0308-5961. doi:10.1016/S0308-5961(02)00028-9. Mapping the evolving telecommunications value chain & market structure — special issue. (Cited on page 35.)

Mäkilä, Tuomas. *Software Development Process Modeling — Developers Perspective to Contemporary Modeling Techniques*. Ph.D. dissertation, Turku Centre for Computer Science, Turku, Finland, November 2012. URL http://urn.fi/URN:ISBN:978-952-12-2790-5. TUCS Dissertations No. 148. (Cited on page 86.)

Mandel, Michael. Where the jobs are: The app economy. A report by TechNet, February 2012. (Cited on page 4.)

Manikas, Konstantinos and Hansen, Klaus Marius. Software ecosystems — A systematic literature review. *Journal of Systems and Software*, 86(5):1294–1306, May 2013a. ISSN 0164-1212. doi:10.1016/j.jss.2012.12.026. (Cited on pages 11, 12, 36, 37, 38, 39, 40, 41, 43, and 45.)

Manikas, Konstantinos and Hansen, Klaus Marius. Reviewing the health of software ecosystems — a conceptual framework proposal. In Alves, Carina F.; Hanssen, Geir K.; Bosch, Jan, and Jansen, Slinger, editors, *Proceedings of the 5th International Workshop on Software Ecosystems*, volume 987 of *CEUR Workshop Proceedings*, pages 33–44, Potsdam, Germany, June 2013b. CEUR-WS. URL http://ceur-ws.org/Vol-987/3.pdf. (Cited on pages 36, 59, 60, 108, and 125.)

Maxwell, Elliot. Open standards, open source, and open innovation: Harnessing the benefits of openness. *Innovations: Technology, Governance, Globalization*, 1(3):119–176, Summer 2006. ISSN 1558-2477. doi:10.1162/itgg.2006.1.3.119. (Cited on page 50.)

McKendrick, Joe. Is the 'app economy' dead? Or just morphing? ZDNet, October 2013. http://www.zdnet.com/is-the-app-economy-dead-or-just-morphing-7000021560/ Accessed on February 7th, 2014. (Cited on page 3.)

Messerschmitt, David G. and Szyperski, Clemens. *Software Ecosystem: Understanding an Indispensable Technology and Industry*. The MIT Press, Cambridge, MA, USA, 2003. ISBN 0262134322. (Cited on pages 7, 11, 37, and 38.)

Meyer, Marc H and Lehnerd, Alvin P. *The Power of Product Platforms: Building Value and Cost Leadership*. Free, New York, NY, USA, preprint (2011) edition, 1997. ISBN 9781451655308. (Cited on page 42.)

Mills, H.D. The management of software engineering, Part I: Principles of software engineering. *IBM Systems Journal*, 19(4):414–420, 1980. ISSN 0018-8670. doi:10.1147/sj.194.0414. (Cited on page 9.)

Montgomerie, Johnna and Roscoe, Samuel. Owning the consumer—getting to the core of the Apple business model. *Accounting Forum*, 37(4):290–299, December 2013. ISSN 0155-9982. doi:10.1016/j.accfor.2013.06.003. The Apple Business Model: Value Capture and Dysfunctional Economic and Social Consequences — special issue. (Cited on page 79.)

Moore, James F. Predators and prey: A new ecology of competition. *Harvard Business Review*, 71(3):75–86, May-June 1993. (Cited on pages 14, 30, 32, 33, 34, 35, 83, 104, and 113.)

Moore, James F. *The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems*. Harper Business, New York, NY, USA, 1996. (Cited on pages 9, 14, 30, 40, and 57.)

Moore, James F. Business ecosystems and the view from the firm. *The Anti-trust Bulletin*, 51(1):31–75, Spring 2006. ISSN 0003-603X. (Cited on pages 14 and 34.)

Müller, Roland M.; Kijl, Björn, and Martens, Josef K. J. A comparison of inter-organizational business models of mobile app stores: There is more than open vs. closed. *Journal of Theoretical and Applied Electronic Commerce Research*, 6(2):63–76, August 2011. ISSN 0718-1876. doi:10.4067/S0718-18762011000200007. (Cited on page 82.)

Mulligan, Mark and Card, David. Sizing the EU app economy. GigaOm Research report, February 2014. Available at http://eurapp.eu/sites/default/files/Sizing%20the%20EU%20App%20Economy.pdf. (Cited on page 5.)

N   Neelakanta, Perambur and Yassin, Raef. A co-evolution model of competitive mobile platforms: Technoeconomic perspective. *Journal of Theoretical and Applied Electronic Commerce Research*, 6(2):31–49, August 2011. ISSN 0718-1876. doi:10.4067/S0718-18762011000200005. (Cited on page 82.)

Newell, Allen; Perlis, Alan J., and Simon, Herbert A. Computer science. *Science*, 157(3795):1373–1374, September 1967. (Cited on page 22.)

Nokia Corporation. Nokia Form 20-F 2007. Press release, March 2008. (Cited on page 5.)

Nokia Corporation. Nokia corporation Q4 and full year 2012 interim report. Press release, January 2013a. (Cited on page 5.)

Nokia Corporation. Nokia to sell Devices & Services business to Microsoft in EUR 5.44 billion all-cash transaction. Press release, September 2013b. URL http://press.nokia.com/2013/09/03/nokia-to-sell-devices-services-business-to-microsoft-in-eur-5-44-billion-all-cash-transaction. (Cited on page 6.)

O

OECD. The app economy. OECD Digital Economy Papers 230, OECD Publishing, December 2013. doi:10.1787/5k3ttftlv95k-en. (Cited on page 61.)

Oetting, Martin. *Ripple Effect: How Empowered Involvement Drives Word of Mouth.* Gabler | GWV Fachverlage GmbH, Wiesbaden, Germany, 1st edition, 2009. ISBN 978-3-8349-2009-6. doi:10.1007/978-3-8349-8372-5. (Cited on page 72.)

Ohrt, Julian and Turau, Volker. Cross-platform development tools for smartphone applications. *IEEE Computer*, 45(9):72–79, September 2012. ISSN 0018-9162. doi:10.1109/MC.2012.121. (Cited on page 68.)

Olston, Christopher and Najork, Marc. Web crawling. *Foundations and Trends in Information Retrieval*, 4(3):175–246, March 2010. ISSN 1554-0669. doi:10.1561/1500000017. (Cited on pages 23 and 91.)

Ongtang, Machigar. *Securing Mobile Phones in the Evolving Mobile Ecosystem.* Dissertation, Pennsylvania State University, PA, USA, August 2010. (Cited on pages 16 and 79.)

Orlikowski, Wanda J. and Baroudi, Jack J. Studying information technology in organizations: Research approaches and assumptions. *Information Systems Research*, 2(1):1–28, 1991. doi:10.1287/isre.2.1.1. (Cited on pages 23 and 88.)

Osterwalder, Alexander and Pigneur, Yves. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers.* Wiley, West Sussex, UK, 1st edition, 2009. (Cited on page 10.)

P

Palmieri, Manuel; Singh, Inderjeet, and Cicchetti, Antonio. Comparison of cross-platform mobile development tools. In *Intelligence in Next Generation Networks (ICIN), 2012 16th International Conference on*, pages 179–186. IEEE Computer Society, October 2012. doi:10.1109/ICIN.2012.6376023. (Cited on page 68.)

Park, Cheol and Lee, Thae Min. Information direction, website reputation and eWOM effect: A moderating role of product type. *Journal of Business Research*, 62(1):61–67, 2009. ISSN 0148-2963. doi:10.1016/j.jbusres.2007.11.017. (Cited on page 75.)

Parker, Geoffrey and Van Alstyne, Marshall W. Innovation, openness, and platform control. MIT Sloan School Working Paper 4684-08, Massachusetts Institute of Technology, Cambridge, MA, USA, December 2013. (Cited on page 70.)

Parker, Geoffrey G. and Van Alstyne, Marshall W. Two-sided network effects: A theory of information product design. *Management Science*, 51(10):1494–1504, October 2005. ISSN 0025-1909. doi:10.1287/mnsc.1050.0400. (Cited on pages 14, 62, and 70.)

Parkin, Simon. A serious game about sweatshops ... you won't find it in Apple's App Store. The Guardian, March 2013. http://www.theguardian.com/commentisfree/2013/mar/22/sweatshop-game-apple-app-store Accessed February 4th, 2014. (Cited on page 78.)

Patterson, Anna. Why writing your own search engine is hard. *ACM Queue*, 2(2):48–53, April 2004. ISSN 1542-7730. doi:10.1145/988392.988407. (Cited on page 91.)

160 BIBLIOGRAPHY

Peppard, Joe and Rylander, Anna. From value chain to value network: Insights for mobile operators. *European Management Journal*, 24(2–3):128–141, April–June 2006. ISSN 0263-2373. doi:10.1016/j.emj.2006.03.003. (Cited on page 36.)

Perez, Sarah. Nearly 60K low-quality apps booted from Google Play store in February, points to increased spam-fighting. Techcrunch.com, April 2013. URL http://techcrunch.com/2013/04/08/nearly-60k-low-quality-apps-booted-from-google-play-store-in-february-points-to-increased-spam-fighting/. Last accessed on January 2nd, 2014. (Cited on page 46.)

Philip, Joji Thomas. Nokia's bet on Microsoft is beginning to pay-off: Stephen Elop, Nokia. The Economic Times, March 2012. URL http://articles.economictimes.indiatimes.com/2012-03-12/news/31153009_1_dual-sim-segment-nokia-chief-executive-stephen-elop. Last accessed on October 21, 2013. (Cited on page 30.)

Pohl, Klaus; Böckle, Günter, and van der Linden, Frank J. *Software Product Line Engineering: Foundations, Principles and Techniques*. Springer New York, Inc., Secaucus, NJ, USA, 2005. ISBN 3540243720. (Cited on pages 42 and 43.)

Popa, Bogdan. Windows 8 ends 2013 with 142,000 metro apps available for download. Softpedia, December 2013. http://news.softpedia.com/news/Windows-8-Ends-2013-with-142-000-Metro-Apps-Available-for-Download-412989.shtml Accessed on February 6th, 2014. (Cited on page 83.)

Popp, Karl-Michael and Meyer, Ralf. *Profit from Software Ecosystems: Business Models, Ecosystems and Partnerships in the Software Industry*. Books on Demand GmbH, 2010. ISBN 9783839169834. (Cited on pages 9, 11, and 13.)

Porra, Jaana. Colonial systems. *Information Systems Research*, 10(1):38–69, March 1999. ISSN 1047–7047. doi:10.1287/isre.10.1.38. (Cited on page 37.)

Potts, Colin. Software-engineering research revisited. *IEEE Software*, 10(5): 19–28, September 1993. ISSN 0740-7459. doi:10.1109/52.232392. (Cited on page 22.)

Q Qiu, Yixin; Gopal, Anand, and Hann, Il-Horn. Synthesizing professional and market logics: A study of independent iOS app entrepreneurs. In Galletta, Dennis F. and Liang, Ting-Peng, editors, *Proceedings of the Thirty Second International Conference on Information Systems*, ICIS, pages 1–21, Shanghai, China, December 2011. Association for Information Systems. ISBN 978-0-615-55907-0. URL http://aisel.aisnet.org/icis2011/proceedings/breakthroughideas/10. Paper 10. (Cited on page 80.)

R Raivio, Yrjö and Luukkainen, Sakari. Mobile networks as a two-sided platform — case Open Telco. *Journal of Theoretical and Applied Electronic Commerce Research*, 6(2):77–89, 2011. ISSN 0718-1876. doi:10.4067/S0718-18762011000200008. (Cited on page 36.)

Rajala, Risto. *Determinants of Business Model Performance in Software Firms*. Ph.D. dissertation, Helsinki School of Economics. Acta Universitatis oeconomicae Helsingiensis. A-357, Helsinki, Finland, December 2009. A:357. (Cited on page 8.)

Rajala, Risto; Rossi, Matti; Tuunainen, Virpi Kristiina, and Vihinen, Janne. Revenue logics of mobile entertainment software — observations from companies producing mobile games. *Journal of Theoretical and Applied Electronic Commerce Research*, 2(2):34–47, August 2007. ISSN 0718-1876. (Cited on page 37.)

Ramesh, V.; Glass, Robert L., and Vessey, Iris. Research in computer science: an empirical study. *Journal of Systems and Software*, 70(1-2):165–176, February 2004. ISSN 0164-1212. doi:10.1016/S0164-1212(03)00015-3. (Cited on page 22.)

Ramos, Sergio; Gómez-Barroso, José-Luis, and Feijóo, Claudio. Evolution and regulation of mobile ecosystems: European information society policies for the mobile search domain. In Hadjiantonis, Antonis M. and Stiller, Burkhard, editors, *Telecommunication Economics — Selected Results of the COST Action IS0605 Econ@Tel*, volume 7216 of *Lecture Notes in Computer Science*, pages 5–13. Springer Berlin Heidelberg, Berlin, Germany, 2012. ISBN 978-3-642-30381-4. doi:10.1007/978-3-642-30382-1_3. (Cited on page 36.)

Rapport, David; McMichael, Anthony, and Costanza, Robert. Reply from D.J. Rapport, A.J. McMichael and R. Costanza. *Trends in Ecology & Evolution*, 14 (2):69–70, 1999. ISSN 0169-5347. doi:10.1016/S0169-5347(98)01538-9. (Cited on page 54.)

Rapport, David J. Evaluating ecosystem health. *Journal of Aquatic Ecosystem Health*, 1(1):15–24, 1992. ISSN 0925-1014. doi:10.1007/BF00044405. (Cited on page 54.)

Rapport, David J. Defining ecosystem health. In Rapport, David J., editor, *Ecosystem Health*, chapter 2, pages 18–33. Blackwell Science Inc, Malden, MA, USA, 1998. ISBN 0-632-04368-7. (Cited on page 54.)

Rapport, David J.; Costanza, Robert, and McMichael, Anthony J. Assessing ecosystem health. *Trends in Ecology & Evolution*, 13(10):397–402, 1998. ISSN 0169-5347. doi:10.1016/S0169-5347(98)01449-9. (Cited on page 54.)

Ribeiro, Andre and da Silva, Alberto Rodrigues. Survey on cross-platforms and languages for mobile apps. In *Proceedings of the 2012 Eighth International Conference on the Quality of Information and Communications Technology*, QUATIC '12, pages 255–260, Washington, DC, USA, 2012. IEEE Computer Society. ISBN 978-0-7695-4777-0. doi:10.1109/QUATIC.2012.56. (Cited on page 68.)

Rochet, Jean Charles and Tirole, Jean. Platform competition in two-sided markets. *Journal of the European Economic Association*, 1(4):990–1029, June 2003. doi:10.1162/154247603322493212. (Cited on pages 14, 62, 64, 65, 66, and 67.)

Rochet, Jean-Charles and Tirole, Jean. Two-sided markets: A progress report. *The RAND Journal of Economics*, 37(3):645–667, September 2006. ISSN 1756-2171. doi:10.1111/j.1756-2171.2006.tb00036.x. (Cited on pages 14, 63, 64, 66, and 68.)

Rohrbeck, René; Hölze, Katharina, and Gemünden, Hans Georg. Opening up for competitive advantage — How Deutsche Telekom creates an open innovation ecosystem. *R&D Management*, 39(4):420–430, 2009. ISSN 1467-9310. doi:10.1111/j.1467-9310.2009.00568.x. (Cited on page 30.)

Roma, Paolo; Perrone, Giovanni, and Valenti, Filippo. An empirical analysis of revenue drivers in the mobile app market. In Schoenherr, Tobias and Seshadri, Sahil, editors, *Proceedings of the 24th Annual Conference of the Production and Operations Management Society*, POMS'2013, pages 1–10, Denver, CO, USA, May 2013. (Cited on page 80.)

Rönkkö, Mikko and Peltonen, Juhana. *Software Industry Survey 2011*, pages 1–2. Aalto University, School of Science, Espoo, Finland, July 2011. (Cited on page 8.)

Rönkkö, Mikko; Valtakoski, Aku, and Peltonen, Juhana. The case for software business as a research discipline. In Tyrväinen, Pasi; Jansen, Slinger, and Cusumano, Michael A., editors, *Software Business*, volume 51 of *Lecture Notes in Business Information Processing*, pages 205–210. Springer Berlin Heidelberg, Berlin, Germany, 2010. ISBN 978-3-642-13632-0. doi:10.1007/978-3-642-13633-7_21. (Cited on page 7.)

Rowan, David and Cheshire, Tom. The app explosion. Wired.co.uk, December 2009. http://www.wired.co.uk/magazine/archive/2010/02/features/the-app-explosion Accessed on February 4th, 2014. (Cited on pages 61 and 71.)

Ruddock, David. Breaking: Google has begun purging ad-blocking apps from the Play store. Androidpolice.com, March 2013. http://www.androidpolice.com/2013/03/13/breaking-google-has-begun-purging-ad-blocking-apps-from-the-play-store/ Accessed on January 2nd, 2014. (Cited on page 46.)

Rysman, Marc. The economics of two-sided markets. *The Journal of Economic Perspectives*, 23(3):125–143, Summer 2009. ISSN 08953309. URL http://www.jstor.org/stable/27740544. (Cited on pages 65 and 67.)

S Salminen, Joni. *Startup Dilemmas — Strategic problems of early-stage platforms on the Internet*. Doctoral dissertation, Turku School of Economics, University of Turku, Turku, Finland, November 2014. URL http://urn.fi/URN:ISBN:978-952-249-371-2. Series A-12:2014. (Cited on pages 13, 41, 42, and 117.)

Salminen, Joni and Teixeira, Jose. Fool's gold? Developer dilemmas in a closed mobile application market platform. In Järveläinen, Jonna; Li, Hongxiu; Tuikka, Anne-Marie, and Kuusela, Tiina, editors, *Co-created Effective, Agile, and Trusted eServices — Proceedings of the 15th International Conference on Electronic Commerce, ICEC 2013*, volume 155 of *Lecture Notes in Business Information Processing*, pages 121–132, Berlin, Germany, August 2013. Springer Berlin Heidelberg. ISBN 978-3-642-39807-0. doi:10.1007/978-3-642-39808-7_11. (Cited on pages 51 and 52.)

Sandberg, Jörgen and Alvesson, Mats. Ways of constructing research questions: gap-spotting or problematization? *Organization*, 18(1):23–44, January 2011. ISSN 1461–7323. doi:10.1177/1350508410372151. (Cited on page 18.)

Sangani, Kris. Open all hours [iPhone]. *Engineering & Technology*, 5(3):18–19, February 2010. ISSN 1750-9645. doi:10.1049/et.2010.0302. (Cited on page 82.)

Santana, Francisco W. and Werner, Cláudia M. L. Towards the analysis of software projects dependencies: An exploratory visual study of software

ecosystems. In Alves, Carina F.; Hanssen, Geir K.; Bosch, Jan, and Jansen, Slinger, editors, *Proceedings of the 5th International Workshop on Software Ecosystems*, volume 987 of *CEUR Workshop Proceedings*, pages 1–12, Potsdam, Germany, June 2013. CEUR-WS. URL http://ceur-ws.org/Vol-987/1.pdf. (Cited on page 38.)

Scacchi, Walt. Free/open source software development: recent research results and emerging opportunities. In *The 6th Joint Meeting on European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering: Companion Papers*, ESEC-FSE companion '07, pages 459–468, New York, NY, USA, 2007. ACM. ISBN 978-1-59593-812-1. doi:10.1145/1295014.1295019. (Cited on page 37.)

Schaeffer, David J.; Herricks, Edwin E., and Kerster, Harold W. Ecosystem health: I. Measuring ecosystem health. *Environmental Management*, 12(4): 445–455, July 1988. ISSN 0364-152X. doi:10.1007/BF01873258. (Cited on pages 54 and 58.)

Scheffler, Israel. *In Praise of the Cognitive Emotions: And Other Essays in the Philosophy of Education*. Routledge Revivals. Routledge, Chapman & Hall, Inc., London, UK, 1st edition, 2010. ISBN 0-203-8947-7. (Cited on page 31.)

Schlagwein, Daniel; Schoder, Detlef, and Fischbach, Kai. Openness of information resources — a framework-based comparison of mobile platforms. In Alexander, P. M.; Turpin, Marita, and van Deventer, J. P., editors, *Proceedings of the 18th European Conference on Information Systems*, ECIS, pages 1–16, Pretoria, South Africa, June 2010. ISBN 978-0-620-47172-5. URL http://aisel.aisnet.org/ecis2010/163. (Cited on page 82.)

Schultz, Nicolai; Zarnekow, Rüdiger; Wulf, Jochen, and Nguyen, Quoc-Tuan. The new role of developers in the mobile ecosystem: An Apple and Google case study. In *15th International Conference on Intelligence in Next Generation Networks (ICIN)*, pages 103–108, October 2011. doi:10.1109/ICIN.2011.6081055. (Cited on pages 16, 80, and 114.)

Seaman, Carolyn B. Qualitative methods in empirical studies of software engineering. *IEEE Transactions on Software Engineering*, 25(4):557–572, July 1999. ISSN 0098-5589. doi:10.1109/32.799955. (Cited on page 86.)

Seppänen, Marko. *Business Model Concept: Building on Resource Components*. Ph.D. dissertation. Publication 745, Tampere University of Technology, Tampere, Finland, August 2008. URL http://URN.fi/URN:NBN:fi:tty-200809051006. (Cited on page 8.)

Shabtai, Asaf; Fledel, Yuval; Kanonov, Uri; Elovici, Yuval; Dolev, Shlomi, and Glezer, Chanan. Google Android: A comprehensive security assessment. *IEEE Security and Privacy*, 8(2):35–44, March 2010. ISSN 1540-7993. doi:10.1109/MSP.2010.2. (Cited on page 79.)

Shankland, Steven. Google: 500 million Android devices activated. CNET, September 2012. http://news.cnet.com/8301-1035_3-57510994-94/google-500-million-android-devices-activated/ Accessed February 5th, 2014. (Cited on page 98.)

Shapiro, Carl and Varian, Hal R. *Information rules: a strategic guide to the network economy*. Harvard Business School Press, Boston, MA, USA, 1999. ISBN 0-87584-863-X. (Cited on page 70.)

Sharma, Chetan. Sizing up the global mobile apps market. Industry Study Commissioned by Getjar, March 2010. (Cited on page 3.)

Shaw, Mary. Prospects for an engineering discipline of software. *IEEE Software*, 7(6):15–24, November 1990. ISSN 0740-7459. doi:10.1109/52.60586. (Cited on page 22.)

Shaw, Mary. The coming-of-age of software architecture research. In *Proceedings of the 23rd International Conference on Software Engineering*, ICSE '01, pages 656–664, Washington, DC, USA, 2001. IEEE Computer Society. ISBN 0-7695-1050-7. URL http://dl.acm.org/citation.cfm?id=381473.381549. (Cited on page 22.)

Siegler, MG. Project Spartan: Facebook's hush-hush plan to take on Apple on their own turf: iOS. Techcrunch.com, June 2011. URL http://techcrunch.com/2011/06/15/facebook-project-spartan/. Accessed on January 12th, 2014. (Cited on pages 53 and 65.)

Síthigh, Daithí Mac. App law within: rights and regulation in the smartphone age. *International Journal of Law and Information Technology*, 21(2):154–186, Summer 2013. ISSN 1464-3693. doi:10.1093/ijlit/eat002. (Cited on page 78.)

Solberg Søilen, Klaus; Kovacevic, Mauricio Aracena, and Jallouli, Rim. Key success factors for Ericsson mobile platforms using the value grid model. *Journal of Business Research*, 65(9):1335–1345, 2012. ISSN 0148-2963. doi:10.1016/j.jbusres.2011.10.002. (Cited on page 36.)

Song, Jaeki; Choi, Hyoungyong; Baker, Jeff, and Bhattacherjee, Anol. Mobile application development platform adoption: A grounded theory investigation. In *Proceedings of the Nineteenth Americas Conference on Information Systems*, pages 1–8, Chicago, IL, USA, August 2013a. (Cited on page 80.)

Song, Jaeki; Choi, Hyoungyong; Baker, Jeff, and Bhattacherjee, Anol. Towards a theory of information technology platform adoption. In *Proceedings of the Thirty Fourth International Conference on Information Systems*, pages 1–8, Milan, Italy, 2013b. (Cited on page 80.)

Spreeuwenberg, Kimberley and Poell, Thomas. Android and the political economy of the mobile internet: A renewal of open source critique. *First Monday*, 17(7), July 2012. ISSN 13960466. doi:10.5210/fm.v17i7.4050. (Cited on page 50.)

Stallman, Richard M. *Free Software, Free Society: Selected Essays of Richard M. Stallman*. Free Software Foundation, Inc., Boston, MA, USA, second edition, 2010. ISBN 978-0-9831592-0-9. (Cited on page 32.)

Stanley, Jo and Briscoe, Gerard. The ABC of digital business ecosystems. *Communications Law — Journal of Computer, Media and Telecommunications Law*, 15(1):12–25, 2010. ISSN 1746–7616. URL http://arxiv.org/abs/1005.1899. (Cited on page 30.)

Stelter, Brian. A Pulitzer winner gets Apple's reconsideration. The New York Times, April 2010. http://www.nytimes.com/2010/04/17/books/17cartoonist.html Accessed February 4th, 2014. (Cited on page 78.)

Stremersch, Stefan; Tellis, Gerard J.; Franses, Phillip Hans, and Binken, Jeroen L.G. Indirect network effects in new product growth. *Journal of Marketing*, 71(3):52–74, July 2007. ISSN 0022-2429. doi:10.1509/jmkg.71.3.52. (Cited on pages 67, 69, and 71.)

Suh, Yongyoon; Lee, Hakyeon, and Park, Yongtae. Analysis and visualisation of structure of smartphone application services using text mining and the set-covering algorithm: a case of App Store. *International Journal of Mobile Communications*, 10(1):1–20, December 2012. ISSN 1470-949X. doi:10.1504/IJMC.2012.044520. (Cited on page 81.)

Sullivan, Patricia. Maurice R. Hilleman dies; created vaccines. The Washington Post, April 2005. http://www.washingtonpost.com/wp-dyn/articles/A48244-2005Apr12.html Accessed on January 7th, 2014. (Cited on page 119.)

Sun, Mingchun and Tse, Edison. When does the winner take all in two-sided markets?. *Review of Network Economics*, 6(1):16–40, March 2007. ISSN 1446-9022. doi:10.2202/1446-9022.1108. (Cited on page 67.)

Sun, Mingchun and Tse, Edison. The resource-based view of competitive advantage in two-sided markets. *Journal of Management Studies*, 46(1):45–64, 2009. ISSN 1467-6486. doi:10.1111/j.1467-6486.2008.00796.x. (Cited on pages 15, 20, 66, 67, 89, 103, 104, 112, 113, and 123.)

Sun, Monica. How does the variance of product ratings matter? *Management Science*, 58(4):696–707, April 2012. ISSN 0025-1909. doi:10.1287/mnsc.1110.1458. (Cited on pages 74, 76, 89, 102, 111, 123, and 128.)

Suominen, Arho; Hyrynsalmi, Sami, and Knuutila, Timo. Young mobile phone users: radical and individual — not. *Telematics and Informatics*, 31(2):266–281, May 2014. ISSN 0736-5853. doi:10.1016/j.tele.2013.08.003. (Cited on pages 14 and 81.)

Taudes, Alfred; Feurstein, Markus, and Mild, Andreas. Options analysis of software platform decisions: a case study. *MIS Quarterly*, 24(2):227–243, June 2000. ISSN 0276-7783. doi:10.2307/3250937. (Cited on page 43.)

Tedre, Matti. Computing as a science: A survey of competing viewpoints. *Minds and Machines*, 21(3):361–387, August 2011. ISSN 0924-6495. doi:10.1007/s11023-011-9240-4. (Cited on page 22.)

Teixeira, Jose. Understanding coopetition in the open-source arena: The cases of WebKit and OpenStack. In *Proceedings of The International Symposium on Open Collaboration*, OpenSym '14, pages 39:1–39:5, New York, NY, USA, August 2014a. ACM. ISBN 978-1-4503-3016-9. doi:10.1145/2641580.2641627. (Cited on page 49.)

Teixeira, Jose. Understanding collaboration in the open-source arena: The cases of WebKit and OpenStack. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, EASE '14,

T

pages 52:1–52:5, New York, NY, USA, 2014b. ACM. ISBN 978-1-4503-2476-2. doi:10.1145/2601248.2613086. (Cited on page 49.)

Teixeira, Jose. Open-coopetition in the PC and mobile industries: the WebKit case. arXiv:1409.2255, September 2014c. URL http://arxiv.org/abs/1409.2255. (Cited on page 49.)

Teixeira, Jose and Lin, Tingting. Collaboration in the open-source arena: The WebKit case. In *Proceedings of the 52nd ACM Conference on Computers and People Research*, SIGSIM-CPR '14, pages 121–129, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2625-4. doi:10.1145/2599990.2600009. (Cited on page 49.)

Thelwall, Mike. Methodologies for crawler based web surveys. *Internet Research*, 12(2):124–138, 2002. ISSN 1066–2243. doi:10.1108/10662240210422503. (Cited on pages 23 and 91.)

Thelwall, Mike and Stuart, David. Web crawling ethics revisited: Cost, privacy, and denial of service. *Journal of American Society for Information Science and Technology*, 57(13):1771–1779, 2006. ISSN 1532-2890. doi:10.1002/asi.20388. (Cited on page 91.)

Thomas, Daniel and Bradshaw, Tim. Smartphone owners' appetite for new apps wanes. The Financial Times, August 2014. http://www.ft.com/intl/cms/s/0/4c3e5708-2628-11e4-9bca-00144feabdc0.html Accessed on December 13rd, 2014. (Cited on page xi.)

Tichy, Walter F.; Lukowicz, Paul; Prechelt, Lutz, and Heinz, Ernst A. Experimental evaluation in computer science: a quantitative study. *Journal of Systems and Software*, 28(1):9–18, January 1995. ISSN 0164-1212. doi:10.1016/0164-1212(94)00111-Y. (Cited on page 22.)

Tilson, David and Lyytinen, Kalle. Making broadband wireless services: An actor-network study of the US wireless industry standard adoption. *Sprouts: Working Papers on Information Systems*, 5(21):138–154, 2005. ISSN 1535-6078. URL http://sprouts.aisnet.org/5-21. (Cited on page 36.)

Tilson, David and Lyytinen, Kalle. The 3G transition: Changes in the US wireless industry. *Telecommunications Policy*, 30(10–11):569–586, 2006. ISSN 0308-5961. doi:10.1016/j.telpol.2006.09.002. (Cited on page 36.)

Tilson, David; Sørensen, Carsten, and Lyytinen, Kalle. Change and control paradoxes in mobile infrastructure innovation: The Android and iOS mobile operating systems cases. In *45th Hawaii International Conference on System Science (HICSS)*, pages 1324–1333, January 2012. doi:10.1109/HICSS.2012.149. (Cited on page 82.)

Tiwana, Amrit. *Platform Ecosystems: Aligning Architecture, Governance, and Strategy*. Morgan Kaufmann, Waltham, MA, USA, 1st edition, 2014. ISBN 978-0124080669. (Cited on page 44.)

Tonner, Matthew. Tethering applications and open internet rules for the mobile broadband: Lessons from the FCC-Verizon settlement. *Hastings Communications and Entertainment Law Journal*, 35(3):471–492, 2013. (Cited on page 78.)

Tracy, Kim W. Mobile application development experiences on Apple's iOS and Android OS. *IEEE Potentials*, 31(4):30–34, August 2012. ISSN 0278-6648. doi:10.1109/MPOT.2011.2182571. (Cited on page 61.)

Tåg, Joacim. Competing platforms and third party application developers. *Communications & Strategies*, 74(2):95–114, June 2009. URL http://ssrn.com/abstract=1559094. (Cited on page 70.)

Tsotsis, Alexia. This is Facebook's Project Spartan [screenshots]. Techcrunch, September 2011. URL http://techcrunch.com/2011/09/28/this-sure-looks-a-lot-like-facebooks-project-spartan-screenshots/. Accessed on January 14th, 2014. (Cited on page 53.)

Tuikka, Anne-Marie; Hyrynsalmi, Sami; Kimppa, Kai K., and Suominen, Arho. Challenges in entering application markets among software producers in developing countries. In Ward Bynum, Terrell; Fleishman, William; Gerdes, Anne; Møldrup Nielsen, Gitte, and Rogerson, Simon, editors, *Proceedings of the Thirteenth International Conference: The possibilities of Ethical ICT (ETHICOMP 2013)*, pages 478–487, Kolding, Denmark, June 2013. Print & Sign University of Southern Denmark. ISBN 978-87-92646-72-9. (Cited on pages 27, 105, and 107.)

Tuunainen, Virpi Kristiina; Tuunanen, Tuure, and Piispanen, Jouni. Mobile service platforms: Comparing Nokia OVI and Apple App Store with the IISIn model. In *Proceedings of the 2011 10th International Conference on Mobile Business*, ICMB '11, pages 74–83, Washington, DC, USA, 2011. IEEE Computer Society. ISBN 978-0-7695-4434-2. doi:10.1109/ICMB.2011.42. (Cited on page 82.)

Tyrväinen, Pasi and Jansen, Slinger. Preface. In Tyrväinen, Pasi; Jansen, Slinger, and Cusumano, Michael A., editors, *Proceedings of Software Business — First International Conference, ICSOB 2010, Jyväskylä, Finland, June 21-23, 2010*, volume 51 of *Lecture Notes in Business Information Processing*, pages v–vi, Berlin, Germany, 2010. Springer Berlin Heidelberg. ISBN 978-3-642-13632-0. doi:10.1007/978-3-642-13633-7. (Cited on page 7.)

Ulrich, Karl T. and Eppinger, Steven D. *Product Design and Development*. McGraw-Hill Higher Education, New York, NY, USA, fourth edition, 2008. (Cited on page 41.)

United Nations. World population prospects: The 2012 revision, DVD edition. Pop/db/wpp/rev.2012/pop/f01-1, Department of Economic and Social Affairs. Population Division (2013), June 2013. Accessed on February 18th, 2014. (Cited on page 106.)

Unno, Masaru and Xu, Hua. Optimal platform strategies in the smartphone market. *Electronics and Communications in Japan*, 96(7):1–10, July 2013. ISSN 1942-9541. doi:10.1002/ecj.11462. (Cited on page 64.)

Vahtera, Hannu. *Views for focal companies on exploitation of market disruptions amidst industry evolution*. Doctoral dissertation, Turku School of Economics, University of Turku, Turku, Finland, 2014. Unpublished. (Cited on page 30.)

van Angeren, Joey; Blijleven, Vincent, and Jansen, Slinger. Relationship intimacy in software ecosystems: A survey of the Dutch software industry. In Grosky, William I.; Badr, Youakim, and Chbeir, Richard, editors, *Proceedings*

U

V

of the International Conference on Management of Emergent Digital EcoSystems, MEDES '11, pages 68–75, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-1047-5. doi:10.1145/2077489.2077502. (Cited on page 57.)

van Angeren, Joey; Blijleven, Vincent; Jansen, Slinger, and Brinkkemper, Sjaak. Complementor embeddedness in platform ecosystems: The case of Google Apps. In *7th IEEE International Conference on Digital Ecosystems and Technologies*, DEST'2013, pages 37–42, July 2013. doi:10.1109/DEST.2013.6611326. (Cited on page 57.)

Van Couvering, Elizabeth. New media? The political economy of internet search engines. In *Proceedings of the Conference of the International Association of Media & Communications Researchers (IAMCR)*, Porto Alegre, Brazil, September 2004. The Communication Technology Policy section. (Cited on page 91.)

van den Berk, Ivo; Jansen, Slinger, and Luinenburg, Lútzen. Software ecosystems: A software ecosystem strategy assessment model. In *Proceedings of the Fourth European Conference on Software Architecture: Companion Volume*, ECSA '10, pages 127–134, New York, NY, USA, August 2010. ACM. ISBN 978-1-4503-0179-4. doi:10.1145/1842752.1842781. (Cited on pages 35 and 57.)

van Lingen, Sonny; Palomba, Adrien, and Lucassen, Garm. On the software ecosystem health of open source content management systems. In Alves, Carina F.; Hanssen, Geir K.; Bosch, Jan, and Jansen, Slinger, editors, *Proceedings of the 5th International Workshop on Software Ecosystems*, volume 987 of *CEUR Workshop Proceedings*, pages 45–56, Potsdam, Germany, June 2013. CEUR-WS. URL http://ceur-ws.org/Vol-987/4.pdf. (Cited on page 57.)

Vannieuwenborg, Frederic; Mainil, Laurent; Verbrugge, Sofie; Pickavet, Mario, and Colle, Didier. Business models for the mobile application market from a developer's viewpoint. In *16th International Conference on Intelligence in Next Generation Networks*, ICIN'2012, pages 171–178. IEEE Computer Society, October 2012. doi:10.1109/ICIN.2012.6376022. (Cited on pages 79 and 119.)

Vannini, Stefano. Bargaining and two-sided markets: The case of global distribution systems (GDS) in travelport's acquisition of worldspan. *Competition Policy Newsletter*, 2008(2):43–50, 2008. ISSN 1025-2266. (Cited on page 123.)

Verkasalo, Hannu. Open mobile platforms: Modeling the long-tail of application usage. In *Fourth International Conference on Internet and Web Applications and Services*, ICIW, pages 112–118, Los Alamitos, CA, USA, 2009. IEEE Computer Society. ISBN 978-0-7695-3613-2. doi:10.1109/ICIW.2009.24. (Cited on page 43.)

Vessey, Iris; Ramesh, V., and Glass, Robert L. Research in information systems: An empirical study of diversity in the discipline and its journals. *Journal of Management Information Systems*, 19(2):129–174, October 2002. ISSN 0742-1222. URL http://www.jstor.org/stable/40398580. (Cited on page 22.)

VisionMobile and Plum Consulting. The European App Economy: Creating jobs and driving growth — Sizing the European App Economy and advocating policy options to drive growth. A report prepared by VisionMobile and Plum Consulting. Sponsored by ACT4Apps, September 2013. (Cited on pages 4 and 5.)

W

Walsham, Geoff. Interpretive case studies in IS research: nature and method. *European Journal of Information Systems*, 4(2):78–81, May 1995. ISSN 0960-085X. doi:10.1057/ejis.1995.9. (Cited on page 88.)

Walsham, Geoff. Doing interpretive research. *European Journal of Information Systems*, 15(3):320–330, June 2006. ISSN 0960-085X. doi:10.1057/palgrave.ejis.3000589. (Cited on page 88.)

Waltl, Josef. *IP Modularity in Software Products and Software Platform Ecosystems*. Dissertation, Technische Universität München, München, Germany, January 2013. (Cited on page 114.)

Wegner, Peter. Research paradigms in computer science. In *Proceedings of the 2nd International Conference on Software Engineering*, ICSE '76, pages 322–330, Los Alamitos, CA, USA, 1976. IEEE Computer Society Press. URL http://dl.acm.org/citation.cfm?id=800253.807694. (Cited on pages 9 and 22.)

West, Joel and Mace, Michael. Browsing as the killer app: Explaining the rapid success of Apple's iPhone. *Telecommunications Policy*, 34(5–6):270–286, June 2010. ISSN 0308-5961. doi:10.1016/j.telpol.2009.12.002. (Cited on pages 3, 16, 35, 79, and 114.)

West, Joel and Wood, David. Evolving an open ecosystem: The rise and fall of the Symbian platform. In Adner, Ron; Oxley, Joanne E., and Silverman, Brian S., editors, *Collaboration and Competition in Business Ecosystems*, volume 30 of *Advances in Strategic Management*, pages 27–67. Emerald Group Publishing Limited, 2013. ISBN 978-1-78190-827-3. doi:10.1108/S0742-3322(2013)0000030005. (Cited on page 46.)

Weyl, E. Glen. A price theory of multi-sided platforms. *American Economic Review*, 100(4):1642–1672, September 2010. doi:10.1257/aer.100.4.1642. (Cited on page 62.)

Wilkins, D.A. Assessing ecosystem health. *Trends in Ecology & Evolution*, 14 (2):69, 1999. ISSN 0169-5347. doi:10.1016/S0169-5347(98)01526-2. (Cited on page 54.)

Wingfield, Nick. From the land of Angry Birds, a mobile game maker lifts off. Bits — The New York Times Technology, October 2012. Available at http://bits.blogs.nytimes.com/2012/10/08/from-the-land-of-angry-birds-a-mobile-game-maker-lifts-off/ Accessed on February 28th, 2013. (Cited on page 5.)

Wohlin, Claes; Höst, Martin, and Henningsson, Kennet. Empirical research methods in software engineering. In Conradi, Reidar and Wang, Alf Inge, editors, *Empirical Methods and Studies in Software Engineering*, volume 2765 of *Lecture Notes in Computer Science*, pages 7–23. Springer Berlin Heidelberg, Berlin, Germany, 2003. ISBN 978-3-540-40672-3. doi:10.1007/978-3-540-45143-3_2. (Cited on page 86.)

Wu, Tim. If a time traveller saw a smartphone. The New Yorker, January 2014. URL http://www.newyorker.com/online/blogs/elements/2014/01/if-a-time-traveller-saw-a-smartphone.html. Accessed on January 16th, 2014. (Cited on page 291.)

X Xanthopoulos, Spyros and Xinogalos, Stelios.   A comparative analysis of cross-platform development approaches for mobile applications.   In *Proceedings of the 6th Balkan Conference in Informatics*, BCI '13, pages 213–220, New York, NY, USA, 2013. ACM.   ISBN 978-1-4503-1851-8. doi:10.1145/2490257.2490292. (Cited on page 68.)

Xia, Ruixue; Rost, Mattias, and Holmquist, Lars Erik. Business models in the mobile ecosystem. In *Proceedings of the 2010 Ninth International Conference on Mobile Business / 2010 Ninth Global Mobility Roundtable*, ICMB-GMR '10, pages 1–8, Washington, DC, USA, June 2010. IEEE Computer Society. ISBN 978-0-7695-4084-9. doi:10.1109/ICMB-GMR.2010.30. (Cited on pages 9, 10, 16, 36, and 79.)

Y Yamakami, Toshihiko. Foundation-based mobile platform software engineering: Implications to convergence to open source software. In *Proceedings of the 2nd International Conference on Interaction Sciences: Information Technology, Culture and Human*, ICIS '09, pages 206–211, New York, NY, USA, 2009. ACM.   ISBN 978-1-60558-710-3.   doi:10.1145/1655925.1655962.   (Cited on page 36.)

Yamakami, Toshihiko. A mobile digital ecosystem framework: Lessons from the evolution of mobile data services. In *Proceedings of the 2010 13th International Conference on Network-Based Information Systems*, NBIS '10, pages 516–520, Washington, DC, USA, September 2010. IEEE Computer Society. ISBN 978-0-7695-4167-9. doi:10.1109/NBiS.2010.26. (Cited on page 16.)

Yan, Bo and Chen, Guanling. AppJoy: personalized mobile application discovery. In *Proceedings of the 9th International Conference on Mobile Systems, Applications, and Services*, MobiSys '11, pages 113–126, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0643-0. doi:10.1145/1999995.2000007. (Cited on pages 17 and 77.)

Yin, Robert K. *Case Study Research: Design and Methods*, volume 5 of *Applied Social Research Method Series*. SAGE Publications, Thousand Oaks, CA, USA, 4th edition, 2009. ISBN 978-1-4129-6099-1. (Cited on page 86.)

Young-Eisendrath, Polly. Suffering from biobabble: Searching for a science of subjectivity. In Dockett, Kathleen H.; Dudley-Grant, G. Rita, and Bankart, C. Peter, editors, *Psychology and Buddhism From Individual to Global Community*, International and Cultural Psychology Series, chapter 5, pages 125–138. Springer US, New York, NY, USA, 2003. ISBN 978-0-306-47937-3. doi:10.1007/0-306-47937-0_6. (Cited on page 31.)

Yu, Liguo; Ramaswamy, Srini, and Bush, John. Software evolvability: An ecosystem point of view. In *Third International IEEE Workshop on Software Evolvability*, pages 75–80. IEEE, 2007. doi:10.1109/SE.2007.8. (Cited on pages 32, 37, 48, 49, and 50.)

Yu, Liguo; Ramaswamy, Srini, and Bush, John.   Symbiosis and software evolvability. *IT Professional*, 10(4):56–62, July/August 2008. ISSN 1520-9202. doi:10.1109/MITP.2008.94. (Cited on pages 38, 48, 49, and 125.)

Z Zeidler, Sue. Hollywood targets "rogue" mobile apps in war on pirated content. Reuters, February 2013. http://www.reuters.com/article/2013/03/

`01/net-us-hollywood-apps-idUSBRE92003Y20130301` Accessed on January 2nd, 2014. (Cited on page 46.)

Zelkowitz, Marvin V. and Wallace, Dolores. Experimental validation in software engineering. *Information and Software Technology*, 39(11):735–743, 1997. ISSN 0950-5849. doi:10.1016/S0950-5849(97)00025-6. (Cited on page 22.)

Zhang, Jing and Liang, Xiong-Jian. Business ecosystem strategies of mobile network operators in the 3G era: The case of China Mobile. *Telecommunications Policy*, 35(2):156–171, March 2011. ISSN 0308-5961. doi:10.1016/j.telpol.2010.12.009. (Cited on page 36.)

Zhang, Lin; Ma, Baolong, and Cartwright, Debra K. The impact of online user reviews on cameras sales. *European Journal of Marketing*, 47(7):1115–1128, 2013. ISSN 0309-0566. doi:10.1108/03090561311324237. (Cited on page 75.)

Zhong, Nan and Michahelles, Florian. Long tail or superstar?: An analysis of app adoption on the Android Market. In Poppinga, Benjamin; Cramer, Henriette; Böhmer, Matthias; Morrison, Alistair; Bentley, Frank; Henze, Niels; Rost, Mattias, and Michahelles, Florian, editors, *Proceedings of the 3rd International Workshop on Research in the Large — App Stores, Wide Distribution, and Big Data in MobileHCI Research*, volume 3 of *Research in the Large (LARGE 3.0)*, pages 11–14, San Francisco, CA, USA, September 2012a. (Cited on pages 58 and 81.)

Zhong, Nan and Michahelles, Florian. Where should you focus: Long tail or superstar?: An analysis of app adoption on the Android Market. In *SIGGRAPH Asia 2012 Symposium on Apps*, SA '12, pages 10:1–10:1, New York, NY, USA, 2012b. ACM. ISBN 978-1-4503-1916-4. doi:10.1145/2407696.2407706. (Cited on pages 58 and 81.)

Zhong, Nan and Michahelles, Florian. Google Play is not a long tail market: An empirical analysis of app adoption on the Google Play app market. In *Proceedings of the 28th Annual ACM Symposium on Applied Computing*, SAC '13, pages 499–504, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-1656-9. doi:10.1145/2480362.2480460. (Cited on pages 81 and 120.)

Zhou, Wu; Zhang, Xinwen, and Jiang, Xuxian. AppInk: Watermarking Android apps for repackaging deterrence. In *Proceedings of the 8th ACM SIGSAC Symposium on Information, Computer and Communications Security*, ASIA CCS '13, pages 1–12, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-1767-2. doi:10.1145/2484313.2484315. (Cited on page 79.)

Zhu, Feng and Zhang, Xiaoquan (Michael). The impact of online consumer reviews on sales: the moderating role of product and consumer characteristics. *Journal of Marketing*, 74(2):133–148, 2010. doi:10.1509/jmkg.74.2.133. (Cited on pages 74 and 75.)

Zott, Christoph; Amit, Raphael, and Massa, Lorenzo. The business model: Recent developments and future research. *Journal of Management*, 37(37):1019–1042, July 2011. doi:10.1177/0149206311406265. (Cited on page 8.)

Part II

ORIGINAL PUBLICATIONS

And those who were seen dancing
were thought to be insane by those
who could not hear the music.

— Friedrich Nietzsche (unconfirmed)

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PVI

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MARKETS AMONG SOFTWARE PRODUCERS IN
DEVELOPING COUNTRIES

By Anne-Marie Tuikka, Sami Hyrynsalmi, Kai K. Kimppa &
Arho Suominen

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Part III

APPENDICES

If someone from the 1950s suddenly appeared today, what would be the most difficult thing to explain to them about life today?

I possess a device, in my pocket, that is capable of accessing the entirety of information known to man. I use it to look at pictures of cats and get in arguments with strangers.

— A discussion in Reddit on January 4th, 2013

A

EXAMPLES OF CRAWLED DATA

With our machines, we are augmented humans and prosthetic gods, though we're remarkably blasé about that fact, like anything we're used to.

— Professor Tim Wu, 2014

This appendix aims to illustrate the collected datasets and the used variables with a few applications from each marketplace. The values presented in the following are in the form in which they were crawled. In the following tables, an ellipsis ('...') indicates that the full value does not fit in the table and thus it has been presented in a partial form.

Table A.1 presents data collected of three Google Play applications in June 2012. The field *'Updated'* refers to the date when the application had been updated. *'Version'* is the version of the application as defined by the developer. *'Android ver.'* refers to the minimum version of Android operating system that is needed to run the application. *'Top Dev.'* and *'Editor'* refer to the top developer status and Editor's choice list in the marketplace, respectively.

Table A.2 presents data of three Apple App Store applications in March 2012. The field *'Support'* refers to the web address where a consumer can get help with the application. The marketplace contain three possibly different values for the vendor of the application: *'Seller'* is the general name of the application ISV, *'Seller (for.)'* refers to the more formal name of the ISV and *'Copyright'* indicates the IPR holder of the application. *'Ver.'* is an abbreviation of the version of the application. *'Votes (c)'* and *'Rating (c)'* refer to the number of star ratings given and the average of the given stars in the current version of the application. Respectively, *'Votes'* and *'Rating'* indicate the same variables but for all versions of the application. *'Top in-app'* and *'(Price)'* refer to the best selling in-application purchase and its price.

Table A.3 presents data of three Windows Phone Store applications in March 2012. The field *'Free-to-Try'* indicates a customer

can install a free, but somehow limited or restricted, version of an application. *'Policies'* indicate what rights the application requests from the phone to be used. For example, an application might need to transfer data to or from the phone via either cellular data or Wi-Fi connection. This is indicated by a requirement of 'data services'.

Table A.1: The collected data of three Google Play applications in June 2012.

	NAME	DEVELOPER	PRICE	UPDATED
1.	Facebook for Android	Facebook	Free	June 15, 2012
2.	Anomaly Warzone Earth...	11 bit studios	2.99 €	May 23, 2012
3.	NYTimes app for tablet	The New...	Free	June 26, 2011

	VERSION	ANDROID VER.	CATEGORY
1.	Varies with device	Varies with device	Social
2.	1.15	2.2 and up	Arcade
3.	1.0.3	1.6 and up	News and Magazines

	DOWNLOADS	SIZE	CONTENT RATING
1.	100,000,000 - 500,000,000	Varies with device	Medium Maturity
2.	50,000 - 100,000	1.7M	Low Maturity
3.	100,000 - 500,000	1.1M	Medium Maturity

	DESCRIPTION	URL
1.	Keep up with friends...	http://www.facebook.com/apps...
2.	Turn tower defense on its...	http://www.11bitstudios.com
3.	Enjoy the award-winning...	http://www.nytimes.com/mobile

	VOTES	RATING	TOP DEV.	EDITOR	EMAIL
1.	3,790,314	3.6	Yes	No	android-support@fb.com
2.	1,251	4.5	No	No	support@11bitstudios...
3.	335	3.1	Yes	No	android@nytimes.com

	IDENTIFIER
1.	com.facebook.katana
2.	com.elevenbitstudios.AnomalyWarzoneEarthHD
3.	com.nytimes.android.tablet

Table A.2: The collected data of three (Apple) App Store applications in March 2012.

	NAME	SELLER	PRICE	DESCRIPTION
1.	Facebook	Facebook, Inc.	Free	Facebook for...
2.	Angry Birds HD	Chillingo Ltd	$2.99	Use the unique...
3.	Proyector Palabras...	On Target Apps	$1.99	Apps para...

	WEB SITE	SUPPORT
1.	http://www.facebook.com/mobile	http://www.facebook.com/...
2.	http://www.angrybirds.com	http://www.chillingo.com/...
3.	http://www.ontargetapps.com	

	CATEGORY	UPDATED	SELLER (FOR.)	VER.	SIZE
1.	Social Networking	Dec 18, 2011	Facebook, Inc.	4.1	10.1 MB
2.	Games	Mar 20, 2012	Chillingo Ltd	2.1.0	14.1 MB
3.	Education	Sep 28, 2010	Keith Costello	1.0	3.7 MB

	LANGUAGES	COPYRIGHT	AGE
1.	English, Chinese, Dutch, French...	Facebook, Inc.	Rated 4+
2.	English, Chinese, French, German...	Rovio Mobile	Rated 4+
3.	English	On Target Apps	Rated 4+

	COMPATIBLE	REQUIREMENTS	VOTES (C)	RATING (C)
1.	iPhone, iPod touch...	iOS 4.0 or later	55729	2.50
2.	iPad	iOS 3.2 or later	672	4.00
3.	iPad	iOS 3.2 or later	-	-

	VOTES	RATING	TOP IN-APP	(PRICE)	IDENTIFIER
1.	1904796	4	-	-	id284882215
2.	60193	4.5	Unlimited use...	($0.99)	id364234221
3.	-	-	-	-	id393803479

Table A.3: The collected data of three (Microsoft) Windows Phone Store applications in March 2012.

	NAME	PRICE	FREE-TO-TRY	DESCRIPTION
1.	Angry Birds	$2.99	Yes	Angry Birds by Rovio...
2.	Flashlight-X	Free	No	Flashlight-X is the only...
3.	Facebook	Free	No	Facebook for Windows...

	CATEGORY	REQUIREMENTS	PUBLISHER
1.	action + adventure	Windows Phone 7 or higher	Rovio
2.	tools + productivity	Windows Phone 7.5 or higher	Asleroid
3.	social	Windows Phone 7.5 or higher	Microsoft...

	RELEASED	VERSION	SIZE	LANGUAGES
1.	5/27/2011	1.1.0.0	19 MB	Deutsch; English; Español...
2.	9/22/2011	3.0.0.0	< 1 MB	English
3.	10/19/2010	2.4.0.0	1 MB	Deutsch; English; Español...

	AGE	RATING	VOTES	POLICIES
1.	E (Everyone)	4.00	4595	data services; music and video...
2.	-	4.50	9490	data services; microphone...
3.	-	3.00	12511	location services; data services...

	IDENTIFIER
1.	e4571a02-0b87-e011-986b-78e7d1fa76f8
2.	2638b778-5eab-45f1-a511-a08e1dbde751
3.	82a23635-5bd9-df11-a844-00237de2db9e

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