1 Introduction

1.1 Motivation

Telecommunications markets all over the world recently have been, and still are, undergoing drastic changes, fuelled by market reforms and technological progress. State-owned monopolists have been privatized and markets have been liberalized. These transformed markets have attracted entrants in many varieties. Some entrants roll out complete networks, while others build only partial networks or perhaps offer services without having infrastructure themselves but by having access to the networks of incumbent operators.

The move away from regulated monopolies has been made possible by advances in communications technology, which have made the view that markets for fixed telephony are natural monopolies less plausible. The argument in the past was that the cost of connecting end users by digging holes for fixed lines was too high to support more than one operator. Arguably, since the speed at which entrants have been rolling out local networks is perhaps lower than was expected, it is not completely clear to what extent the natural-monopoly argument is no longer valid, in particular in residential and rural segments of the market. However, in the relatively young markets for mobile telephony, voice and data are transmitted over the airwaves so that costly fixed connections are not needed. The argument in favor of competition is therefore more clear cut for mobile telephony. In most national markets in Europe, several network operators have been able to gain substantial customer bases within a couple of years of liberalization taking place.

Telecommunications markets also receive a lot of attention, because they provide the pipes and services that make "convergence" possible, that is, the vertical integration of infrastructure and content, the interchangeability of different types of networks, and the digitalization of different types of information (e.g. voice, data, and video). The growing importance of telecommunications for the functioning of both the "old" and the "new" economy raises the stakes. Hence, regulation in telecommunications markets indirectly affects the whole economy. Against this background of drastic change, which goes together with

a lot of uncertainty, it has become vital to develop a thorough understanding of the economic mechanisms at play in telecommunications markets.

This book explores entry in telecommunications markets in a rich set of environments, incorporating details and asymmetries that are relevant in the light of observed market characteristics and regulatory practices. Each of the settings that we analyze focuses on competition between an initially dominant incumbent and an entrant. The settings are different in three dimensions: (i) the type of entrant, e.g. with a complete or a partial network; (ii) the way the operators compete, e.g. in two-part tariffs or in linear prices; and (iii) possible segmentation of the market into different types of customers. In each case we are interested in the possibilities for entry in the market and the extent to which consumers benefit from competition. Each situation may give rise to different possibilities for policy and regulation.

Clearly, in a mature market, there are no reasons for a regulator to treat the incumbent and entrants differently, that is, if there is a level-playing field, then regulation should be symmetric. Our main interest is the impact of regulation in immature markets without a level playing field. In such situations, it is important to explore the potential benefits of asymmetric regulation, possibly favoring entrants on a temporary basis. Large parts of the book are therefore dedicated to *asymmetric regulation in asymmetric markets* – this is a central issue for regulators in the "early" stages of competition in a liberalized market, in other words, in an infant market (as we will call it throughout the book).[1]

We aim at filling a gap between, on the one hand, the economic literature on competition in telecommunications markets, and on the other hand, real-life application of theory to policy and regulation. This book, which is based on models from the theory of industrial organization and techniques of numerical simulation, and the accompanying software, can be seen as a toolbox for economists involved in policy and regulation of telecommunications markets. The simulation programs allow policy makers to perform mock exercises before implementing a certain measure in practice. Testing the effects of policy measures in a simulation model can greatly enhance the understanding of the complicated causalities and interactions in telecommunications markets. Such an understanding makes the existing theory, which is rather abstract, more accessible to policy makers.

At a more general level, applied economists, economic consultants, and telecommunications professionals may find this book useful because it can also be seen as an application of microeconomics to pricing, competitive strategy and regulation. For instance, one can use the simulation programs to experiment with different pricing strategies for the retail market, to work out targeted entry strategies, or to better understand how wholesale prices affect the overall

[1] Previous literature on competition in telecommunications hardly addresses this issue.

profitability, which is potentially valuable in negotiations about interconnection agreements. We are convinced that numerical exploration of economic theory by simulation methods adds great value in such applications. Also, it is our experience that numerical simulations are very helpful to communicate general insights and guidelines for policy that can be derived from economic analysis.

1.2 Contribution to existing literature

An important reference on the economics of telecommunications is *Competition in telecommunications* by Jean-Jacques Laffont and Jean Tirole (2000). It is essentially an overview of recent economic theory and its implications for policy and regulation. The main themes in the book are regulation of access to essential facilities, competition between network operators, and universal service provision. Laffont and Tirole make the existing theory of, among others, regulation of access to essential facilities and regulation of markets with competing networks accessible to a broader audience, including policy makers.

Our work builds on and is complementary to Laffont and Tirole's book, and the underlying academic articles on two-way access, in several ways.[2] While recognizing the importance of presenting the central ideas that have emerged in the academic literature, we have experienced in practice that policy makers and regulators still have a need for more direct applications of theory, fine-tuned to the specific problems that they are dealing with. It is because of this need that we have developed a range of models – based on and inspired by existing theory – that can cope with a wide range of policy issues that surface in the real world. Each model clearly demonstrates the main trade-offs that are encountered by policy makers dealing with, for instance, regulation of access prices or retail prices.

Additionally, we merely focus on *entry*. Despite its real-world importance in the light of recent market liberalization, entry is a topic which is relatively unexplored in the literature within the context of telecommunications. In particular, we address how different entry strategies are affected by policy and regulation. More generally, we analyze how regulatory instruments, such as regulation of interconnection tariffs and retail price caps, affect market shares, profit levels, consumers surplus, and so on, as the market gradually matures. We have experienced that policy makers are eager to learn more about the effects of policy instruments in situations of asymmetry between incumbents and entrants. In such asymmetric markets characterized by imperfect competition we explore in detail the virtue of asymmetric regulation. Repeatedly, we find that asymmetric regulation that favors the entrant positively affects consumers

[2] See Armstrong (1998) and Laffont, Rey, and Tirole (1998a, b); see also Carter and Wright (1999a).

surplus and entrant's profits. It can thus be seen as a means to promote both short- and long-term gains for consumers.

Another contribution of this book stems from the methods that are deployed. We start with a simple, game-theoretic model that captures the main features of a competitive situation in a telecommunications market. Next, we adapt this model to explore a range of entry strategies, and how market outcomes are affected by regulation, using simulations on a computer. Accordingly, on the one hand a rich and varied set of outcomes is generated, and on the other hand, the standard economic framework provided by game theory gives the reader a good sense of the broad picture.[3]

For problems that are too difficult to solve analytically, simulation is often a method of last resort. Here also, the use of numerical simulations turned out to be useful, and often necessary. This is partly due to the asymmetries between entrant and incumbent that we incorporate in our models. Nevertheless, while some may view numerical methods as inferior to analytical methods, we are convinced that they generate major benefits for the application of economic theory to the practice of policy and regulation – especially for the problems that telecoms professionals are most likely trying to deal with.

1.3 Approach

1.3.1 Game theory and industrial organization

In situations where a relatively small number of firms compete, a sensible analysis of firm behavior and market structure should involve the strategic interaction between firms. Game theory is the mathematical analysis of rational behavior in situations where one player's payoff depends on the actions of other players, that is, the optimal action of one player depends on their belief about the actions the other players are going to take.[4]

Game theory is particularly useful to the telecommunications industry, which is more complex than many product markets. At first glance, one may think that an operator simply sells voice telephony. Nevertheless, sales volume not only contributes to revenues and costs, but also generates traffic between operators. Traffic that goes from one operator's network to another generates access payments between operators. Therefore, the cost and profit structures of an operator are not straightforward. By using a formal model, it becomes easier to understand the operators' incentive structures.

[3] De Bijl and Peitz (2000), a study at the request of the Dutch telecommunications authority Opta (the report that led to this book), demonstrates the usefulness for policy purposes of obtaining qualitative insights with numerical methods.

[4] An introductory text book on game theory is Gibbons (1992). A more elaborate reference is Fudenberg and Tirole (1991).

During the last three decades, economists have exerted a lot of effort to apply game-theoretic techniques to problems in industrial economics.[5] The models in this book are applications of the theory of industrial organization. They are based on recent economic theory developed by Armstrong (1998) and Laffont, Rey, and Tirole (1998a, b).

Although models of industrial organization have their limitations just as other theories do, they impose discipline on the researcher to carefully define the boundaries of the problem at hand, and are unique in generating insights into complicated interactions and trade-offs. By itself, game theory is not a theory of firm behavior and market structure, but a set of logical tools that constrain and shape arguments about strategic interaction among firms. The role of game-theoretic models is to deliver insights through structured reasoning. In particular, they build up a system of logic that enables one to recognize flawed reasoning, and provide a common language and framework for analysis.

As a disclaimer, we want to stress that our models do not describe reality in full detail. To analyze strategic interaction in telecommunications markets, one has to solve puzzles in which many pieces are missing. In general, the tools of game theory are not powerful enough to make precise or quantitative predictions about real-world cases, but then neither can other theories. In any case, that is beyond our purposes. As always, one should never rely merely on stylized models but complement them with empirical observations and expert opinion.

1.3.2 Simulation models

As a start, we develop and analyze a stylized, static model of competition, and next, we explore several dynamic extensions of this basic model. Extensions incorporate (i) entry modes; (ii) the nature of price competition; and (iii) possible segmentation of the market.

Both the basic model and its extensions incorporate the fact that operators may initially have different market shares that are "sticky" owing to consumer switching costs. In other words, history matters in the sense that it gives the former monopolist the advantage of a large installed base of customers. In the extensions, we explicitly analyze the speed at which an entrant can gain market share.

The main elements of our approach are the following.

- We assume that its large customer base and reputation for established quality ("track record") gives the incumbent operator a head start. This assumption captures the initial real-world situation in recently liberalized telecommunications markets.

[5] See, for example, Tirole (1988), and more recently, on a more basic level, Cabral (2000).

- The evolution of market shares, and the ways they are affected by network investments and regulation, are at the core of the analysis.
- We allow for realistic and interesting asymmetries between incumbent and entrant, in particular with respect to network structures.

To keep the analysis tractable, we assume that in each period operators maximize their per-period profits and consumers maximize their per-period net benefits. Abstracting from intertemporal linkages that would result in a dynamic game, this seems a good starting point for the analysis. We describe operators in their pricing decisions as myopic players who ignore the impact of current market share on future profits when analyzing pricing decisions. Although this assumption is obviously restrictive, at the same time it has some realistic content. For instance, investors sometimes give managers incentives to aim at a fast recovery of investments, hence introducing a bias towards short-run profit maximization. Additionally, a quick turnover of personnel at sales and marketing departments may make it difficult to implement long-term pricing strategies. Finally, we are convinced that this simplification is very useful for the purpose of deriving policy implications, given that one acknowledges its limitations.

The entry situations that we explore cover the most important entry modes observed in most European countries, where the former national monopolist faces different types of competition. For the sake of illustration, we adopt cost and demand parameters that, to a certain extent, depict a small country that resembles the Netherlands. We do not claim that the simulations depict the situation in the Netherlands, though. It is also important to note that within reasonable ranges, the levels of the parameters do not qualitatively affect the policy implications of the models.

The use of numerical methods is becoming more and more standard in economic analysis.[6] We used *Mathematica* software from Wolfram Research to program and analyze numerical simulations on a computer. For the benefit of the reader, we have included one of the main simulation programs in an appendix in this book, while all programs are available at the Cambridge University Press Web site.[7] This allows the reader to perform his or her own simulations under different parameter constellations and regulatory policies.

1.4 Outline

Our book consists of nine chapters. Chapter 2 provides background material on telecommunications technology, markets, institutional settings, and economic

[6] For an overview of numerical methods in economics we refer to Judd (1998). For the use of *Mathematica* for numerical analysis in economics see Huang and Crooke (1997) and Varian (1996). Froeb and Werden (1996) and Green (2000) provide applications of numerical analysis to problems in industrial organization.

[7] See http://uk.cambridge.org/resources/0521808375.

concepts. Chapters 3 to 6 analyze competition in a non-segmented market. Chapter 3 describes the basic model and provides some general insights on competition in telecommunications markets. Chapters 4 and 5 analyze three different modes of entry (facilities-based entry, entry based on local loop unbundling, and entry based on "carrier select").[8] In these chapters, we assume that operators compete in two-part tariffs, that is, by setting subscription fees as well as per-minute prices. Chapter 6 explores different pricing strategies, such as linear prices and flat fees. It also analyzes termination-based price discrimination. Chapters 7 and 8 focus on segmented markets and targeted entry (supposing that operators compete in two-part tariffs). Exploring competition in segmented markets at a general level, Chapter 7 concentrates on facilities-based entry in all market segments. Chapter 8 focuses on strategies of targeted entry, where an entrant targets different segments in different ways, or targets only one segment of the market. Throughout Chapters 3 to 8, we highlight the main insights relevant for policy as numbered guidelines. Chapter 9 puts the results and guidelines in perspective by discussing further topics that are relevant for policy from a broader perspective.

Each chapter contains an introduction, laying out in more detail how we proceed. Also, each chapter concludes with a non-technical summary of the main results, allowing the reader to learn the basic insights without going through the analysis. Several chapters contain extensive appendices which contain more technical or supplementary material. Chapters 3 and 6 contain mathematical derivations in the main text. Nevertheless, we have tried to explain them in words, so that readers can skip the mathematics without interrupting the line of reasoning.

We will now describe in more detail the contents of Chapters 3 to 8, the main body of the book. Chapter 3 presents the basic model, the simplest version of our models, which serves as a starting point for the analysis and as a reference point to understand more complicated models. It depicts competition between two operators that are identical except for their installed customer base. In particular, each operator has a network consisting of a long-distance backbone and customer access infrastructure (the "local loop"). Hence this model depicts a situation of "facilities-based competition." We provide a detailed description of its components: operators, consumer demand, consumer switching costs, realized market shares, costs, volumes of on-net and off-net traffic, profit functions, surplus, welfare, and equilibrium concept (Section 3.2). We also relate our model with consumer switching costs to models of differentiated networks. In Section 3.3, preliminary results in a symmetric setting are based on straightforward calculations. Here, we establish equilibrium properties. For asymmetric initial market shares, we use numerical methods which

[8] See Chapter 2 for explanations of terminology.

are described in Section 3.4. With the help of simulations we assess the effects of reciprocal terminating access prices and non-reciprocal terminating access prices (Section 3.5). Throughout the book, results are evaluated by looking at prices, market shares, profit levels, consumer surplus, producer surplus, and welfare. In the basic model, the operators compete by setting two-part tariffs (consisting of a subscription fee and a per-minute price). In Section 3.6, we then compare the results derived under two-part tariffs with those under linear prices (consisting of only a per-minute price). Within that context, we discuss the possibility of using the access price as an instrument of tacit collusion. In Section 3.7, we analyze retail price caps on the incumbent's subscription fee and per-minute price.

Whereas Chapter 3 depicts facilities-based competition in a mature market with identical operators and in an infant market with asymmetric operators, Chapter 4 focuses on entry in a dynamic context. The basic model is modified and extended to incorporate market dynamics, as explained in Section 4.2. The subsequent sections investigate access price regulation (we consider cost-based, reciprocal, and non-reciprocal access prices) and retail price regulation by the means of price caps.

In Chapter 5, we explore "local-loop unbundling" and entry by "carrier-select" operators. Section 5.2 analyzes unbundled access to the incumbent's local loop, assuming that the entrant has a long-distance backbone. In order to serve end users, it leases the incumbent's local loop on a per-period and per-customer basis. The lease price then becomes an additional regulatory variable. In Section 5.3, we look at the case where the entrant, having its own backbone but no customer access network, uses originating access to the incumbent's local loop to serve end users. Consumers dial a carrier-select prefix to make calls through the entrant's network. Section 5.4 compares the entry modes explored in Chapters 4 and 5 to discuss entrants' incentives to build a local network. By comparing the entrant's profit levels under different modes of entry for a given regulatory regime, one can assess the effect of the regulatory regime on the entrant's incentives to invest in infrastructure.

The results in Chapters 4 and 5 are based on the assumption that the operators compete with two-part tariffs. Chapter 6 complements those results by considering alternative pricing strategies. In Section 6.2, we have a closer look at linear pricing (i.e., the operators only set per-minute prices). Section 6.3 analyzes flat fees (i.e., the operators only set subscription fees while call minutes are free). Termination-based price differentiation is the subject of Section 6.4: operators are allowed to differentiate the per-minute prices of on-net and off-net calls. This situation applies, for example, to competition between a fixed and a mobile operator.

In the chapters presented so far, the market is assumed to be unsegmented: consumers are homogeneous (with the exception of switching costs). In

Chapters 7 and 8, we consider facilities-based entry in a segmented market. We consider markets with two market segments and assume that either operators can explicitly discriminate between them or that they are subject to a uniform pricing constraint. The typical example of a segmented market is that the market consists of residential and corporate customers, but other interpretations are given as well.

In Chapter 7, the entrant targets both segments of the market; the corresponding model extension is explained in Section 7.2. In Section 7.3, we analyze price discrimination by both operators and, in Section 7.4, we look at price discrimination only by the entrant, and uniform pricing across market segments. Of particular interest is the role of consumers' calling patterns between the segments, that is, their inclination to make relatively more calls to customers in a certain segment.

Chapter 8 complements Chapter 7 by focusing on different modes of targeted entry. Firstly, we look at partial entry, that is, the entrant targets only one segment of the market. We focus on regulation in situations of facilities-based entry (Section 8.2), local loop unbundling (Section 8.3) and carrier-select-based entry (Section 8.4). Secondly, we consider mixed entry, that is, the entrant targets both segments but in different ways (Section 8.5). We consider two cases: a combination of facilities-based entry in one segment and local loop unbundling in the other segment, and a combination of facilities-based entry and carrier-select-based entry. Througout the chapter, we discuss price discrimination as well as uniform pricing across the segments.

The concluding chapter, Chapter 9, addresses further issues, such as efficient entry, regulatory uncertainty, and convergence of markets and technologies. We also discuss the usefulness and limitations of our results.

The appendix contains the simulation program in Mathematica for the model analyzed in Chapter 3. All other programs are available through the Web site of Cambridge University Press.

2 Telecommunications

This chapter provides background material. It first explains the basics of telecommunications technology. It then gives a short account of the developments in the telecommunications industry in Europe and the United States, including regulatory issues. Finally it discusses the characteristics of telecommunications markets and regulatory policy from the viewpoint of the literature on industrial organization and regulation.

2.1 Technology

This section gives a brief overview of the telecommunications technology.[1] It can be skipped by readers who are familiar with telecommunications markets, as the information presented here is of an introductory and descriptive nature. The reader should keep in mind that telecommunications technology is changing very rapidly owing to technological progress and that this section only describes the basic elements.

2.1.1 Circuit-switched networks

This subsection briefly describes the main elements of fixed, "circuit-switched" telecommunications systems. Although other types of networks are gaining importance (see the next subsection), circuit-switched telephony is still the main type of telecommunications service in current, regulated markets.

The traditional telecommunications network, that is, the fixed network to which consumers are connected, is often called the *public switched telephone network* (PSTN). The PSTN is a *circuit-switched* network, that is, each telephone call reserves an end-to-end physical circuit between the calling party and called party during a telephone call. For the duration of a call, this

[1] This section is based on, among others, a glossary at Oftel's Web site (http://www.oftel.gov.uk), Glass (1997), and Morgan Stanley Dean Witter (1999). The publisher has used its best endeavors to ensure that the URLs for external websites referred to in this book are correct and active at the time of going to press. However, the publisher has no responsibility for the websites and can make no guarantee that a site will remain live or that the content is or will remain appropriate.