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Competition between multiple asymmetric networks: Theory and applications☆

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ABSTRACT

This paper presents a tractable model of network competition with many firms, elastic subscriber demand, off-net price discrimination, call externalities, and cost and market share asymmetries. We characterize stability in expectations and equilibrium under firm- and market-level network effects. The model is applied to simulate the effects of termination rates, market maturity, and retail pricing strategies. We show that predictions based on duopoly models can be misleading, in particular concerning the effects of termination rates.

1. Introduction

Two great obstacles of applying models of telecommunications competition to real-world markets are that most assume either symmetric networks or duopoly. Yet, telecommunications markets are characterized either by at least three networks which have entered at different points in time, as in mobile telephony, or by one large incumbent and smaller rivals using different technologies, as is usually the case in fixed telephony. Allegations of strategic retail pricing, diverging interests about mobile termination rates (MTRs, the wholesale price for terminating each others' calls), and different growth prospects of early and late entrants need to be addressed in a framework that allows as much for asymmetries as for different numbers of competitors. The justification for the assumptions of symmetry and duopoly that is usually advanced is that models with several asymmetric networks are not tractable. Here we attempt to show otherwise and follow up on the implications.

While a series of recent papers has presented models of network competition with more than two networks, all either have assumed symmetry or have not been able to give closed-form solutions for the equilibrium. In this paper we set out to develop and solve a rather general model of competition between interconnected telecommunications networks. We allow for i) a given arbitrary number of networks; ii) networks asymmetric in costs and size; iii) elastic subscription demand; iv) call externalities, i.e. receiving calls conveys utility; v) multi-part tariffs with price discrimination between "on-net" and "off-net" calls (on the same network or between different networks, respectively).

Our model is set up such that it can easily be calibrated to real-world communications markets. This exercise is becoming ever more useful for academics and regulators, as the quality of the assessment of the impact of different regulatory options depends heavily on which features of the relevant markets can be captured. Below we present simulations that illustrate how our model can be applied.

The paper has three principal parts. First we set out the modeling framework, then we characterize the equilibrium, and then we consider applications to policy issues such as competitive implications of retail pricing strategies and interconnection regulation. In the first sections, we show how to set up and solve the model. Most of the calculations

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are rendered in matrix notation, exploiting maximally the underlying linear structure which is inherited from the traditional Hotelling model. This technique, which is new to the network competition literature, vastly reduces the complexity of the derivations and leads to compact equilibrium conditions.

We offer a novel generalization of the condition of stability in expectations introduced by Laffont et al. (1998b, LRTb) to multiple networks and elastic subscription demand. It imposes upper limits on both firm-level and market-level network effects. The former are caused by the tariff-mediated network effects due to price discrimination between on- and off-net calls, while the latter are related to the size of the "hinterland" of consumers with elastic subscription demand.

We then derive the equilibrium outcomes in the price competition game with multi-part tariffs. We show that in the presence of call externalities off-net prices depend on market shares and hinterland size, and on whether networks set "uniform off-net prices", i.e. the same off-net price to all other networks, or a different price for separate groups of other networks. That is, while the result of Jeon et al. (2004) that off-net prices are strategically distorted continues to hold, this distortion now interacts with considerations about further price discrimination and market-level network effects. On-net prices continue to be set at the efficient level independently of asymmetries, the number of networks, or hinterland size.

Then we study further the demand system under inelastic subscription demand. We discuss the structure of cross-price effects under firm- and market-level network effects and show that the resulting substitution patterns may lead to unusual price effects, such as demand increasing in own price even in the absence of income effects. Still, with stability in expectations and uniform off-net prices demand is shown to be well-behaved in the sense that the law of demand holds. We also consider symmetric networks under elastic subscription demand, obtaining explicit expressions for the stability condition, highlighting the importance of network effects, and equilibrium market outcomes.

In the third part of the paper we study policy-relevant applications of our model. We reconsider the issue of mobile-to-mobile (MTM) termination rates, showing how privately and socially optimal rates depend on both the number of networks and the elasticity of subscription demand. Our main findings here are that two known results from the duopoly literature are not robust to the introduction of more networks. First, even with elastic subscription demand the welfare-maximizing level of MTRs may remain below termination cost. Second, with enough networks consumer surplus decreases with higher MTRs if call externalities exist or if MTRs are already above cost. Thus higher MTRs reduce both consumer surplus and welfare.

Then we perform some simulation exercises. First, since mature markets have less elastic subscription demand, we show that in the latter *ceteris paribus* market shares are more asymmetric and that the differential between on- and off-net prices increases. That is, while there are feedback effects between market shares and retail prices, both are simultaneously driven by the market development cycle. Second, we consider an MTR asymmetry in favor of the smallest network and show that it can be counterproductive if it is too large. Third, we compare market outcomes under different retail price discrimination strategies. We show that if large networks price discriminate between off-net calls to all recipients this can have a strong negative impact on their smallest rivals while bringing little benefit to themselves. On the other hand, imposing the obligation to charge the same price for all on- and off-net calls, as has been proposed in several countries in order to protect recent entrants, raises the profits of all networks but harms consumers in the short run.

1.1. Related literature

A vast amount of work has sprung from the seminal contributions of Armstrong (1998) and Laffont et al. (1998a,b), for the various combinations of network competition under linear or multi-part tariffs with uniform prices or price discrimination between on- and off-net calls. In the following we will concentrate on the papers that assume both multi-part tariffs and price discrimination in the tradition of LRTb. See Laffont and Tirole (2000), Armstrong (2002) and Vogelsang (2003) for surveys about the literature on network competition.

Duopoly equilibria under multi-part tariffs have been considered, among others, by Gans and King (2001), who showed that lowering MTRs below cost decreases consumer surplus. Hurkens and Jeon (2012) introduced elastic subscription demand in a logit model and show that welfare-maximizing termination rates are above cost if services are weak substitutes.[1] Jullien et al. (2013) reconsider the privately and socially optimal choice of MTRs if consumers have different subscription elasticities, and show that welfare-maximizing MTRs are above cost. Call externalities and their effects have been considered in Jeon et al. (2004), Hermalin and Katz (2004), Berger (2005), Armstrong and Wright (2007, 2009), and Cambini and Valletti (2008). Our modeling of asymmetries is related to that introduced by Carter and Wright (1999, 2003), taken up in Peitz (2005).[2] Hoernig (2007) joins these three features in order to consider the competitive effects of on-/off-net price discrimination.

Our main contribution as compared to these papers is that we provide a tractable model with many networks that encompasses most of the previous work. We put their main conclusions to test, point out the interplay between firm-level and market-level network effects, and show which previous predictions need to be qualified.

Several papers on MTM interconnection considered more than two competing networks. Symmetric networks are assumed by Calzada and Valletti (2008)[3] and Armstrong and Wright (2007). Dewenter and Haucap (2005) consider more than two asymmetric networks, but take market shares as given and thus do not close the model for an equilibrium analysis. Closest to our paper is Thompson et al. (2007), with many asymmetric networks and a similar preference space. Subscription demand is elastic due to heterogeneous call demand. Yet, in their model networks do not price-discriminate between on- and off-net calls, and no closed-form solution for the equilibrium is derived.

Section 2 presents the modeling framework. Section 3 derives the equilibria and additional results. Section 4 contains applications to regulatory and competition policy issues, while Section 5 concludes. The appendix contains a table summarizing the notation and most proofs.

2. Framework

2.1. Model setup

2.1.1. Demand and consumer surplus

The following model is a generalization of the network competition models of Armstrong (1998), LRTb and Carter and Wright (1999) to many asymmetric networks. It leads to a demand formulation that is related to the pyramid model of Von Ungern-Sternberg (1991), the hinterland model of Armstrong and Wright (2007, 2009) and the spokes model by Chen and Riordan (2007), but allows explicitly for exogenous asymmetries between networks. Below we consider both inelastic subscription demand, as in the standard Hotelling framework, and elastic subscription demand, through the addition of hinterlands. The equilibrium concept we employ is a subgame-perfect equilibrium where first firms choose multi-part tariffs with price discrimination between on- and off-net prices, and then consumers decide which networks to join and how many calls to make.

[1] Dessein (2003) derived a similar result with elastic subscription demand but without discrimination between on- and off-net calls.

[2] Cambini and Valletti (2004) and Valletti and Cambini (2005) present duopoly models where asymmetries arise through previous investment choices.

[3] They also consider asymmetric calling patterns with three networks.