THE ECONOMICS OF MOBILE INTERNATIONAL ROAMING

by

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Abstract

International roaming is a hot topic in the telecommunications industry. Many countries have witnessed a downward trend in mobile domestic prices. On the contrary, international roaming prices remained reluctant to follow the domestic trend. In Europe, the service has been regulated with price cap since 2007, and regulation is maintained for years to come.

The existing literature on the economics of international roaming has focused on theoretical modelling, which assumes a uniform retail price (i.e. common across visited networks). The main finding is that wholesale and retail prices rise with the number of visited networks. Additionally, vertical merger is found unprofitable; and home network steering does not cause downward pressure on wholesale prices.

We found that the assumption of uniform retail pricing leads to results that are inconsistent with wholesale competition because visited networks appear in the demand as complements rather than substitutes. We present theoretical models that match the existing literature's findings, and compare results to the case whereby the retail price is discriminatory (i.e. differs by visited networks). With discriminatory retail, substitutability of networks reduces prices, and the incentive for vertical merger exists. In a steering game, steering is found able to reduce wholesale prices; and networks alliances are formed in equilibrium.

The empirical literature on international roaming is limited to few industry studies. We use an aggregated dataset on prices and quantities for networks visited by roamers from one major mobile provider whose subscribers travel a lot across the world, Etisalat. The study period witnessed a retail price shift from discriminatory to uniform. The main findings are: (1) competition, as measured by the number of visited networks, reduces wholesale price; (2) traffic steering is effective, especially towards preferred networks (alliance and cross-owned); (3) only alliance networks offer wholesale discounts; and (4) demand is more elastic than crude industry studies.

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LIST OF ACRONYMS

AED	UAE currency Dirham; pegged to US dollar (1 AED=$0.27)
CAMEL	Customized Applications for Mobile Enhanced Logic
CPI	Consumer Price Index
EC	European Commission
EEA	European Economic Area
EU	European Union
GCC	Gulf Cooperation Council (member states: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the UAE)
GDP	Gross Domestic Product
IOT	Inter-Operator Tariff (wholesale price used in mobile international roaming)
MB	Megabytes of data
NBS	The National Bureau of Statistics in the UAE
NRA	National Regulatory Authority
OECD	The Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares estimator
POSTPAID	Mobile Monthly Plan Subscription
PREPAID	Mobile Pay-As-You-Go Subscription
SMS	Short Message Service (text message)
TAP	Transferred Account Procedure code
UAE	United Arab Emirates
1SLS	First Stage Least Squares estimator
2SLS	Second Stage Least Squares estimator

Dedicated To

My Wife

And

Our Children

Chapter (1). Introduction

When two mobile networks licensed in two different countries sign a bilateral Inter-Operator Tariff (IOT) agreement, their subscribers are allowed to roam across the networks with their phone handsets to make or receive phone calls and text messages (SMS), and to access mobile wireless internet.

Many countries have witnessed a declining trend in most mobile domestic prices due to different reasons such as competitive pressures, price regulation and technological improvements that increased networks efficiency. On the contrary, international roaming prices had increased and remained reluctant to follow the domestic trend. Inspired by this phenomenon, we are interested in understanding how networks would set their wholesale prices under their bilateral IOT agreements, which also affect their retail prices.

The existing literature assumes the roamer only cares about the average retail price, and hence the retail price used in the demand is uniform. The home network marks up the average wholesale price. We introduce in the modelling the assumption of retail prices that differ by visited networks (i.e. discriminatory). The assumptions made on retail pricing (uniform versus discriminatory) give opposite predictions with regards to competition and the incentives for networks to vertically merge.

The empirical literature on wholesale competition is limited to few industry studies. We make use of an aggregated dataset on prices and quantities for networks visited by roamers from one major mobile provider whose subscribers travel a lot across the world, Etisalat. The study period records a shift in Etisalat retail pricing policy (from discriminatory to uniform), which provides an empirical experiment to measure wholesale competition.

This chapter is organized as follows. Section (1.1) explains international roaming in the context of mobile services. Section (1.2) provides thesis motivations, and Section (1.3) outlines the next chapters.

1.1 The Service Of Mobile International Roaming

If a mobile network is closed, its subscribers can only communicate within the network's subscribers. If the network interconnects with other networks (i.e. signs interconnection/wholesale agreements), it enables its subscribers to communicate with subscribers to those networks. Interconnection agreements therefore make networks compatible.

Interconnection agreements can be classified into two types: one-way access, whereby only one network needs to access the facility of another network; and two-way access whereby the two networks need access to one another's facilities. The agreeing networks can be competing within the same geographic market, or operating in different geographic markets.

Mobile-to-mobile (MTM) call termination access for off-net calls and national roaming tariffs are examples of wholesale prices of interconnection agreements within a geographic market. In parallel, international settlement rate agreements for terminating international calls and international roaming tariffs (IOT) are examples of wholesale prices of cross-border interconnection agreements. If interconnection charges are per unit of use, they act as "perceived marginal cost" to the network that incurs them.

This thesis concentrates on international roaming services governed by IOT agreements that allow a home network subscriber to use his same phone number while using (roaming on) a foreign network[1]. IOT agreements are typically a bilateral (two-way access) agreement.

Despite international roaming similarities with other telecommunications services that involve interconnection agreements, international roaming has some features that make it unique, as explained below.

The consumer of international roaming has to be in a different geographic market. He effectively borrows the facilities of a foreign network to originate or terminate traffics (e.g. making an outgoing call while roaming). The IOT agreement is between non-rivals, which is similar to the international settlement rate agreement for international calling.

1 For a technical definition, see GSMA (2013).

With national roaming, the consumer usually does not pay a premium for any mobile service when roaming on a different network than his home network within the same market. In other words, retail prices are the same whether the consumer uses his home network or any other domestic network. In addition, in areas where the home network provides coverage, the consumer cannot select manually (on his handset) between networks other than his home network. Given no price differentials, consumers typically leave handsets on automatic mode to be picked up by the home network or by its national roaming partners in areas the home network has a lack of coverage.

On the contrary, with international roaming, the consumer is usually aware that the traffic he uses costs a premium[2] when roaming in a foreign land, and he will be charged for incoming calls[3]. Paying for incoming calls (rather than free) is supposed to eliminate consumer's substitutability in call making-receiving[4]. In addition, the consumer can select manually (on his handset) between visited networks that are IOT partners of his home network. In other words, the consumer can choose a wholesale supplier to his home network. We will later assume the consumer leaves his handset on automatic mode if there are no price differentials.

The home network collects retail roaming revenues from its travelling subscribers, and pays IOTs (i.e. wholesale prices) to visited networks[5] for the use of their facilities. The retail price is typically the IOT plus a markup[6].

Retail prices for international roaming are generally classified into four categories which also represent the wholesale services in a typical IOT agreement: (i) making an outgoing call (destined to local phone number within the visited country or to the home country or a third country); (ii) receiving a call from any destination; (iii) sending a SMS to any destination[7]; and (iv) using megabytes (MB) of data roaming.

In order to enjoy international roaming, the consumer has to be a subscriber to a home network, and this home network has an IOT agreement with visited networks. In order for his demand to be satisfied, the roamer has to be in an area where a visited network provides coverage. In populated areas, where roamers would typically visit, visited networks would

2 Of course, the consumer can quit roaming and use outside options instead, such as using a visitor SIM-card or public payphones.
3 This is true even in countries that follow the Calling Party Pay (CPP) regime.
4 Hakim and Lu (1993) modelled international calling (under international settlement rate agreement) assuming making the call and receiving it as near-perfect substitutes.
5 Mobile operators use TAP as the billing standard, by which a visited network sends billing records of roaming subscribers to their respective home network (GSMA, 2013).
6 Some countries impose value-added tax (VAT) on wholesale or/and retail prices.
7 Incoming SMS is free.

tend to have coverage overlaps that should enable roamers to substitute between visited networks.

Roamers have two options at their handsets to select a visited network: automatic or manual network selection. The automatic mode is usually the default setting in mobile handsets, which would be typically picked up by the network with the strongest coverage signal. Leaving a handset on the default selection could be due to a number of reasons: (1) the roamer's unawareness of manual selection; (2) unawareness of retail price differential between visited networks (discriminatory); or (3) the roamer has no preference over the visited networks. The automatic mode of handsets is a necessity for home network's traffic direction technologies (i.e. steering) to take effect.

The rational roamer is supposed to manually select between visited networks if this selection raises his utility, such as reducing his expenditure. The roamer's manual selection is a demand-side substitution, which obstructs steering made by his home network (supply-side substitution). One way to make the roamer indifferent in the selection between visited networks is by charging him a uniform retail price.

The roamer with prepaid subscription can enjoy international roaming if both his home network and the visited network installed Customised Applications for Mobile Enhanced Logic (CAMEL) technology to allow the home network to instantly deduct the credits according to usage. At the wholesale level, a visited network charges an IOT price to a home network with no price discrimination between the home network's (prepaid/postpaid) subscribers or their place of visit within the visited market[8]. At the retail level, prepaid subscribers tend to be charged more for roaming compared to postpaid.

Mobile networks may involve in preferential IOT agreements in the form of cross-ownership or roaming alliance membership, which result in preferential wholesale prices, and lower retail prices when roaming on a member's network. Vodafone and ten of its affiliates in Europe notified the European Commission (EC) in 2001 to set preferential wholesale prices and to offer a pan-Europe retail price (Eurocall) for roaming on Vodafone networks (O.J. 2001).

8 Networks located near borders may unintentionally cause accidental roaming. This happens if two networks are IOT partners and the subscriber to any of them is at his home country but near the border. If the foreign network has a stronger signal with coverage stretching over the subscriber whose handset is on automatic mode, the subscriber unintentionally consumes international roaming units and the foreign network charges IOT bills to the home network. Accidental roaming is usually solved through consumer complaints.

At the retail level, Vodafone' Eurocall is lower for roaming on its' cross-owned networks, but differs by visited networks. The practise of the home network setting retail prices that are discriminatory (by visited networks) used to be the common practise in this industry. Many mobile networks shifted from this discriminatory policy to a uniform policy[9] (i.e. identical retail price across visited networks in the same market), despite being charged different wholesale prices by the visited networks, as noted by Ambjørnsen, et al. (2011).

The practise of uniform retail policy and the formation of roaming alliances are also observed outside Europe. In the UAE, the mobile operators Etisalat and Du used to charge discriminatory retail prices. Du started offering uniform retail prices in 2008 (EITC, 2008); while Etisalat in 2010 started uniform prices based on geographic zones (Gulfnews.com, 2010).

In an IOT agreement, each mobile operator serves two distinct demands: (1) own subscribers at the retail level (or outbound) and (2) visitors at the wholesale level (or inbound). Any cross-subsidisation between the two groups (outbound and inbound roamers) can be a response to competition on one side, but there is no linkage between the two groups. That is, there is no pricing structure for the two groups that can lead to an inter-group network externality. Hence, international roaming is not a two-sided market (Shortall, 2010). We shall see in the next chapters that the wholesale and retail demands for a network are independent.

Despite competition for subscribers within a market, a mobile network holds monopoly power in providing access to its subscriber because any communication with him has to come through it. This competitive bottleneck, as in Armstrong and Wright (2009), is reinforced after crossing borders, where different interconnection agreements may intersect to serve the travelling bottleneck.

For example, consider a voice call by *A1*'s subscriber to *A2*'s subscriber, where *A1* and *A2* are mobile networks in country *A*. Let us suppose that *A2*'s subscriber happens to be roaming on foreign network *B*. In this case, *A1*'s subscriber pays local (off-net) retail price to *A1*; *A1* pays mobile-to-mobile (MTM) domestic access (wholesale) to *A2* for terminating the call; *A2* charges its travelling subscriber a retail price for incoming call while roaming; and *A2* pays *B* an international settlement rate (wholesale) for the international leg of the call plus an

9 In Appendix (A), we show discriminatory pricing is superior to uniform pricing for a monopolist selling two substitutable goods with different (actual) marginal costs, ignoring upstream strategic behaviours for simplicity. This conclusion is more appealing as the two goods become more asymmetric in marginal costs or/and more substitutable.

IOT (wholesale) price for the incoming call. In this example, three interconnection agreements are involved: MTM access, international settlement rate and IOT.

Nonetheless, interconnection agreements are complementary. An IOT agreement does not replace non-IOT interconnection agreements since they are typically signed independently and billed to end users in different transactions (Shortall, 2010). Moreover, IOT agreements are voluntary agreements, similar to international settlement rates[10], and are widely unregulated compared to other interconnection agreements.

1.2 Motivation

Despite the rise in the number of mobile networks overtime, technological improvement, and decrease in domestic prices, prices of international mobile roaming services are exceptional to the observed price trend in the mobile industry. In Europe, the EC regulated international roaming by imposing price caps for roaming within the European Economic Area (EEA) countries. This phenomenon inspired the theoretical modelling of Salsas and Koboldt (2004), Lupi and Manenti (2009), Ambjørnsen, et al. (2011), and some others as shall be surveyed in Chapter (2).

The gap in the theoretical modelling of wholesale competition lies in the assumption of a uniform retail price. By assuming a uniform price, the demand reflects visited networks as perfect complements rather than substitutes. This will be elaborated in the next chapters, and will become clear as we compare price equilibria to the case of discriminatory retail prices.

Contrary to the existing literature, we provide a game for home network steering investment and roaming alliance formation, assuming uniform retail price that takes into account substitutability of visited networks.

In addition, IOT agreements are rarely regulated as opposed to most wholesale agreements, making it interesting to undertake empirical research on market outcomes. We are not aware of any empirical paper that examines competition in international roaming.

10 Cave and Donnelly (1996) describe international settlement agreements as voluntary, which satisfies Edgeworth's requirement: any agreement must make both parties at least as well off as no agreement (individual rationality) and any agreement must be Pareto optimal.

We are provided with access to data on Etisalat's outbound roaming at the visited network level, observed over four years. Etisalat retail prices were discriminatory in the first two years, then uniform in the rest of years. Such data will help in testing the theoretical predictions regarding the impact of the retail policy and preferential IOT partners on wholesale competition and on market share to explore for steering. Furthermore, the data will help in the estimation of the demands for visited networks.

The thesis focuses on the economics of mobile international roaming because of the aforementioned gaps in both the theoretical and empirical literatures. We draw attentions to the implications of home network retail policy (discriminatory versus uniform) on consumers' choice between automatic and manual network selection, and on visited networks' wholesale prices and steering by the home network.

1.3 Outline Of Thesis

The next chapters are organized as follows. Chapter (2) reviews the literature. It starts with the EU experience with international roaming as a competition case. The chapter summarizes: the main findings of the EC's sector inquiry, competition analyses by European NRAs, and the EC's intervention in the industry. Then the chapter reviews the literature on vertically related industries, and reviews the existing papers on international roaming. Finally, the chapter places our next chapters in the context of the existing literature.

Chapter (3) lays down the base model. The chapter explains the underlying assumptions used in modelling the behaviours of networks at the retail and wholesale levels. Then different wholesale pricing strategies are explored under discriminatory and uniform retail pricing policies. Finally, results are discussed.

Chapter (4) extends the base model to address preferential IOT agreements. The chapter examines the incentive for networks to engage in vertical mergers, and compares results under discriminatory and uniform retail pricing policies. Finally, a steering game is presented to understand the incentive for steering investment and the formation of roaming alliances.

Chapters (5) describes the dataset of Etisalat outbound roaming. The chapter explains the relevance of the dataset with regards to understanding wholesale competition, and explains the data gathering process. Finally, the dataset variables are explained and summarized.

Chapter (6), (7) and (8) contain the empirical estimations, using the dataset on Etisalat outbound roaming. Chapter (6) estimates the demands by Etisalat roamers for visited networks. Chapter (7) estimates the visited networks' wholesale prices to Etisalat. The chapter takes into consideration the visited networks characteristics which may reflect preferential IOT agreements, and market structure that may reflect competition effects. Chapter (8) estimates visited networks' market shares to explore for the effectiveness of steering by Etisalat.

The Appendices at the end contain: (A) a model for a monopolist choosing between discriminatory and retail policies; (B) the derivations of the base model's solutions; (C) a game for networks choosing between discriminatory and uniform retail policies; (D) the evaluations of instrumental variables used in demand estimations; (E) the estimated own price elasticities of demands for EEA networks; and (F) the list of all foreign networks visited by Etisalat roamers during the study period.

Chapter (2). Literature Review

This chapter reviews the literature related to Inter-Operator Tariff (IOT) agreements between mobile network operators, which govern international roaming.

We start with a brief history on international roaming under the EC legal framework (Section 2.1). In Section (2.2), we provide a short survey on vertically related industries that encompasses interconnection agreements. Specifically, we review three papers on international settlement rates due to its similarity to IOT agreements; and a paper on fixed-to-mobile network access as it is referred to in some papers that model IOT agreements. In Section (2.3), we extensively review the available papers on IOT agreements, including the ones with empirical estimations. Section (2.4) discusses the gap in the literature and how this thesis can contribute to the literature.

2.1 International Roaming In EU

2.1.1 Sector Inquiry

In 1999, the EC opened a sector inquiry into mobile international roaming after receiving numerous complaints. This section summarizes the information contained in the EC (2000) document regarding the history of the IOT agreements and the initial findings.

Since 1992, members of the GSM Association (GSMA) applied the Normal Network Tariff (NNT) regime for setting international roaming wholesale prices, which used the local retail price for the equivalent service as a reference price plus a 15% markup. Because the wholesale price was linked to the retail price in the visited market, it was subject to local price competition. Visited networks kept changing the reference price to the more expensive one in their range of retail prices (e.g. outside-the-package price for a minute of call).

In 1996, the GSMA notified its Standard International Roaming Agreement (STIRA) to the EC for clearance from the cartel prohibition. STIRA clauses state that (i) wholesale service is offered exclusively by licensed mobile networks (i.e., excluding virtual networks); (ii) wholesale prices are non-discriminatory (i.e., applying same terms and conditions to all members); and (iii) wholesale prices are uploaded to the GSMA *Infocentre* to be accessible by a member network, where the member network cannot access the wholesale price set by its competitor. The EC issued comfort letter conditional on the limited accessibility in item (iii)[11].

In 1998, the GSMA notified its IOT regime to the EC as the new regime for bilateral wholesale price setting, replacing the NNT regime. The GSMA also received the EC's comfort letter. Since 1998, STIRA and IOT regime became the common framework for the international roaming agreements.

The EC predicted that agreements based on the IOT regime would bring competition in the wholesale market because domestic retail prices would not be used as reference prices. Paradoxically, the referenced retail prices declined over time in response to domestic competition, while international roaming wholesale prices increased dramatically.

For the sake of the sector inquiry, the EC defined the relevant national markets as: *"The market for retail roaming services,* and *the market for the provision of wholesale roaming to foreign mobile network operators*." The initial findings in the EC (2000) are summarized as follows.

- Revenues from international roaming amount to 10-25% of the total revenue for a mobile network.
- The market has high barriers to entry with few network (oligopolists) that have similar cost structures.
- Wholesale roaming is offered exclusively by licensed public mobile networks, and few, if any, are found to be dominant in the market.
- Retail roaming is part of a bundle of mobile retail services, with almost complete absence of retail competition. Other (outside) options, such as hotel phones or international calling cards, are poor substitutes.
- International roaming is a homogeneous product.
- Due to lack of price transparency, consumers' impact on pricing is trivial if they override manually what their handsets had automatically selected.
- Wholesale prices are set for each roaming service, which are usually based on regional zones. Few networks offer wholesale discount, which is limited to the invoice level (i.e., at the IOT bill level, rather than the listed wholesale price).
- The retail price equals the wholesale price plus a handling charge (markup) of about 10-35%, which usually differs by visited networks.

11 See Valletti (2004) for possible remedies on STIRA clauses.

- During the years 1997-2000, wholesale prices between EEA networks witnessed absolute increases (126% for calling internationally and 166% for calling nationally), with relative increases converging towards a higher overall price. All these price changes bear no relation to the underlying costs. Consequently, retail prices increased as well. These trends are in contrast to domestic prices.
- Excessive pricing and tacit collusion (via identical pricing) are likely to be taking place in the pricing behaviours of networks.

2.1.2 Aftermath Of Sector Inquiry

In this section, we summarize what happened after the EC's 2000 sector inquiry till its closure in 2007, relying on reports by Cullen International (2013).

The EC raided nine mobile operators in July 2001 in Germany, the Netherlands and the UK to gather evidence on alleged price fixing. Later on, the focus of the investigation shifted from collusion to abuse of dominant position, where the EC compared wholesale prices of international roaming to domestic mobile termination rates since both share considerable similarities in their actual costs, but have huge price differentials.

In July 2004, the EC sent statements of objection to O2 and Vodafone in the UK on abuse of their dominant positions under Article 82 of the EC Treaty. Each network constituted a separate market in the period 1997/1998 until the end of September 2003, during which, each network enjoyed a dominant position in the provision of wholesale international roaming on its own network. The abuse consists of unfair and excessive wholesale prices charged to other European mobile networks.

In February 2005, the EC sent similar statements of objections to T-Mobile and Vodafone in Germany. T-Mobile (since 1997) and Vodafone (since 2000) each enjoyed a dominant position in the provision of wholesale international roaming on own network till the end of 2003.

In these statements of objections, the EC applied a market definition whereby each visited network is considered a monopolist[12]. This definition is different to the one set out in the EC 2003 recommendation on relevant markets, which defines the market for international roaming (known as Market 17) as: "*Wholesale national market for international roaming on*

12 Martino (2007) supports such market definition. Martino views if demand is randomly assigned between visited networks, then each network is a monopolist over its share of traffic. This randomness makes steering by the home network ineffective.

public mobile networks" (O.J., 2003). This definition includes all mobile networks in a given country.

Under the EU 2003 regulatory framework[13], international roaming was among 18 markets that national regulatory authorities (NRAs) must review as part of market analysis procedure. During the years 2005-2006, six NRAs finished their market analysis exercise for Market (17). Their definitions of the geographic market corresponded to the EC's definition of Market (17). For analysis purposes, the NRAs considered outgoing calls as a product market, where half of the NRAs calculated market shares in revenues and the other half market shares in minutes of use (i.e. quantity).

The EC stated that the analysis of dominant position should be based on comparing market shares with/out intra-groups (or cross-owned networks, e.g. Vodafone in the UK and in Germany). NRAs which compared market shares with/out intra-group are Slovenia and Italy. Table (2.1) summarizes their findings.

The six NRAs took into account expected competitive pressures on wholesale prices caused by traffic steering as a countervailing buying power by home networks. All NRAs did not find either single or joint significant market power. Their conclusions were based on the reduced risk of coordinated behaviours due to market structure, growth of the market and its seasonality nature. In addition, the existence of roaming alliance discounts were found to reduce wholesale price transparency, and hence credible retaliation mechanism to discourage deviation was assumed absent. In summary, all NRAs concluded that the market was effectively competitive despite high roaming prices.

Although all NRAs found the market competitive at the wholesale level, the EC was concerned that reductions in wholesale prices were not passed on to consumers. It was also concerned that prices (retail and wholesale) remained unjustifiably high and showed no signs of decline.

In June 2007, the EC issued roaming regulation to address the concerns of its sector inquiry and law proceedings. The EC closed the sector inquiry, and closed the competition law proceedings against the UK mobile networks (O2 and Vodafone) and against Germany mobile networks (T-Mobile and Vodafone). In addition, the EC removed Market 17 from its recommendation on relevant markets.

13 See Buigues and Rey (2004) for market definitions in the telecommunications industry.

Table (2.1) NRAs' responses to the EC market analysis notification exercise for Market (17).

Country (Date of report)	Notes
Finland (15 December 2005)	➢ Market shares were calculated in quantities for 2005: Sonera (45%) Elisa (39%) Finnet (14%) Alands (2%) ➢ Rise in traffics, steering and wholesale prices
Italy (7 June 2006)	➢ Market shares were calculated in revenues for 2005: TIM (38.8%; or 51.2% without intra-group) Vodafone (42.6%; or 23.9% without intra-group) Wind (18.3%; or 24.8% without intra-group) H3G (0.3%, or 0.1% without intra-group) ➢ TIM's share exceeded 50% when intra-group was excluded, but since its share by volume was higher than share by revenue, TIM was conceived unable to charge higher wholesale price than its competitors
Denmark (28 July 2006)	➢ Market shares were calculated in quantities for 2004: A (37%) B (25%) C (38%) ➢ High level of wholesale prices that did not change since 2001 ➢ Mobile operators belonged to different roaming alliances in Europe, making it difficult to coordinate nationally
Slovenia (7 August 2006)	➢ Market shares were calculated in quantities for 2005: Mobitel (47%; or 55% without intra-group) Simobil (50%; or 42% without intra-group) WWI (3%; or 3% without intra-group) ➢ High level of wholesale prices
Austria (25 August 2006)	➢ Market shares were calculated in revenues for 2005: Mobilkom (<40%) T-Mobile & Telering (merged) (>40%) The rest for One & Hutchison ➢ 70% of overall demand was from 5 countries, while 56% was from subsidiaries of T-Mobile and Vodafone ➢ No network could charge higher wholesale price than its competitors, and all tried to grant discounts to large buyers. ➢ Significant reductions in wholesale prices since 2001, particularly for alliance networks
Spain (25 August 2006)	➢ Market shares were calculated in revenues for 2005: Vodafone (44%) Telefonica (39.6%) Amena (16.4%) ➢ Home networks were able to steer 75-80% of traffics ➢ Difficulty in determining the actual wholesale price due to existence of discounts

Source: Adapted from Cullen International (2013).

2.1.3 EC Roaming Regulation

In June 2007, the EC roaming regulation applied price-caps on both wholesale and retail prices, known as the *Eurotariffs*. The regulation also mandated home networks to send free SMS to their travelling subscribers informing them about the retail prices[14].

According to Falch et al. (2009), before the EU roaming regulation, retail prices for international roaming calls were approximately four times higher than for national mobile calls, indicating prices were exceeding underlying costs. Such excessive pricing provided justification for the EU regulation, after a lengthy review from 1999 to 2007. In September 2007, the new regulation was fully implemented; as a result, retail prices were reduced by 57% for outgoing calls and 60% for incoming calls. After 2007, the EC amended the regulation to lower the Eurotariffs and to include other services such as SMS and data roaming.

2.2 Vertically Related Industries

The literature on vertically related industries addresses the vertical relationship of firms. It investigates incentives for maximizing the individual profit versus joint profit and the choice of contract (i.e. vertical restraints such as retail price maintenance or franchise fee compared to linear pricing)[15].

The main incentive for an upstream monopolist and downstream monopolist to vertically integrate is to overcome the double marginalisation problem (Spengler, 1950). This problem exists when the wholesaler marks up the input sold to the retailer, with the retailer itself also adding another markup. Vertical integration internalizes this vertical externality by charging the monopoly retail price, which increases producer surplus; and since this monopoly price is lower than the double-markup price, consumer surplus is also increased. Therefore, total welfare is enhanced. The incentive to vertically integrate may not hold under competition and/or the use of vertical restraints.

Bonanno and Vickers (1988) develop a price game model for the case whereby a wholesaler and a retailer compete with another pairing in the provision of final goods. The game is

14 This transparency measure was implemented in the Arab World. For a chronology of regional regulatory actions in this regard, see Sutherland (2008) for the EU case and Sutherland (2011) for the Arab World.
15 See Vickers and Waterson (1991) for an introduction on the economics of vertical integration and vertical restraints.

played in two stages, where the wholesaler sets a linear wholesale price (with/out a franchise fee), and the retailer sets the retail price. If the goods are independent (monopoly), the wholesaler's profit from vertical integration is greater than the profit from vertical separation due to elimination of double markups; but equal if franchise fee is used. On the other hand, if goods are substitutes, the wholesaler can use the franchise fee to extract the retailers' surplus and subsequently charges a wholesale price above marginal cost. This results in greater total profit under vertical separation than under vertical integration[16].

The model in Economides (1994) is similar to the one in Bonanno and Vickers (1988), except that Economides restricts the model to linear pricing and assumes that each good consists of two complements in fixed proportions. These complement goods are produced by two separate producers[17]. With linear demands for the final goods, the game is played in two stages: producers decide whether or not to merge; then they set their input prices. The game makes provision for four ownership structures: independent ownership; partial vertical integration; parallel vertical integration; and joint ownership. The equilibria are then compared at different degrees of substitutability. Playing the game out, Economides concludes that when final goods are poor substitutes, producers have an incentive to integrate; but this incentive diminishes as goods become perfect substitutes.

Telecommunications networks are similar to vertically related industries as they involve wholesale pricing for handling interconnection services, such as terminating a call that is originated on a different network. Networks would typically sign bilateral interconnection agreements, commonly taking the form of two-way access agreements with linear wholesale pricing. Examples include international settlement rates for international calling, domestic access agreements for terminating local calls (e.g. mobile-to-mobile (MTM), mobile-to-fixed (MTF) and fixed-to-mobile (FTM)), and IOT agreements for international roaming. In the context of vertically related industries, the proceeding sections will review some papers on international settlement rates[18] that share similarity with IOT agreements, and following this we review a paper on FTM that is referred to in the existing literature on international roaming.

16 See Cyrenne (1994) for a closed form model in this line which only involves linear pricing.
17 That is, given fixed proportionality, the sum of the input prices equals the final price of the good. An example of this case is given in Section (2.2.2).
18 See Armstrong (2002) for a comprehensive summary on the theory on access, including international settlement rates, and see Einhorn (2002) for a literature survey on international settlement rates.

2.2.1 Access Theory

The similarity between IOT agreements and international settlement rates lies in the nature of two-way access agreement between non-rivals that involves wholesale linear prices. The literatures for both agreements share similarity in strategies and payoffs.

Consider the following simple example. If two non-rivals are monopolists within their respective countries, assuming zero marginal costs for simplicity, the profit function to partner i is

$$\Pi_i(p_i, w_i) = \overbrace{(p_i - w_j)q_i(p_i)}^{retail\ profit} + \overbrace{w_i \quad q_j(p_j)}^{wholesale\ profit} \quad , (i \neq j), \tag{2.1}$$

where p, w, and q are retail price, wholesale price and demand respectively. Notice Eq. (2.1) is separately additive: there exists profits derived from retail and wholesale. Each partner of an agreement is a wholesaler and a retailer and therefore the wholesale demand for one partner is the retail for the other. This typically represents the profit maximization problem for international settlement rates, and IOT agreements as well.

Carter and Wright (1994) provide a model for two countries, each is served by a monopolist offering international calling services and terminating international calls from the other country (i.e. symbiotic producers). Their main finding is that, unilateral wholesale pricing results in profits that are Pareto inefficient (due to double markups), and both networks can be made better off by an appropriate choice of wholesale prices. Therefore, as the incentive to remove the double marginalisation problem works both ways, both networks can maximize their joint profits by accepting the division of profits with the sole use of wholesale linear pricing, (while the retail price is set independently). This removes the need for other mechanisms such as franchise fees.

The authors found that removing the double marginalization problem has a second order loss in own profit but first order increase in the other's profit. This is clear with firms having equal demands[19], and would hold if the asymmetry is not excessive. If excessive, the network with the larger wholesale demand will do better by not cooperating.

Cave and Donnelly (1996) focus on understanding the circumstances that may lead to nonreciprocal bargained prices. Networks use the unilateral wholesale price as a threat point

19 If demands are identical, networks can agree on a reciprocal wholesale price equals marginal cost; hence the net payment is zero, retail prices are lower and monopoly profit is achieved as demonstrated in a closed-form model in (Box 5.1) in Laffont et al (2000).

for the Nash bargaining solution. Each network maximizes its own profit with respect to the pair of wholesale prices, then both networks bargain over their solutions. The authors found nonreciprocal wholesale prices as the outcome if profits are unequal when evaluated at wholesale prices that equal marginal costs.

Wright (1999) provides a model to test the USA's NRA claim that artificially high international settlement rates led to high retail prices for American consumers, and that the deficit in net payments subsidized foreign networks in low-income countries. He assumes a representative consumer's utility for international calling, with two countries where each is served by a monopolist. The author then allows for retail competition. He assumes here a common wholesale price equal to the weighted average cost of incoming calls, with weights determined by income levels. Income disparity in this setting increases the common wholesale price, and this wholesale price is reached by Nash bargaining solution.

In Wright (1999), starting with the threat of no agreement (zero profit), the network with the high profit from any agreement (due to high demand or low actual costs) will gain more; thus it is willing to share some of its profit with its partner, resulting in wholesale prices above marginal cost.

With comparative statics, Wright concludes that competition has strong pressures on both retail and wholesale prices. However, with reciprocal wholesale pricing and asymmetry between networks, wholesale competition may not be effective. This is because networks can inflate the wholesale price to keep retail prices artificially high.

Shy (2001) agrees with Wright. Shy assumes asymmetric unit demands for international calling in two countries. The game is played in two stages: wholesale pricing followed by retail. For simplicity, he assumes the networks agree on a mutual wholesale price equivalent to the average of both unilaterally-set wholesale prices. Due to asymmetry in demands, the network with high (retail) demand has a negative net payment with the low-demand network, but still makes a positive profit. Shy then assumes perfect retail competition, where the retail price equals the wholesale price (i.e. the perceived marginal cost). He concludes that, in equilibrium, if each network has zero net payment and its profit equals its retail revenue, networks can use the wholesale price as a means of collusion by artificially inflating it in order to raise the retail price to the monopoly level.

Nonetheless, Shy views the supply-side alternatives, which can bypass high international settlement rates, challenges such collusion. For example, the home network can rout the call through international resellers, internet telephony, or through the cheapest terminating network in the destined country[20].

On local access, we review a paper by Gans and King (2000) who model FTM calling originated from a single fixed network and terminated on a mobile network, where there are more than one mobile network. They assume uniform retail prices for FTM calls because either the consumer is unaware to which mobile network the mobile number belongs (due probably to mobile number portability), or because the fixed network is unable to price discriminate by mobile network (i.e. unable to set discriminatory retail prices by destined mobile networks). Therefore, the fixed network's consumer is likely to base his calling patterns on the average retail price.

The model is built on a two-stage game: each mobile network sets a wholesale price, and then the fixed network marks up the average wholesale price weighted by the market shares of the mobile networks. The solution method is backward induction.

The authors found that wholesale price increases in the number of mobile networks, and is negatively related to own market share. A wholesale price rise by one mobile network raises the final price, which reduces total demand. Such price rise can represent a profit gain to the undertaking network, while any loss in sales is shared with the rest of the mobile networks. This effect is larger with smaller networks as the smaller network sets a higher wholesale price. However, with linear demands, changes in wholesale prices (due to changes in market shares) exactly offset each other and hence the retail price is independent from market shares.

Gans and King (2000) concluded that competition between wholesalers does not exist because any undercutting by a wholesaler does not raise its market share. As the number of networks rises, the effect of horizontal separation increases, pushing up the wholesale price.

The authors' model assumes a uniform retail price. The literature on retail on-net/off-net pricing by domestic networks is abundant, where networks take into account the strategic choice on access (or termination rates)[21]. In this case, a uniform retail price entails that the network does not set any price differential between on-net and off-net calling. On the other

20 This requires liberalisation of international gateway.
21 See Peitz et al. (2004) for a literature survey on the theory of national access; and Hoernig and Valletti (2012) for a recent survey.

hand, a discriminatory retail price entails that the network sets price differential between on-net and off-net calling[22].

In international roaming, there is a noticeable trend in shifting from discriminatory retail pricing to uniform, as noted by Ambjørnsen, et al. (2011). In fact, the EC (2000) found a few mobile networks that offer uniform retail price; while the EC (2006) noted that often mobile networks offer uniform retail prices.

As shall be demonstrated below, the existing models on international roaming are based on assuming uniform retail price. Therefore, the conclusions of Gans and King (2000) are similar to Salsas and Koboldt (2004), Lupi and Manenti (2009) and Ambjørnsen, et al. (2011). All these papers assume the subscriber of a home network is unaware of the retail prices per the interconnecting networks (wholesalers); and the consumer only cares about the average retail price. This average price is uniform since it does not discriminate between wholesalers.

We draw attention to the perfect complementarity feature in the aforementioned papers. We argue that by assuming uniform retail price, wholesalers appear in the demand functions as perfect complements, rather than substitutes. An explanation is provided below on the effect of perfect complementarity on equilibria, which leads to results similar to the ones found by Gans and King (2000) and by the published papers on international roaming.

2.2.2 Perfect Complementarity

Sonnenschein (1968) points out to the duality between the two Cournot's theories of duopoly (where two firms sell identical products) and complementary monopoly (where two products are used in fixed proportions), where the difference lies in the interpretation placed on the symbols[23]. Singh and Vives (1984) found that with differentiated products[24]: "*Cournot (Bertrand) competition with substitutes is the dual of Bertrand (Cournot) competition with complements*."

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22 In this case, the price for off-net calling is viewed as a departure of termination rate from the true marginal cost of call-termination (Hoernig and Valletti, 2012).
23 That is, for two firms *A* and *B*, the Cournot indirect demand is given by $p = f(q_A + q_b)$; while the complementary monopoly direct demand is given by $q = f(p_A + p_b)$.
24 Singh and Vives use a parameter in the demand that can be positive for substitutes or negative for complements.

In this section, we illustrate perfect complementarity in order to show how the number of perfect complementary firms impacts upon equilibria. Assume firms sell products in fixed proportions to one buyer, where the buyer in this case is the complementary monopoly.

Let the buyer's demand for the products be given by

$$Q = 1 - \sum_{i=1}^{n} p_i \,, \tag{2.2}$$

where p_i is the product price by firm i, and n is the number of complementary firms. Assuming symmetric marginal costs (normalized to zero), each firm unilaterally maximizes the profit

$$\underset{(p_i)}{max}\, \pi_i = p_i \left(1 - \sum_{i=1}^{n} p_i\right).$$

The first order condition for firm 1, for example, is

$$\frac{\partial \pi_1}{\partial p_1} = 0,$$

and its response function is given by

$$p_1 = \frac{1 - \sum_{j=2}^{n} p_j}{2}. \tag{2.3}$$

Eq. (2.3) is downward sloping with respect to price charged by the rest of firms (i.e. response functions are strategic substitutes). If the rest of firms respond symmetrically, Eq. (2.3) can be expressed as

$$p_1 = \frac{1 - (n-1)p_j}{2} \quad , \qquad (j = 2, .., n).$$

If firm j responds symmetrically to firm 1, the (unilateral) price equilibrium is given by

$$p^* = \frac{1}{1+n}. \tag{2.4}$$

Thus, the final price the buyer pays is

$$\sum_{i=1}^{n} p_i = np^* = \frac{n}{1+n}, \tag{2.5}$$

and the equilibrium demand is

$$Q^* = 1 - \frac{n}{1+n} = \frac{1}{1+n}. \tag{2.6}$$

In the duopoly case, therefore, $p^* = 1/3$, which also equals Q^*. In this case, p^* equals the quantity equilibrium under Cournot duopoly competition, reflecting Sonnenschein's duality. This is due to the downward sloping in the respective response functions.

Table (2.2) shows equilibria for different values of n. As n rises: (1) own unilateral price decreases, (2) total price to the buyer increases while its demand reduces, and (3) unilateral profit to each firm declines. If all firms merge, the buyer will be charged the monopoly price (½) and firms can share the monopoly profit (¼).

Table (2.2) Illustration of perfect complementarity at different values of n.

Number of (complementary) firms n	Unilateral price by each firm p^*	Final price charged to the buyer np^*	Quantity demanded by the buyer Q^*	Unilateral profit to each firm $\pi^* = p^*Q^*$	Merger profit to each firm $\pi^m = p^m Q^m / n$
1	1/2	1/2	1/2	1/4	1/4
2	1/3	2/3	1/3	1/9	1/8
3	1/4	3/4	1/4	1/16	1/12
4	1/5	4/5	1/5	1/25	1/16

Figure (2.1) below demonstrates the prices at different values of n. Clearly, as the number of firms increases, the buyer pays less to each firm (p^*, the dotted-line), but pays more in total (np^*, the dashed-line). These prices equally depart from the monopoly price (½).

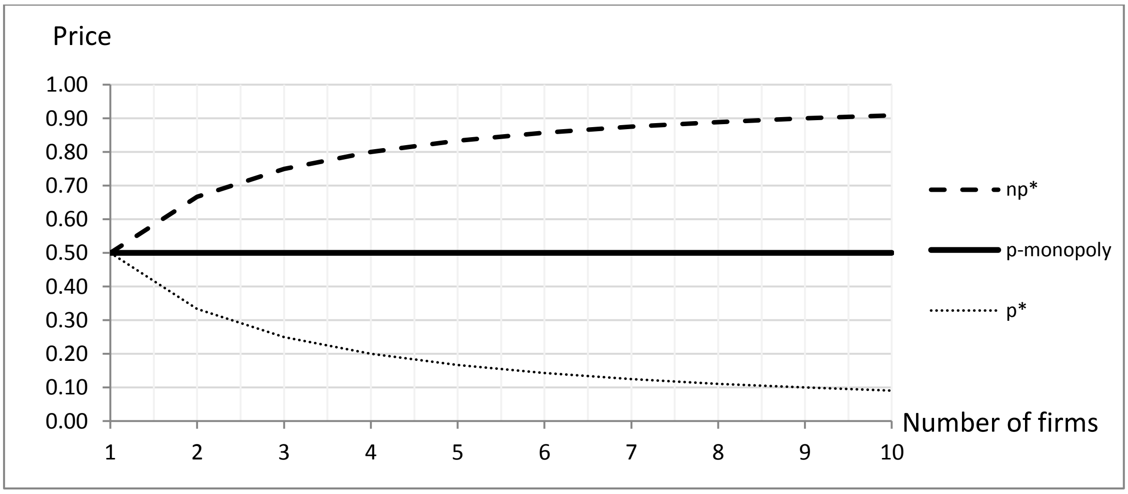

Figure (2.1) Prices of perfect complementary firms at different values of n.

Each firm unilaterally charges a markup; thus double marginalisation takes place horizontally between complementary firms. This horizontal separation externality can be internalised through a merger. Nonetheless, competition does not exist because firms are complements.

This section demonstrated the effect of perfect complementarity on equilibria. Perfect complementarity is a feature in the demands used in Gans and King (2000), Salsas and Koboldt (2004), Lupi and Manenti (2009) and in Ambjørnsen, et al. (2011).

2.3 Literature On International Roaming

In this section, we review the available published and working papers that theoretically modelled international roaming. We also review the available empirical papers.

2.3.1 Published Papers

The first published paper is Salsas and Koboldt (2004). They assume consumers put mobile handsets on automatic selection mode because consumers only care about the average retail price. The home network marks up the average wholesale price weighted by the market shares of visited networks. The base model does not assume any supply-side substitution (i.e. no steering), and thus the choice of visited networks is assumed to be random.

The demand facing a home network is assumed to be linear (i.e. representative consumer, with a substitutability parameter referring to downstream competition). Home networks set linear retail prices and the consumer decides on a home network to subscribe to, based merely on retail price for international roaming (ignoring switching costs). The retail price in this case is non-differentiated by visited networks (i.e. uniform retail). Assuming two countries, each country has two networks with symmetric coverage and costs. The price game is played in two stages: wholesale price setting then retail price setting, solved by backward induction.

Due to perfect complementarity of visited networks, the unilateral wholesale price in Salsas and Koboldt (2004) is above the monopoly price. Under collusion, the equilibrium price equals the monopoly level. These wholesale price equilibria do not change with retail competition[25], as retail competition only reduces retail markup.

Salsas and Koboldt conclude that wholesalers cannot enlarge their market shares via lowering wholesale prices because any undercutting has less than a proportionate impact on

25 The wholesale profit changes in the retail markup, but the effect cancels out in the first order condition of the wholesale objective function.

the average wholesale price and consequently on the average retail price. They also found the equilibrium wholesale price increases by the number of visited networks. Visited networks on the other side benefit from retail competition because retail competition lowers the retail markup and enhances demand.

The authors extend the base model by allowing default market shares to be asymmetric. This leads to wholesale prices being negatively related to market shares. The authors found that the visited network with low market share has an incentive to increase its wholesale price. This is due to its smaller impact on the weighted average wholesale price. The base model’s retail price does not change with the exception that it marks up the weighted average wholesale price, instead of the simple average. As in Gans and King (2000), the retail price is independent from wholesalers’ market shares.

Salsas and Koboldt also evaluate the model where only one pair of networks engages in a vertical merger. They found the independent networks would set higher wholesale prices compared to the merged entity. These differences lead to asymmetric retail prices (lower with the merged entity). This difference shrinks with intense retail competition. They judged that merger is unprofitable in this case because the consumer is unaware of prices. Then they allowed the merged entity to improve price transparency. The fully informed consumer will subscribe to the merged entity at home and will choose it (manually) in the visited country. In this case, they judged that merger is profitable to the merged parties, which of course comes at the expense of the independent parties (that did not merge). The degree of profitability is stronger under more intense retail competition.

Finally, the authors explore the case when all home networks can steer to the cheapest visited network, using complex expressions for market shares. Depending on the effectiveness of steering, wholesale prices will approach marginal costs; and as a consequence, retail prices will decline.

Lupi and Manenti (2009) study the impact of traffic steering on wholesale prices, building on Salsas and Koboldt (2004), but ignoring retail competition. Similar to Salsas and Koboldt, Lupi and Manenti conclude that wholesale and retail prices rise with the number of visited networks. They relate this result to random traffics, which means each visited network acts as a monopolist over its share of traffic; in other words, the home network deals with many monopolists.

Lupi and Manenti then use a parameter to denote the success of steering, where networks fully overlap in their respective coverages. The authors argue that wholesale prices can reach marginal cost only if steering is perfect (i.e. fully successful). If steering is imperfect, there will be no equilibrium in pure strategies, as explained below.

With imperfect steering, each visited network has a share of random traffic (not successfully steered) as a source of monopoly power, and a share of the steered traffic that induces wholesale competition. The home network will assign a higher market share to the visited network that offers the lowest wholesale price. Asymmetry in market shares (due to steering) causes asymmetry in wholesale prices; hence no equilibrium in pure strategies.

Lupi and Manenti conclude that, under steering, visited networks will offer menu wholesale prices to home networks. They will offer a low price if the home network steers, a high price if the home network steers away and a middle price if the home network does not steer to any. This middle price equals the unilateral wholesale price, which is equivalent to the weighted average of the low and the high prices, since market shares under steering act like weights. However, the retail price is unaffected, similar to Salsas and Koboldt (2004).

Lupi and Manenti also assume a game for steering investment decision. They found investment is the equilibrium in pure strategies. Because of no impact on retail prices, the authors concluded that steering investment is a waste of resources.

Finally, the authors explore vertical merger, where traffic is assumed random (i.e. steering is absent). The cooperative wholesale price between members is equal to marginal cost. A matching game is then played out where each network simultaneously has to choose whether to vertically merge with one IOT-agreement partner. They found non-cooperation is the unique equilibrium of the game, because the non-cooperating pair can charge a higher price without loosing market share.

A recent paper is provided by Ambjørnsen, et al. (2011), who develop a model based on Salsas and Koboldt (2004), and Lupi and Manenti (2009). Ambjørnsen, et al. assume perfect retail competition between two home networks and oligopoly visited networks. The game has three stages: visited networks decide to invest in coverage improvement, and then wholesale prices are set followed by retail prices. The game is solved by backward induction. They assume uniform retail prices because the consumer considers only the average retail price. They also assume steering by home network is absent, and that a visited network can increase its probability of being selected by roamers if it improves its coverage.

The model by Ambjørnsen, et al. uses linear demands, where a retailer faces weighted average wholesale prices. Because of perfect retail competition, the retail price equals the weighted average wholesale price. The model predicts wholesale price increases in the number of firms (beyond the monopoly level). This is interpreted as each visited network raises its wholesale price because it knows that its price does not affect the probability of it being chosen.

The model states that wholesale prices are strategic substitutes if traffic is random, but if manual network selection is assumed (hence no random traffic), wholesale prices can be strategic complements.

Ambjørnsen, et al. highlight the noticeable price policy shift from discriminatory retail prices (by visited networks) to uniform, which took the form of zone (or regional) pricing with some mobile network operators. They also predict that when home networks set a uniform zonal retail price, the weighted average wholesale price can rise further.

Ambjørnsen, et al. concluded that fierce upstream competition would increase both wholesale and retail prices[26]. They also found the wholesale price is decreasing in own market share, and concluded that investment to increase market share, such as coverage improvement, is not profitable because a viable alternative is to reduce the wholesale price.

The authors extend the model to allow for traffic steering, using a parameter for success of steering. Steering causes downward pressure on wholesale prices, and consequently, on retail prices.

2.3.2 Working Papers

Roaming is also studied by Tsyganok (2008), who extends Salsas and Koboldt (2004) model on pricing behaviours by considering non-linear and asymmetric demands, and varying the number of networks. Her results are in line with Salsas and Koboldt’s.

26 Retail price equals wholesale price because of assuming perfect retail competition.

Bühler (2010) assumes two countries; each is served by two networks that compete for subscribers downstream and for hosting visitors upstream. Home networks are differentiated on a Hotelling line, and offer only international roaming service. They charge a two-part tariff (i.e. a rental/fixed fee, and a uniform price per call) for their post-paid subscribers. Subscribers can register with one network only. Assuming symmetric costs and demand parameters, and reciprocal wholesale price setting, the game is as follows: networks set wholesale prices, followed by the retail prices, with subscribers deciding on which home network to join. The model also assumes wholesale roaming is sold non-cooperatively through IOT agreements, or through alliances, where each member of an alliance commits to buy exclusively from the alliance member (based on the agreed upon mutual wholesale price); but each member can however sell to outsiders. This implicitly assumes perfect control over network selection (i.e. perfect steering).

Bühler found that each home network sets the retail price of the call equal to the wholesale price because of perfect retail competition, while the fixed fee is set to extract consumer surplus. In equilibrium, wholesale price equals the marginal cost for non-alliance members.

However, if one alliance is formed, the wholesale price between the members will exceed marginal cost. If two competing alliances are formed, due to strategic complementarity of wholesale response functions, both alliances charge symmetric wholesale prices that exceed prices under a single alliance. The author also found that networks endogenously form alliances in a stage prior to setting wholesale prices, as each network benefits from the higher wholesale price. Therefore, two competing alliances are formed in equilibrium.

The intuition behind excessive wholesale pricing (under alliance) in Bühler (2010) is the following. Due to full steering commitment, alliance members have zero net payments since they have symmetric demands and profits. Each network gets retail profit only from rental (while the price of calling equals wholesale price). It can be determined therefore that a wholesale price increase has two effects on the retail profit, which are: (1) a direct negative effect on profit, and (2) a strategic effect on softening competition for subscribers by inducing the downstream competitor (through strategic complementarity) to offer less attractive contracts to its own subscribers. If the retailer does not join an alliance, the first effect dominates the second; but by joining an alliance, the first effect is offset by gains at the wholesale level (since raising the mutual wholesale price raises wholesale profits).

Bühler extends his base model to cases of imperfect steering. If steering is absent, the selection between networks is random and the equilibrium wholesale price exceeds the one in the base model. This result holds with or without alliances; thus, alliance formation has an impact on wholesale prices only if steering is effective. In the continuous case (imperfect steering), Bühler found that without alliances, no equilibrium in pure strategies exists. With two competing alliances, the effectiveness of steering (i.e. its ability to manipulate market shares) reduces the equilibrium wholesale price, but it is still above marginal cost. In summary, subscribers are worse off under alliances, since retail price of calling increases while the rental fee is unchanged.

Hualong and Shoulian (2009) develop a model similar to Salsas and Koboldt (2004). Under different scenarios, they analyse the case whereby two networks form an alliance first and then charge a lower wholesale price to each other. They concluded that lowered wholesale prices do not improve payoffs, while lower retail prices reduce profits. Therefore, the alliance members can improve their market shares either by steering, or choosing retail prices (discriminated by visited networks) in order to let the consumer manually select an alliance partner. The additional payoff alliance members make is a loss to the independent networks.

Furthermore, Shortall (2010) and Lacasa (2011) address the choice of alliance member when demands are asymmetric. Both papers concluded that, using different scenarios and numerical examples, networks with large retail demands will form an alliance, while small networks will form another alliance.

2.3.3 Empirical Literature

This section surveys the available relevant empirical papers. In Section (2.1.2), we summarized the analyses done by the European NRAs regarding steering and wholesale pricing between European mobile network operators. The focus in the NRAs analyses was about traffic steering as a countervailing buying power by home networks.

Most of the analyses compared a visited network's market shares and wholesale prices over two periods. The NRAs considered aggregate volumes (either traffics or sales), but only two NRAs looked at these volumes with/out intra-group (e.g. networks that are cross-owned). Using outgoing minutes as the product market, half of the analyses calculated market shares based on revenues and the other half on minutes.

The NRAs reached a consensus that steering exists, which should enhance wholesale competition. In Italy, for example, Vodafone has a market share of 42.6% in wholesale revenues. By excluding intra-groups (revenues related to home networks that might have preferential IOT agreements in Italy), Vodafone's market share reduces to 23.9% (see Table 2.1). Therefore, steering by some of the intra-group home networks to Vodafone might be behind the differences in market shares. For example, Vodafone in another country might be steering its roamers in Italy towards Vodafone-Italy. However, this can be due to demand-side substitution because of the existence of Vodafone's Eurocall that offered lower retail price when roaming on Vodafone networks.

Another data analysis topic in the EU is own price elasticity of demand, which has been crucial in the debates regarding the impact assessment of the EC roaming regulation on welfare. The EC (2006) used three scenarios for own price elasticities in its assessment. The scenarios are (-0.55), (-1.0), and (-1.2). The GSMA (2008) disagrees with the EC, and proposes that the elasticity should be (-0.25).

We found two industry studies that derive own price elasticity of demand. The first is a study conducted by Europe Economics (2008) for the European Parliament. The second is a study conducted by the NRA of Spain (CMT, 2009). The focus of both studies is estimating demand elasticity for outgoing calls while roaming within the EU. The studies use roaming total minutes of outgoing calls and average retail prices, all at the country-level, where the study period is the second quarter of 2007 (i.e. a quarter before the EC roaming regulation) to the first quarter of 2008, while CMT also covers up to the third quarter of 2008.

In Europe Economics (2008), the following model is estimated with panel fixed and random effect regressions.

$$ln(Q_{it}) = \beta_0 + \beta_1 \, ln(P_{it-1}) + \beta_2 D_t + \xi_{it} \ , \tag{2.7}$$

where $ln(Q_{it})$ is the natural log of total minutes consumed in country i in time t; $ln(P_{it-1})$ is the natural log of the average retail price per minute in country i and time $t-1$[27]; D_t is a vector of time dummy variables to capture seasonality effects; and ξ_{it} is the error term.

The coefficient β_1 in Eq. (2.7) represents the own price elasticity, which is estimated as (-0.35) in the random–effect model, and (-0.44) in the fixed–effect model, where the significance level is 5% in both estimations.

In CMT (2009), the following model is estimated with panel fixed-effect regression.

27 The use of lagged-time is due to assuming consumers require some time to adjust their behaviors in response to the price change.

$$ln(Q_{it}) = \beta_0 + \beta_1\, ln(P_{it}) + \beta_2 X_{it} + \xi_{it} \ , \tag{2.8}$$

where $ln(Q_{it})$ is the natural log of total minutes consumed in country i in time t; $ln(P_{it})$ is the natural log of the average retail price per minute in country i and time t; X_{it} is a vector of control variables (price of SMS, number of tourists and summer-season dummy); and ξ_{it} is the error term.

CMT (2009) uses instrumental variables to solve the endogeneity problem of price and the error term. The instruments are: the lagged price, a dummy variable if the country's currency is not Euro, and a variable to capture exchange rate variations for non-Euro countries.

The coefficient β_1 in Eq. (2.8) represents the own price elasticity, which is estimated as (-0.37) in the model without instrument, and (-0.36) in the model with instrument, where the significance level is 5% in both estimations.

Obviously, the aforementioned industry studies show that international roaming demand is inelastic. This finding serves the argument against the EU regulation. The GSMA (2008) argues that demand inelasticity implies that consumption would not increase largely by capping retail prices and therefore the impact on producer surplus would raise questions about the expected enhancement of total welfare[28].

In surveying the literature, we found one empirical working paper on roaming alliances by Rieck et al (2005). We also review an empirical paper by Wright (1999) on international calling, since it shares some similarities with international roaming. In addition, we summarize a working paper by Martino (2007) who provides guidance on how future research should test for steering.

Rieck, et al. (2005) analyze empirically the implications of roaming alliance formations on roaming retail prices. They observe the retail prices for outgoing calls (while roaming abroad) to home countries, as listed on the websites of 88 mobile network operators in the OECD countries and five in Asian countries[29], from September to mid-November of 2004. To overcome the complexity in retail prices, the highest retail price for roaming on a given visited network is considered. Network *A1* in country *A* is considered to be favoring network *B1* among the other networks in visited country *B* if the lowest retail price *A1* charges is for

28 The GSMA (2008) argues that the price cap creates a focal point for pricing, which harms competition. The GSMA proposes that transparency measures can enhance competition instead of price regulation.
29 Namely, Singapore, Hong Kong, Malaysia, Taiwan and Thailand.

roaming on *B1*'s network, assuming the rational consumer would manually select the visited network with the cheapest retail price. A dummy variable was created for the network membership in an existing roaming alliance (e.g. Vodafone group, Freemove, etc…).

Based on literature on social network analysis, the authors compute two indices: a network's centrality (how many favoring relations a network has), and networks' clique (a subset of networks forming a group). The control variables used in estimations are a network's total revenues and market shares in local subscribers, and other country-level variables such as population and GDP.

The centrality index is regressed on the dummy for alliance membership and the control variables. The roaming alliance dummy is found insignificant. The results from the control variables suggest that networks in countries with high export-to-import ratio would tend to have a high degree of centrality. In addition, a high degree of centrality is associated with intermediate sized networks (in terms of revenues).

The dummy for alliance membership is regressed on the clique index to see whether an existing alliance behaves like a strategic alliance (where members are expected to be involved in favoring relations). The authors found that only Vodafone group members constitute a strategic alliance (i.e. involving themselves in reciprocal favoring in terms of retail prices) compared to the rest of alliances[30].

Wright (1999) empirically tests his theoretical predictions on international settlement rates. The author uses data on wholesale and retail prices, and volumes (quantities) of international calls between the USA and 167 countries over 17 years. He found that retail and wholesale prices have a strong positive correlation.

Wright investigates the determinants of wholesale prices. He found wholesale prices increase with income disparity between the USA and the foreign countries, but the magnitude decreases after controlling for competition, where competition generally reduces wholesale prices. Marginal cost proxies fall over time, which influence wholesale prices as follows: (1) wholesale price increases with distance between the USA and the country, (2) increases with the country's area, and (3) decreases with the country's population (indicating the existence of economies of scale).

30 We think this result is caused by Vodafone's cross-ownership of mobile networks in multiple markets. Vodafone, as an example, offered a Eurocall plan, which was a common retail price for roaming on any Vodafone network in Europe (O.J., 2001). Vodafone is able to offer such retail plans relying on its presence in many markets. In contrast, another alliance, say Freemove, consists of different networks that may not be able to maintain preferential wholesale prices in each market.

Martino (2007) defines steering in international roaming. He argues that market definition should be based on the success of traffic steering. If traffic steering is not possible, each visited network should constitute a separate market.

Martino tries to answer the question of how to assess the existence of steering. He recommends comparing the market share of a visited network in serving a home network to the visited network's market shares in serving other home networks.

Martino proposes that the calculation of market shares should be done for each service (e.g. outgoing calls) in traffic (i.e. quantities) over a year to smooth out the seasonality effect. To explore for steering, he recommends studying the movements in market shares over years. Information on networks coverage, quality of services, technological developments, lifetime of handsets, preferential agreements, roaming alliance relations, and merger/acquisition events of visited networks should be included within an appropriate dataset.

2.4 Discussion

In this section, we identify how the next chapters complement the existing literature surveyed in this chapter.

We develop a base model on pricing behaviours under IOT agreements. The base model assumes linear (wholesale and retail) prices, and compares equilibria under different cooperative and non-cooperative strategies (with different states of substitutability). It relies on the literature on international settlement rates, in terms of using similar profit functions and game setting. Such profit functions and game settings are also used by Salsas and Koboldt (2004), Lupi and Manenti (2009) and Ambjørnsen, et al. (2011).

Moreover, our base model assumes international roaming is an additional service offered by mobile networks. This, however, is contrary to Salsas and Koboldt (2004) and Bühler (2010) who assume networks only offer international roaming and compete for subscribers.

In line with the existing published papers on roaming, our base model assumes a world of two countries, each served by two networks that compete at the wholesale level but hold monopoly positions at the retail level. The base model compares equilibria under discriminatory retail policy (i.e. retail prices discriminated by visited networks) and uniform policy. In other words, it explores different wholesale pricing strategies with and without the uniform retail pricing constraint. With this uniform constraint, the results in the published papers surveyed in Section (2.3.1) are reproduced. We demonstrate that uniform retail price assumption makes wholesalers appear in the demand as complements rather than substitutes, such that the price maximisation problems provide results that are inconsistent with wholesale competition.

We also model two preferential IOT agreements under cross-ownership and roaming alliance strategies, where the former results in asymmetric retail prices (assuming manual network selection by the consumer), while the later is built on uniform retail price (assuming automatic selection by consumer). We also compare the cross-ownership model's results to the case where retail price is uniform, as in Salsas and Koboldt (2004), and Lupi and Manenti (2009).

We found that cooperating to form a cross-ownership pair is a dominant strategy to each partner under discriminatory retail prices, since retail prices reflect preferential wholesale prices. However, the opposite is true under uniform retail price: non-cooperation is the dominant strategy to each partner; which is also found in Salsas and Koboldt (2004), and Lupi and Manenti (2009).

We model roaming alliance based on assuming all home networks set uniform retail prices, which equal the monopoly price given home networks hold monopoly positions downstream, taken into consideration implications of net payments, as in Shy (2001). Steering requires handsets to be on automatic mode, which is the assumed case under uniform retail price.

We found that investment in steering affects wholesale competition and alliance formations. That is, with investment in steering, the home network can cause downward pressures on wholesale prices. The equilibrium is such that all networks invest in steering, and in this case, it is a waste of resources because profits are reduced by sunk costs. This intuition is also found in Lupi and Manenti (2009), and in Ambjørnsen, et al (2011).

The success of steering is assumed to be dependent on the substitutability of demand, which is different to the success rate used in Lupi and Manenti (2009). If steering is absent, wholesale price equals the monopoly price. This reduces as substitutability increases. The result is different from menu pricing found in Lupi and Manenti (2009), and from above-cost pricing found in Bühler (2010).

We found IOT agreement partners have incentive to form alliances only if mutual steering is insured. Thus, steering is a necessity for alliance formation, as predicted by Bühler (2010) and Hualong and Shoulian (2009).

Investment in network coverage is addressed in Ambjørnsen, et al. (2011), but our model takes coverage as given because visited networks typically set their respective coverages to compete for home subscribers, rather than for visitors.

We also show that with non-zero net payments due to asymmetry in market sizes, each network has an incentive to form an alliance with the largest network. This contradicts with the conclusions of Shortall (2010) and Lacasa (2011) who argue that small networks prefer to form an alliance.

With regards to empirical papers, as far as we know, there is no existing paper about competition in wholesale roaming, structural demand estimation for visited networks, or about the impact of preferred networks on wholesale prices.

We use a dataset on traffics (quantities) demanded by Etisalat outbound roamers and wholesale charges per roaming service for each visited network. We make a distinction between visited networks that are cross-owned by Etisalat and the ones that are considered by Etisalat as alliance networks. This is to emphasize that a home network can steer to an alliance network without necessarily having an ownership stake in it, a fact that is ignored in the European NRAs analyses which mainly consider cross-ownership (intra-groups).

More importantly, the dataset has observations before and after Etisalat retail policy shift from discriminatory pricing (i.e. per visited network) to uniform (i.e. common across visited networks). Before the policy, retail prices were discriminatory and hence the choice between visited networks is assumed to be manually selected by roamers (i.e. demand-side substitution). After the policy, retail prices become uniform, so the choice is assumed to be made by Etisalat through steering (i.e. supply-side substitution), controlling for visited networks non-price characteristics and assuming handsets on automatic mode.

We draw attentions to the retail price policy importance in steering, which is ignored in the European NRAs analyses and in Rieck et al (2005). A roamer can override his home network's steering by manually selecting a visited network with the cheaper retail price. Such obstruction has to be removed for steering to exist. In order to steer, the home network should make the roamer indifferent between visited networks price-wise, which is assumed possible through setting identical retail prices (uniform). In our dataset, we make use of Etisalat retail policy shift, which should act as a shock in the data through which we explore for steering.

In our dataset, we only observe one side of the IOT agreements; that is, what Etisalat pays out to visited networks (its wholesale costs), which is also the visited networks revenues. Therefore, the reciprocity in prices that may exist in IOT agreements cannot be inferred from the dataset, neither on the retail level as in Rieck et al (2005) nor on the wholesale level as in Wright (1999) who studied international calling.

Nonetheless, the dataset is used to improve our understanding about wholesale competition between visited networks. Therefore, we estimate demands for visited networks, estimate the relationship of market structure and preferential IOT partners with wholesale prices. In addition, we explore the effectiveness of steering by the home network, Etisalat.

We study outgoing calls while roaming abroad, similar to the European NRAs analyses, but calculate market shares in quantities (as opposed to shares in sales) since steering is related to market shares in quantities; thus we separate out the impact of wholesale pricing behaviors.

Unlike Rieck et al (2005) who use retail prices to study alliance formation, we have data on wholesale prices which are very relevant to preferential IOT (wholesale) agreements. Wholesale prices charged to Etisalat can be compared between its IOT partners, controlling for its alliance networks and cross-owned networks.

We found that, after the uniform policy, steering by Etisalat is effective. Wholesale discounts are offered by Etisalat alliance networks, but not by its cross-owned networks. Etisalat roamers are found to have higher marginal valuations for visited networks that allow prepaid roaming and networks that are alliance to Etisalat, but less for networks cross-owned by Etisalat.

In addition, the number of networks is found to significantly reduce wholesale prices, reflecting substitutability of visited networks. Moreover, demand is found more elastic than the industry figures in EC (2006), GSMA (2008), Europe Economics (2008) and CMT (2009).

Chapter (3). The Base Model

The exisiting theoritical models on mobile international roaming are based on networks choosing wholesale prices with uniform retail pricing constraint; that is, the retail price is common or non-discriminatory by visited networks, as in Salsas and Koboldt (2004), Lupi and Manenti (2009), and Ambjørnsen, et al. (2011), which are surveyed in Section (2.3.1).

The rationale for assuming home networks applying a uniform retail is the fact that the subscriber in many situations only cares about the average retail price even if prices differ due to probably different wholesale prices. Such assumptions are used in Gans and King (2000) who model the case a fixed network subscriber calling a mobile number without knowing the terminating mobile network. Models on mobile international roaming also follow these assumptions for the roamer who either originates a traffic (e.g. making an outgoing call) or terminates a traffic (e.g. receiving an incoming call) when roaming on a foreign visited network without knowing the applicable retail price for using it. Nonetheless, all these models assume the subscriber knows the average retail price he eventually pays to his home network.

However, as discussed in Chapter (2), this uniform retail price in the demand equation makes networks complements rather than substitues, removing the wholesale competition the existing papers aim at modelling. As a consequence, these papers share similar results: the final wholesale price charged to the home network by non-cooperative upstream networks is higher than the collusive price, which increases with the number of upstream networks. Perfect complementairty explains how these results can exist, as demonestrated in Section (2.2.2).

The assumption on retail pricing policy for mobile international roaming, whether uniform or discriminatory, has implications on the roamer's handset network selection and on wholesale competition as we shall demonestrate in this chapter. The discriminatory retail pricing policy is overlooked in the lietraure, so we aim in this chapter to compare equilibria under this policy to the uniform policy used in the literature.

This chapter lays down the base model for mobile international roaming for the discriminatory and the uniform retail pricing policies. Section (3.1) explains the model background. Section (3.2) outlines the game. Section (3.3) shows game results and welfare implications. Section (3.4) discusses game intuitions and its connection to next chapter.

3.1 Model Background

3.1.1 Demand Side

We base most of our assumptions on the findings in the EC sector inquiry (2000). We make three key assumptions with regards to switching behaviours of the consumer of mobile international roaming.

The first relates to the decision of registering at a home mobile network operator (hereafter home network). The consumer has to be registered at a home network in order to be eligible to roam abroad with his home mobile number. Given roaming is only a component of a mobile bundle that is not offered on its own, it is plausible to assume that subscribers do not decide to subscribe to a home network based on roaming reasons[31].

In addition to the assumed negligible weight for international roaming in consumer's decision to choose a home network, we further assume high switching costs between home networks that outweigh any domestic competitive offering for international roaming. The absence of mobile number portability in some countries is an example, which makes the subscriber who plans to switch away from the current home network unable to use his current mobile number. If international roaming is mainly about using the same mobile number, such convenience will not be enjoyed abroad in this case had the subscriber domestically switched to another home network. Another similar example is a subscription contract with a locked handset, under which the subscriber will not enjoy the convenience of using the same handset abroad with a SIM card from a different home network. Based on all the above, we assume a home network is a monopolist at the retail level.

The second switching assumption is that the outside options in the visited country are inconvenient. Examples of such options include the use of a visitor-SIM, a VOIP communications via WIFI, a satellite handset, a hotel telephone and a public payphone. Due to the temporary nature of visits, we assume those outside options are highly inconvenient as they require technical know-how to use for communication.

The third switching assumption relates to the roamer's selection between different mobile network operators in the visited country (hereafter visited networks). Visited networks are

31 Europe Economics (2008) claim most consumers place little weight on roaming prices in deciding which home network they subscribe to.

assumed to be differentiated in their geographical coverages. Other product differentiation dimensions such as brand are ignored in the base model for simplicity[32]. The roamer is assumed to manually select the visited network (through his handset) with the cheapest retail price as long as its coverage allows. If the retail price is uniform, we assume the roamer would consider leaving his handset on automatic mode.

We assume complete information[33] and rational economic agents. Since visited networks lack information on the heterogeneity of foreign visitors[34], we use the representative consumer approach to model the demands for visited networks.

3.1.2 Supply Side

The travelling subscriber is assumed to choose manually the visited network for his home network based on the visited network's coverage and on the retail price he eventually pays to his home network. With uniform retail, he is assumed to leave his handset on default automatic mode because he has no price reason to manually select between visited networks; and thus the handset would be picked up any visited network (more likely the one with the strongest network signal).

In the case of uniform retail price, in order for the home network to ensure the selected visited network is a preferred visited network (which may offer a lower wholesale price), the home network needs to acquire steering technology, such as SIM application toolkit or over the air programming, to steer to the preferred network. Investment in such technology is supposed to bring efficiency gains to the home network. Steering, as a supply-side substitution, requires overlapping coverages of visited networks in order to be effective, where its success is based on minimizing random traffics. We defer the choice on acquiring steering technology to Chapter (4).

For the demand to be satisfied, visited networks must provide geographic coverages. Both demand-side and supply-side substitutions (through steering) need overlapping coverages of

32 The estimated demand in Chapter (6) addresses visited networks' characteristics, which are: (i) home network's cross-owned networks that may bear the brand of home network, (ii) home network's roaming alliance networks; and (iii) home network's partners that allow prepaid roaming. Chapter (6) tests the significance of these characteristics in explaining the mean utility of Etisalat roamers, where the unobserved characteristics (by the econometrician), such as coverage of visited networks, enter the error term.
33 Mobile international roaming had been blamed for lack of price transparency. Regulators in the EU and Arab states overcame such problem by requesting home networks to send SMS to their travelling subscribers detailing the applicable roaming prices.
34 Visited networks recognise the home network of the visitors, and are not expected to know the details of the foreign visitors. This is why, as observed in the market place (e.g. Etisalat), visited networks do not price discriminate (in their wholesale pricing) between the visitors from the same home network (e.g. business/consumer; postpaid/prepaid, etc.).

visited networks; otherwise each network is an isolated monopolist in its own coverage area. Thus the higher the overlap, the higher will be the substitutability.

Typically, the home network signs IOT agreement with all networks in a given country so that its travelling subscriber can have the most possible network coverage in order to be able to use the service continuously[35]. Therefore, visited networks are assumed to be imperfect substitutes regarding coverage; hence preferential IOT agreements are not assumed to result in exclusive IOT agreements.

Usually, a NRA obliges its licensed mobile network operators to meet the minimum network coverage requirement. In the literature on choice of network coverage[36], the networks choose their coverages strategically to compete for domestic subscribers, where coverage is considered a product quality parameter. As coverage increases product differentiation for domestic subscribers, at the same time, it increases product substitutability for foreign visitors. We do not assume the choice on coverage is made for the sake of hosting visitors; hence it is exogenous to the agents in our model. This also means coverage fixed costs are irrelevant too[37].

In the base model, we use a substitutability parameter as an index to show that visited networks' coverages are overlapping where substitution between visited networks can be made. The nature of mobile networks' coverages does not make them perfect substitutes, so the substitutability parameter is bounded.

Furthermore, we assume networks provide equal coverages; and have unconstrained capacities, symmetric constant actual marginal costs (normalized to zero without loss of generality) on both the retail and wholesale service provisioning, and no fixed costs as networks use existing facilities to serve roamers[38].

The focus of the model is on the pricing behaviour of networks, not their market structures, so we assume a fixed number of players (i.e., mature market). More specifically, we assume

35 This is also noted by the French NRA (ARCEP, 2006).
36 See Valletti (1999) for coverage as a quality parameter, and see Valletti (2003) and Fabrizi and Wertlen (2008) for the choice on coverage and its impact on national roaming agreements.
37 Ambjørnsen, et al. (2011) assume a stage in the game, before the pricing stages, where visited networks choose to invest in coverage improvement, especially in airports, to compete in hosting visitors.
38 CAMEL technology allows roaming by prepaid subscribers, which must be installed by both the home and visited network. The home network instantly deducts from the balance of the prepaid roamer according to his usage. The technology is expensive to acquire, but typically, the home network charges higher retail for prepaid (European Parliament, 2006). According to Etisalat, visited networks do not price discriminate in wholesale prices for prepaid versus postpaid. CAMEL technology is assumed to affect the market size only; but is not assumed to affect the pricing behaviours of visited networks, which is the focus of all theoretical models. Therefore, costs of CAMEL technology are ignored in all the theoretical models.

a duopoly game. Networks are independent of one another (no cross-ownership[39]), and maximize their roaming profits [40] independent from other existing interconnection agreements, such as the international settlement rate agreement for international calls.

3.1.3 Pricing

Wholesale prices under IOT agreements are known to be set on a linear basis (i.e. per unit of use)[41]. For simpification and in line with the EC (2000), the model assumes linear wholesale and retail prices. We start with discriminatory retail prices. Then we assume uniform retail pricing in line with the existing literature. Home networks are assumed not to coordinate their retail pricing strategy as the retail price is irrelevant in a typical IOT-agreement[42].

In line with the literature, a two-stage pricing game is played: wholesale price followed by retail price. In different specification of the model, wholesale price setting may stem from maximizing individual wholesale profit. If networks in the vertical line set the wholesale price to maximize their joint profits, they may avoid the double marginalization problem[43]. Two collusive pricing strategies are also explored[44]: domestic networks fixing the wholesale price to maximize their national cartel profit[45]; and an international cartel aimed at maximizing the market profit[46]. We compare the four wholesale strategies equilibria under discriminatory and uniform retail price setting that aim at maximizing the retail profits of a home network across its IOT agreements.

3.2 The Game

3.2.1 Players

Similar to Salsas and Koboldt (2004) and Lupi and Manenti (2009), we assume there are two countries each is served by two networks. Each network is assumed to be a monopolist in

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39 In Chapter (4), we model cross-ownership, which is a wholesale pricing strategy that results in preferential wholesale prices between the agreeing networks.
40 We assume a home network offers international roaming as an additional service to existing mobile package of services, and therefore will continue to offer it as long as it gains non-negative profit.
41 That is, wholesale prices do not involve two-part tariff at the retail level or franchise fee at the wholesale level. This may be due to demand uncertainty of roaming.
42 See Section (1.1) on IOT agreements.
43 Since each player is a wholesaler and a retailer (i.e. symbiotic producers), the incentive to maximize the vertical profit comes from both sides (Carter and Wright, 1994).
44 Collusive agreements are thought to be unofficial but coexist with the official wholesale (IOT) agreement.
45 This practice is a domestic price fixing against a foreign firm, which is illegal in some countries such as the EU member states.
46 The GSM Association is an example of a global umbrella that has a history in issuing roaming price guidelines (STIRA) and lobbying against price regulation (see Section 2.3.3).

providing the retail service to its travelling subscriber; and at the same time, since it can be used by foreign visiting subscribers, it competes domestically for the wholesale service.

Denote countries by A and B. A pair of networks from the two countries sign a bilateral IOT agreement denoted by (A_i, B_j), where $i,j = \{1,2\}$. Hence, there are four IOT agreements: $(A1, B1)$; $(A1, B2)$; $(A2, B1)$; and $(A2, B2)$. Each agreement defines the wholesale prices charged between the agreeing partners. Figure (3.1) depicts the relationship.

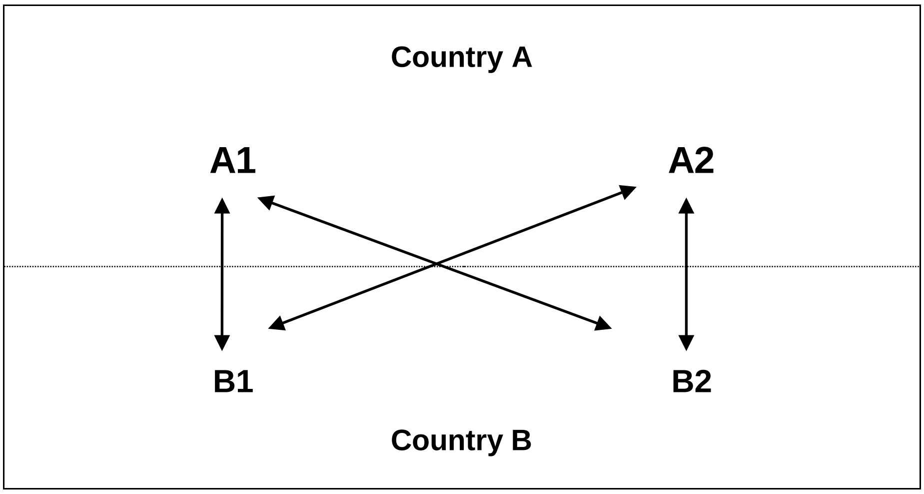

Figure (3.1) International roaming in two countries each with two networks.
-The double arrow represents a pair of two networks in an IOT agreement.

3.2.2 Demand Specification

We use linear demands as in Shubik and Levitan (1980). The main feature of this linear demand is the independence of the substitutability parameter from the market size, which we let vary to compare payoffs without affecting market size[47].

Let us use the subscript as the network in question and the superscript as the foreign network it deals with. The following equations are for network $A1$ which applies similarly to any network. The representative consumer who subscribes to home network $A1$ has preferences to roam on networks $B1$ and $B2$ given by the following quadratic utility

$$U_{A1} = \frac{\alpha}{\beta} Q_{A1} - \frac{Q_{A1}^2}{2\beta} - \frac{(q_{A1}^{B1} - q_{A1}^{B2})^2}{2\beta(1+\gamma)} - p_{A1}^{B1} q_{A1}^{B1} - p_{A1}^{B2} q_{A1}^{B2}, \tag{3.1}$$

where $Q_{A1} = q_{A1}^{B1} + q_{A1}^{B2}$ is the aggregate quantity demanded by $A1$'s subscriber for roaming in country B; p_{A1}^{B1} and p_{A1}^{B2} are the applicable retail prices; and α (the market size) and β

47 In contrast, the market size of the demand in Dixit (1979) is given by $\alpha/(\beta+\gamma)$, which is reduced by the substitutability parameter γ.

(slope of demand curve) are positive constants. The substitutability parameter is $\gamma \geq 0$, which is also the inverse of product differentiation.

The roamer maximizes his utility for roaming in country B by choosing q_{A1}^{B1} and q_{A1}^{B2}

$$\frac{\partial U_{A1}}{\partial q_{A1}^{B1}} = \frac{\partial U_{A1}}{\partial q_{A1}^{B2}} = 0. \tag{3.2}$$

The direct demands for roaming on networks $B1$ and $B2$ respectively are given by

$$q_{A1}^{B1} = \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_{A1}^{B1} + \frac{\beta\gamma}{2}p_{A1}^{B2}\right],$$

and

$$q_{A1}^{B2} = \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_{A1}^{B2} + \frac{\beta\gamma}{2}p_{A1}^{B1}\right]. \tag{3.3}$$

The demands are downward sloping, showing the own price effect is greater than the cross price effect (i.e. $1 + \gamma/2 > \gamma/2$). If the prices are uniform (i.e. $p_{A1}^{B1} = p_{A1}^{B2} = p_{A1}$), the effect of γ is removed from the demands, resulting in identical demands

$$q_{A1}^{B1} = q_{A1}^{B2} = q_{A1} = \frac{1}{2}\left[\alpha - \beta p_{A1}\right]. \tag{3.4}$$

Figure (3.2) shows the direct demands as in Shubik and Levitan (1980). In this Figure, consider firm 1 as visited network $B1$ and firm 2 as $B2$; while home network $A1$ faces their aggregated demands. The $d - d'$ line is the analogy to Eq. (3.3); the $D - D'$ line is the analogy to Eq. (3.4); the $D - F$ line shows the aggregate demand (e.g. Q_{A1}); and the $d' - F'$ line shows the demand for firm 1 when it drives out firm 2 from the market (i.e., firm 2 sells nothing)[48].

48 The kink in the demand curve insures non-negative demands. That is, there exists p_1' at point d' such that $q_2 = 0$ because firm 2 is priced out of the market (Shubik and Levitan, 1980).

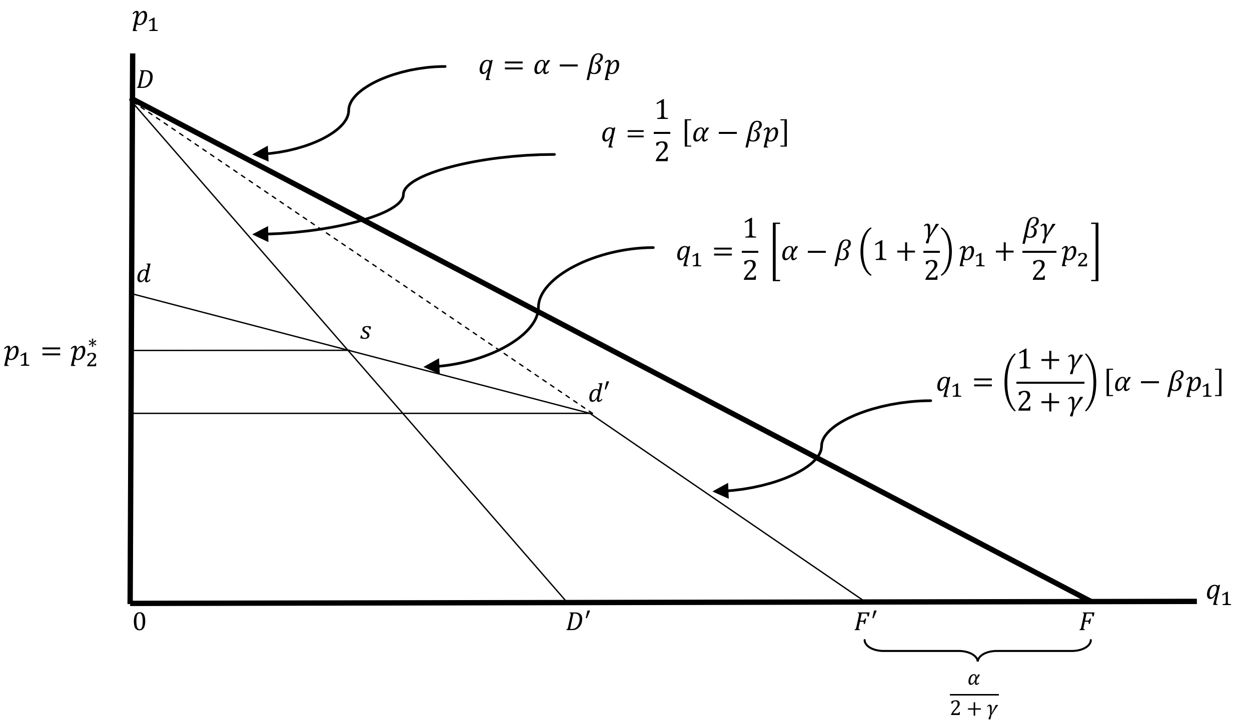

Figure (3.2) The demand facing firm 1.
Source: Figure (6.1) in Shubik and Levitan (1980).

In our case, for example, products are differentiated in their geographic coverages, not as a response to host roamers, but as a response to local licensing obligations and to local competition for subscribers (i.e. exogenous reasons). Visited networks use their existing coverages to host roamers. Given our assumption on symmetric coverages, the roamer may have equal quantities demanded. In the coverage overlapping areas, the roamer can substitute between visited networks.

We let the substitutability parameter γ represent the overlapping coverage. If $\gamma = 0$, the roamer views visited networks as non-substitutes. This is equivalent to non-overlapping coverage. As γ rises, the roamer views visited networks as more substitutable. This corresponds to the increase in overlapping coverage. In the limit of γ, visited networks are perfect substitutes, which means coverage overlap is perfect.

Define $\theta = \gamma/(2+\gamma)$ as the index for the degree of substitutability[49], where $\theta \in [0,1)$. θ is equivalent to the cross price elasticity divided by the absolute value of own price elasticity when prices are symmetric. For example, take the following demand

$$q_1 = \frac{1}{2}\left[\alpha - \beta\left(1+\frac{\gamma}{2}\right)p_1 + \frac{\beta\gamma}{2}p_2\right].$$

The own price elasticity is given by

49 This index is also used in Economides (1994), and is similar to (γ^2/β^2) typically used with Dixit's demand as in Singh and Vives (1984).

$$\eta_{1,p_1} = \frac{dq_1}{dp_1}\frac{p_1}{q_1} = -\frac{\beta}{2}\left(1+\frac{\gamma}{2}\right)\frac{p_1}{q_1},$$

and the cross elasticity is given by

$$\eta_{1,p_2} = \frac{dq_1}{dp_2}\frac{p_2}{q_1} = \frac{\beta\gamma}{4}\frac{p_2}{q_1}.$$

When prices are symmetric in equilibrium for example, θ can be expressed as follows

$$\theta \equiv \frac{\eta_{1,p_2}}{|\eta_{1,p_1}|} = \frac{\gamma/4}{\left(1+\frac{\gamma}{2}\right)/2} = \frac{\gamma}{2+\gamma}.$$

If $\theta = 0$, the services provided by visited networks are independent (isolated monopolists); and if $\theta \to 1$, the services are becoming perfect substitutes. In our model, θ corresponds to the overlapping of coverages of visited networks, under which the roamer[50] can substitute.

3.2.3 Payoffs

The IOT agreement (Ai, Bj) results in $(\Pi_{Ai}^{Bj}, \Pi_{Bj}^{Ai})$ profits to each partner consisting of a retail part and a wholesale part, where $i, j = \{1,2\}$. The following is a separately additive profit function for network Ai based on the (Ai, Bj) IOT agreement

$$\Pi_{Ai}^{Bj} = \overbrace{\left(p_{Ai}^{Bj} - w_{Bj}^{Ai}\right)\; q_{Ai}^{Bj}\left(p_{Ai}^{B1}, p_{Ai}^{B2}\right)}^{Retail\,profit} + \overbrace{w_{Ai}^{Bj}\;\; q_{Bj}^{Ai}\left(p_{Bj}^{A1}, p_{Bj}^{A2}\right)}^{Wholesale\,profit}, \qquad (i, j = 1,2).$$

The retail profit to Ai comes from the situation Ai's subscriber roams on Bj's network. Ai charges its subscriber p_{Ai}^{Bj} and pays w_{Bj}^{Ai} to Bj. (In country B, network Bj is constrained by its rival Bk $(j, k = \{1,2\},\ j \neq k)$ as long as the roamer can substitute and the wholesale prices are reflected in Ai's retail prices).

The wholesale profit to Ai comes from the situation Bj's travelling subscriber roams on Ai's network. (Ai is also constrained by its rival Al $(i, l = \{1,2\},\ i \neq l)$ through the retail prices Bj sets for roaming in country A as long as the roamer can substitute and the wholesale prices are reflected in Bj's retail prices). Notice that a network's wholesale demand is also its IOT agreement partner's retail demand.

Let $\Pi_{(A,B)}$ denote the market profit (i.e., the sum of all profits for all networks). The market profit can be expressed horizontally, where Π_A and Π_B are the sum of profits in country A and B respectively,

50 In Chapter (4), θ is used in modelling the steering game to represent home network's supply-side substitution.

$$\Pi_{(A,B)} = \overbrace{\sum_{i,j=1}^{2} \Pi_{Ai}^{Bj}}^{\Pi_A} + \overbrace{\sum_{i,j=1}^{2} \Pi_{Bj}^{Ai}}^{\Pi_B} = \overbrace{\Pi_{A1}^{B1} + \Pi_{A1}^{B2} + \Pi_{A2}^{B1} + \Pi_{A2}^{B2}}^{\Pi_A} + \overbrace{\Pi_{B1}^{A1} + \Pi_{B1}^{A2} + \Pi_{B2}^{A1} + \Pi_{B2}^{A2}}^{\Pi_B}.$$

Observe above that the summations for Π_{Ai}^{Bj} and Π_{Bj}^{Ai} have identical dimensions. Hence, $\Pi_{(A,B)}$ can also be expressed vertically as follows, where $\Pi_{(Ai,Bj)}$ is the sum of profits to the vertically related partners in the (Ai, Bj) IOT agreement.

$$\Pi_{(A,B)} = \sum_{i,j=1}^{2} \overbrace{\left(\Pi_{Ai}^{Bj} + \Pi_{Bj}^{Ai}\right)}^{\Pi_{(Ai,Bj)}} = \overbrace{\Pi_{A1}^{B1} + \Pi_{B1}^{A1}}^{\Pi_{(A1,B1)}} + \overbrace{\Pi_{A1}^{B2} + \Pi_{B2}^{A1}}^{\Pi_{(A1,B2)}} + \overbrace{\Pi_{A2}^{B1} + \Pi_{B1}^{A2}}^{\Pi_{(A2,B1)}} + \overbrace{\Pi_{A2}^{B2} + \Pi_{B2}^{A2}}^{\Pi_{(A2,B2)}}.$$

Along with the base model's assumptions, all the above payoffs result in symmetric price solutions. In other words, these profit functions do not reflect preferential wholesale agreements, which are deferred to Chapter (4).

3.2.4 Timing Of The Game

The game is played in two stages. In Stage I, networks set their wholesale prices simultaneously. In Stage II, networks set their retail prices simultaneously. The subgame perfect Nash equilibrium (SPNE) is solved by backward induction. The retail price solution of the second stage is a function of the wholesale price(s), which is substituted for to solve for first stage wholesale price equilibria. We call such a function the *retail price mapping function* (RPMF) following Carter and Wright (1994).

For the sake of simplifying notations, we solve for the situation $A1$'s subscriber roaming on $B1$'s network as governed by the $(A1, B1)$ IOT agreement. We show the retail price solution for network $A1$ and the wholesale price solution for $B1$, where all derivations are provided in Appendix (B). With symbiotic production, solutions apply similarly to any network.

3.2.5 Wholesale Pricing Strategies

We explore the profit maximizing strategies for wholesale price setting in the following four types:

i. International cartel strategy;
ii. National cartel strategy;
iii. Narrow vertical strategy; and
iv. Unilateral strategy.

As we shall see next, the maximization problems for the above strategies lead to symmetric wholesale prices for all networks. The unilateral strategy is a non-cooperative strategy, whereby a network sets its wholesale price to maximize its own profit. The other strategies are cooperative.

In the narrow vertical strategy, two vertically related networks set wholesale prices to maximize their (narrow) joint profit ignoring implications on other revenues from their other IOT agreements[51].

The national cartel strategy is whereby two domestic networks maximize their joint profit by fixing the wholesale price to a foreign network with which they have separate IOT agreements. The international cartel strategy is about all players joining a coalition to set the wholesale price between themselves in order to maximize the industry's profit.

3.2.6 Retail Pricing Policies

Retail prices are not part of any IOT agreement, and thus networks are not supposed to coordinate retail prices[52]. We consider uniform and discriminatory retail pricing policies which produce different retail price mapping functions (RPMFs) to solve wholesale price equilibria. To simplify the model, we assume all networks apply the same retail policy in each wholesale pricing strategy.

First, we assume the retail price is differentiated by visited networks (i.e. discriminatory policy). Then, we assume the retail price is uniform. Price equilibria are presented for each retail pricing policy. Equilibria and results of the uniform policy are similar to the ones found in Salsas and Koboldt (2004), Lupi and Manenti (2009), and Ambjørnsen, et al. (2011).

The demands under the uniform policy is given by Eq. (3.4), without the substitutability parameter. The problem here is that the relevant RPMF, once substituted into the demand equation to solve for wholesale prices, shows visited networks as perfect complements instead of substitutes. As a consequence, response functions are downward sloping due to perfect complementarity of visited networks.

51 Chapter (4) explores cross-ownership strategy, which is a wider wholesale strategy that maximizes the joint profit for the two vertically related networks and includes profit margins from their agreements with the other networks. Such strategy results in asymmetric wholesale price solutions.
52 Networks in an IOT agreement are licensed in two different countries and both offer retail services to two distinct groups of subscribers.

3.2.7 Stage II

Discriminatory Retail Policy

With discriminatory retail prices, each home network sets retail prices differentiated by visited networks. The demands are similar to Eq. (3.3). Consider the following home network $A1$'s retail maximization problem when its subscriber roams in country B

$$\max_{(p_{A1}^{B1},p_{A1}^{B2})} \Pi_{A1} = \left(p_{A1}^{B1} - w_{B1}^{A1}\right) q_{A1}^{B1}(p_{A1}^{B1},p_{A1}^{B2}) + w_{A1}^{B1}\, q_{B1}^{A1}\left(p_{B1}^{A1},p_{B1}^{A2}\right)$$
$$+ \left(p_{A1}^{B2} - w_{B2}^{A1}\right) q_{A1}^{B2}(p_{A1}^{B1},p_{A1}^{B2}) + w_{A1}^{B2}\, q_{B2}^{A1}\left(p_{B2}^{A1},p_{B2}^{A2}\right). \tag{3.5.0}$$

$A1$'s retail prices are inside its retail profits (the first and the third terms, where the demands are given by Eq. (3.3)). The RPMFs for roaming on both visited networks are derived by solving

$$\frac{\partial \Pi_{A1}}{\partial p_{A1}^{B1}} = \frac{\partial \Pi_{A1}}{\partial p_{A1}^{B2}} = 0,$$

simultaneously, yielding the following response functions

$$p_{A1}^{B1} = \frac{2\alpha + \beta(2+\gamma)w_{B1}^{A1} + \beta\gamma\left(2p_{A1}^{B2} - w_{B2}^{A1}\right)}{2\beta(2+\gamma)},$$

and

$$p_{A1}^{B2} = \frac{2\alpha + \beta(2+\gamma)w_{B2}^{A1} + \beta\gamma\left(2p_{A1}^{B1} - w_{B1}^{A1}\right)}{2\beta(2+\gamma)}. \tag{3.5.1}$$

By substituting symmetrically for p_{A1}^{B2} and p_{A1}^{B1} in each equation of (3.5.1), we get the following RPMFs

$$p_{A1}^{B1} = \frac{\alpha + \beta\, w_{B1}^{A1}}{2\beta},$$

and

$$p_{A1}^{B2} = \frac{\alpha + \beta\, w_{B2}^{A1}}{2\beta}. \tag{3.6}$$

The RPMFs given in Eq. (3.6) are the monopoly markups[53]. The RPMF is a markup only on the relevant wholesale price due to the following two effects.

Consider p_{A1}^{B2} in the last term of p_{A1}^{B1} response function in Eq. (3.5.1). Substitute p_{A1}^{B2} with its RPMF from Eq. (3.6). One can see the impact of w_{B2}^{A1} is removed by tightening the margin on

53 The RPMFs are similar to Eq. (6.15) in Shubik and Levitan (1980) if $\gamma = 0$, which is $p_i = (\alpha + \beta\, c)/2\beta$, where c is the actual marginal cost.

using $B2$'s network. This is the primary effect. The secondary effect is due to the positive sign of p_{A1}^{B2}. It means a higher price for using $B2$ allows $A1$ to charge a higher price for using $B1$. With the common α (the market size), the effect of substitutability between $A1$'s IOT agreements is removed from each RPMF.

Uniform Retail Policy

In the absence of steering[54] and with uniform retail, each home network is assumed to set identical retail prices for its subscriber when roaming in the visited country, resulting in identical demands. The demands are similar to Eq. (3.4).

Consider home network $A1$'s retail maximization problem when its subscriber roams in country B. The average wholesale price facing $A1$ is $\overline{w}_B^{A1} = (w_{B1}^{A1} + w_{B2}^{A1})/2$. The following retail maximization problem is for $A1$ when its subscriber roams in country B

$$\max_{(p_{A1})} \Pi_{A1} = 2\left(p_{A1} - \overline{w}_B^{A1}\right) q_{A1}(p_{A1}) + w_{A1}^{B1} q_{B1}(p_{B1}) + w_{A1}^{B2} q_{B2}(p_{B2}). \tag{3.7}$$

$A1$'s retail price is inside its retail profit (the first term, where the demands are given by Eq. (3.4)). The first order condition (FOC) must satisfy

$$\frac{\partial\, \Pi_{A1}}{\partial p_{A1}} = 0.$$

By solving for p_{A1}, the RPMF is given by

$$p_{A1} = \frac{\alpha + \beta \overline{w}_B^{A1}}{2\beta}. \tag{3.8}$$

Note importantly that, as compared to Eq. (3.6), p_{A1} depends on both w_{B1}^{A1} and w_{B2}^{A1}. It is also equivalent to Eq. (3.6) if wholesale prices are symmetric. By substituting the RPMF given by Eq. (3.8) to solve for wholesale prices, the demand for a visited network becomes

$$q_{A1} = \frac{1}{4}\left[\alpha - \beta \frac{\left(w_{B1}^{A1} + w_{B2}^{A1}\right)}{2}\right].$$

Clearly in q_{A1} above, wholesale prices have the same negative sign; making the visited networks appear as perfect complements, where the nature of the relationship of visited networks should be substitution. For example, to consume one minute of outgoing call, you only need to be roaming on one visited network; put differently, you do not need to combine half the minute from one network and the other half from the other network. The

54 Chapter (4) looks at a steering model with uniform retail price.

complementarity in this case is similar to the case of a monopoly's demand for inputs from two (perfect) complementary producers (i.e. Cournot complementary monopoly theory).

3.2.8 Stage I

The four wholesale pricing strategies are listed below. In each wholesale strategy, networks are assumed to set their (monopoly) retail prices independently according to the relevant RPMF of the retail policy (discriminatory or uniform).

In the following objective functions, the first order conditions (FOCs) are with respect to w_{B1}^{A1} (i.e. $B1$'s wholesale price to $A1$), where $A1$'s retail price is given by the RPMFs of Eq. (3.6) for the discriminatory policy and by the RPMF of Eq. (3.8) for the uniform policy.

3.2.8i International Cartel Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the international market profit given by

$$\max_{(w_{B1}^{A1},w_{B1}^{A2},w_{B2}^{A1},w_{B2}^{A2},w_{A1}^{B1},w_{A1}^{B2},w_{A2}^{B1},w_{A2}^{B2})} \Pi_{(A,B)} =$$

$$\begin{aligned} & p_{A1}^{B1}\ q_{A1}^{B1}(p_{A1}^{B1},p_{A1}^{B2}) + p_{A1}^{B2}\ q_{A1}^{B2}(p_{A1}^{B1},p_{A1}^{B2}) \\ & + p_{A2}^{B1}\ q_{A2}^{B1}(p_{A2}^{B1},p_{A2}^{B2}) + p_{A2}^{B2}\ q_{A2}^{B2}(p_{A2}^{B1},p_{A2}^{B2}) \\ & + p_{B1}^{A1}\ q_{B1}^{A1}\left(p_{B1}^{A1},p_{B1}^{A2}\right) + p_{B1}^{A2}\ q_{B1}^{A2}\left(p_{B1}^{A1},p_{B1}^{A2}\right) \\ & + p_{B2}^{A1}\ q_{B2}^{A1}\left(p_{B2}^{A1},p_{B2}^{A2}\right) + p_{B2}^{A2}\ q_{B2}^{A2}\left(p_{B2}^{A1},p_{B2}^{A2}\right). \end{aligned} \tag{3.9}$$

Eq. (3.9) shows the market profit equals the retail revenues of all networks as wholesale profits/costs cancel out. Note the relevant wholesale prices will be embedded in the relevant RPMFs.

Under Discriminatory Retail Policy

Using the demands as in Eq. (3.3), and substituting Eq. (3.6) in Eq. (3.9), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A,B)}}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the international cartel's best wholesale price is given by

$$w_{B1}^{A1} = \theta\ w_{B2}^{A1}\ , \tag{3.10}$$

where $\theta = \gamma/(2+\gamma)$. Since $\theta \in [0,1)$, the only symmetric wholesale equilibrium is when $\theta = 0$. Thus the equilibrium wholesale solution is

$$w^* = 0,$$

then from Eq. (3.6),

$$p^* = \frac{\alpha}{2\beta}. \tag{3.11}$$

With a wholesale price equals zero (the marginal cost), the retail price is at the monopoly level.

Under Uniform Retail Policy

Using the demands as in Eq. (3.4), and substituting Eq. (3.8) in Eq. (3.9), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A,B)}}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the international cartel's best wholesale price is given by

$$w_{B1}^{A1} = -w_{B2}^{A1}. \tag{3.12}$$

The only symmetric wholesale price solution is zero. Thus the equilibrium wholesale solution is

$$w^* = 0,$$

then from Eq. (3.8),

$$p^* = \frac{\alpha}{2\beta}. \tag{3.13}$$

The wholesale price equals zero (the marginal cost), and the retail price is at the monopoly level.

3.2.8ii National Cartel Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the national profit. The maximization problem for networks in country B is

$$\max_{(w_{B1}^{A1},w_{B1}^{A2},w_{B2}^{A1},w_{B2}^{A2})} \Pi_B =$$

$$\begin{aligned}
&\left(p_{B1}^{A1} - w_{A1}^{B1}\right) q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A1}\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) \\
&+\left(p_{B1}^{A2} - w_{A2}^{B1}\right) q_{B1}^{A2}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A2}\ q_{A2}^{B1}(p_{A2}^{B1}, p_{A2}^{B2}) \\
&+\left(p_{B2}^{A1} - w_{A1}^{B2}\right) q_{B2}^{A1}\left(p_{B2}^{A1}, p_{B2}^{A2}\right) + w_{B2}^{A1}\ q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2}) \\
&+\left(p_{B2}^{A2} - w_{A2}^{B2}\right) q_{B2}^{A2}\left(p_{B2}^{A1}, p_{B2}^{A2}\right) + w_{B2}^{A2}\ q_{A2}^{B2}(p_{A2}^{B1}, p_{A2}^{B2}).
\end{aligned}$$

(3.14)

Under Discriminatory Retail Policy

Using the demands as in Eq. (3.3), and substituting Eq. (3.6) in Eq. (3.14), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_B}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the national cartel's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\alpha}{\beta(2+\gamma)} + \theta\, w_{B2}^{A1},$$

(3.15)

where $\theta = \gamma/(2+\gamma)$. By substituting symmetrically for w_{B2}^{A1} in Eq. (3.15), then substituting for θ, we get

$$w^* = \frac{\alpha}{2\beta},$$

then from Eq. (3.6),

$$p^* = \frac{3\alpha}{4\beta}.$$

(3.16)

With a wholesale price at the monopoly level, the retail price reflects the double marginalization problem.

Under Uniform Retail Policy

Using the demands as in Eq. (3.4), and substituting Eq. (3.8) in Eq. (3.14), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_B}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the national cartel's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\alpha}{\beta} - w_{B2}^{A1}.$$

(3.17)

By substituting symmetrically for w_{B2}^{A1} in Eq. (3.17), the solution will be indeterminate. If we let $w_{B1}^{A1} = w_{B2}^{A1} = w^*$, the wholesale price solution will be the monopoly price, similar to the collusion case assumed in Salsas and Koboldt (2004) and Lupi and Manenti (2009).

Hence, the equilibrium wholesale price solution that maximizes the national market profit is

$$w^* = \frac{\alpha}{2\beta},$$

then from Eq. (3.8),

$$p^* = \frac{3\alpha}{4\beta}. \tag{3.18}$$

The wholesale price is fixed at the monopoly level resulting in a retail price with double marginalisation problem.

3.2.8iii Narrow Vertical Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the vertical profits of the two IOT partners within each separate IOT agreement. The maximization problem for the networks in the $(A1, B1)$ IOT agreement is

$$\max_{(w_{B1}^{A1}, w_{A1}^{B1})} \Pi_{(A1,B1)} = p_{A1}^{B1}\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + p_{B1}^{A1}\ q_{B1}^{A1}(p_{B1}^{A1}, p_{B1}^{A2}). \tag{3.19}$$

Eq. (3.19) is equivalent to the retail revenues of $A1$ and $B1$ as their wholesale profits/costs cancel out. It does not include their profits from their separate IOT agreements with $A2$ and $B2$[55].

Under Discriminatory Retail Policy

Using the demands as in Eq. (3.3), and substituting Eq. (3.6) in Eq. (3.19), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A1,B1)}}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the narrow vertical strategy's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\theta}{2}\left(w_{B2}^{A1} - \frac{\alpha}{\beta}\right), \tag{3.20}$$

where $\theta = \gamma/(2+\gamma)$. By substituting symmetrically for w_{B2}^{A1} in Eq. (3.20), we get

55 A wider vertical (cross-ownership) strategy that includes such cross profits is deferred to Chapter (4).

$$w^* = \frac{\alpha\,\theta}{\beta\,(\theta - 2)}\,,$$

then from Eq. (3.6),

$$p^* = \frac{2\alpha}{\beta(4+\gamma)}.$$

(3.21)

Since $\theta \in [0,1)$, w^* is negative if $\theta > 0$. The negative wholesale price reduces the retail price and effectively enhances the demand for the IOT partner. The retail price approaches zero (the marginal cost) as $\gamma \to \infty$.

Under Uniform Retail Policy

Using the demands as in Eq. (3.4), and substituting Eq. (3.8) in Eq. (3.19), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A1,B1)}}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the narrow vertical strategy's best wholesale price is given by

$$w_{B1}^{A1} = -\,w_{B2}^{A1}.$$

(3.22)

The only symmetric wholesale price solution is zero. Thus the equilibrium wholesale solution is

$$w^* = 0,$$

then from Eq. (3.8),

$$p^* = \frac{\alpha}{2\beta}.$$

(3.23)

The wholesale price equals zero (the marginal cost), and the retail price is at the monopoly level.

3.2.8iv Unilateral Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the own profit for each network. The maximization problem for $B1$ is

$$\max_{(w_{B1}^{A1}, w_{B1}^{A2})} \Pi_{B1} = \left(p_{B1}^{A1} - w_{A1}^{B1}\right) q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A1}\; q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})$$
$$+\left(p_{B1}^{A2} - w_{A2}^{B1}\right) q_{B1}^{A2}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A2}\; q_{A2}^{B1}(p_{A2}^{B1}, p_{A2}^{B2}).$$

(3.24)

Under Discriminatory Retail Policy

Using the demands as in Eq. (3.3), and substituting Eq. (3.6) in Eq. (3.24), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{B1}}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the unilateral strategy's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\alpha}{\beta(2+\gamma)} + \frac{\theta}{2} w_{B2}^{A1}, \tag{3.25}$$

where $\theta = \gamma/(2+\gamma)$. By substituting symmetrically for w_{B2}^{A1} in Eq. (3.25), then substituting for θ, we get

$$w^* = \frac{2\alpha}{\beta(4+\gamma)},$$

then from Eq. (3.6),

$$p^* = \frac{\alpha(6+\gamma)}{2\beta(4+\gamma)}. \tag{3.26}$$

The substitutability parameter γ reduces both prices. As $\gamma \to \infty$, the wholesale price approaches zero (the marginal cost) and the retail price approaches the monopoly price.

Under Uniform Retail Policy

Using the demands as in Eq. (3.4), and substituting Eq. (3.8) in Eq. (3.24), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{B1}}{\partial w_{B1}^{A1}} = 0.$$

By solving for w_{B1}^{A1}, the unilateral strategy's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\alpha}{\beta} - \frac{w_{B2}^{A1}}{2}. \tag{3.27}$$

By substituting symmetrically for w_{B2}^{A1} in Eq. (3.27), we get

$$w^* = \frac{2\,\alpha}{3\,\beta},$$

then from Eq. (3.8),

$$p^* = \frac{5\,\alpha}{6\,\beta}. \tag{3.28}$$

The price equilibria in Eq. (3.28) match the equilibria found in Salsas and Koboldt (2004) and Lupi and Manenti (2009). With wholesale price already above the monopoly level, the double marginalisation problem is prominent in the retail price.

3.3 Results

This section discusses the game results regarding the response functions, payoffs and welfare implications.

3.3.1 Response Functions

Under a given retail pricing policy, the response functions have the same sign with all wholesale strategies of the game. However, the response functions in the two retail pricing policies (discriminatory and uniform) have opposite signs. This leads to the following proposition.

Proposition (3.1). In all wholesale pricing strategies of the game, wholesale prices are strategic complements under the discriminatory retail policy, and strategic substitutes under the uniform retail policy.

Proof. The derivative with respect to the competitor's wholesale price is positive in the response functions under the discriminatory retail pricing policy given by Eq. (3.10), (3.15), (3.20), and (3.25); hence strategic complements. The derivative with respect to the competitor's wholesale price is negative in the response functions under the uniform retail pricing policy given by Eq. (3.12), (3.17), (3.22), and (3.27); hence strategic substitutes. ■

Visited networks are substitutes in nature, such that in a price game, the response functions should be upward sloping (i.e., positively related or strategic complements). This is the case under the discriminatory retail policy. On the other hand, when the response functions are downward sloping (i.e., negatively related or strategic substitutes) in a price game, we conclude that networks are made perfect complements. This is the case under the uniform retail policy, as visited networks carry the same negative sign in the demand.

Salsas and Koboldt (2004), Lupi and Manenti (2009), and Ambjørnsen, et al. (2011) all assume the roamer only cares about the average retail price, which in this case is similar to the uniform retail policy in our model. With uniform retail, the roamer is assumed to leave his handset on automatic mode; and given absence of steering, network selection becomes random. Random network selection is attributed by Ambjørnsen, et al. (2011) to be causing the wholesale pricing response functions to become strategic substitutes. Ambjørnsen, et al. (2011) argue that the response functions can be, instead, strategic complements if roamers manually select between networks, or if steering is effective by the home network.

Nevertheless, none of the aforementioned papers recognize that with uniform retail price, the nature of visited networks turns to complements, instead of substitutes. Competition, therefore, cannot be modelled between complementary networks.

Notice that with the national cartel wholesale strategy, Eq. (3.17) is downward sloping, but it would lead to indeterminate solution. Instead, we imposed a common wholesale price that led to a monopoly wholesale price, following the treatment made by Salsas and Koboldt (2004), and in Lupi and Manenti (2009).

3.3.2 Payoffs Comparison

All price equilibria of the game have a convenient expression in separating out α/β (the price when demand falls to zero) from a fraction of one (except for the wholesale solutions that equal zero). Let x^* and X^* represent standardised wholesale and retail prices respectively, as shown in the Table (3.1). Assume market parameters (α, β, γ) are symmetric for all networks.

Table (3.1) Standardised wholesale and retail prices under discriminatory and uniform retail policies.

Strategy	Discriminatory retail policy		Uniform retail policy	
	Wholesale	Retail	Wholesale	Retail
International cartel	$x^* = 0$	$X^* = \frac{1}{2}$	$x^* = 0$	$X^* = \frac{1}{2}$
National cartel	$x^* = \frac{1}{2}$	$X^* = \frac{3}{4}$	$x^* = \frac{1}{2}$	$X^* = \frac{3}{4}$
Narrow vertical	$x^* = \frac{\theta}{\theta - 2}$	$X^* = \frac{2}{4+\gamma}$	$x^* = 0$	$X^* = \frac{1}{2}$
Unilateral	$x^* = \frac{2}{4+\gamma}$	$X^* = \frac{6+\gamma}{2(4+\gamma)}$	$x^* = \frac{2}{3}$	$X^* = \frac{5}{6}$

$w^* = \frac{\alpha}{\beta}x^*$, $p^* = \frac{\alpha}{\beta}X^*$.
$\gamma \in [0, \infty)$.
$\theta = \gamma/(2+\gamma); \theta \in [0,1)$.

Based on Table (3.1), the relation ($x^* < X^* < 1$) holds for any value of γ under any strategy: x^* is less than X^* indicating wholesale price is not greater than retail price; and X^* is less than one reflecting positive demand. The equilibrium profit to network i (i is any network) from an IOT agreement is given by

$$\Pi_i^* = \overbrace{\frac{\alpha^2}{2\beta}\,(X^* - x^*)(1 - X^*)}^{Retail\ profit} + \overbrace{\frac{\alpha^2}{2\beta}\ x^*(1 - X^*)}^{Wholesale\ profit} = \overbrace{\frac{\alpha^2}{2\beta}\ X^*(1 - X^*)}^{Retail\ revenue}, \tag{3.29}$$

where x^* and X^* are standardised wholesale and retail prices respectively. Obviously, the equilibrium profit equals the retail revenue because, in equilibrium, the wholesale cost and wholesale profit cancel out. Since each network has two IOT agreements, each network will get $2\Pi_i^*$ in equilibrium.

Notice that $\alpha^2/(2\beta)$ in Eq. (3.29) equals the own market share, $\alpha/2$, times α/β (the price when demand falls to zero). Both of these are the intercepts of the $D - D'$ line in Figure (3.2). With ($0 < X^* < 1$), Π_i^* is a strictly concave function and symmetric around its maximum (i.e. ½, the monopoly price), as depicted in Figure (3.3).

Notice also that the limit exists for any X^* solution that involves γ, which means X^* is a rational function of γ; hence continuous at any value of γ (with negative derivatives with respect to γ). In addition, since changes in γ do not affect the market size α, the curve in Figure (3.3) is stable at any value of γ. Therefore, this curve can take all the X^* solutions in Table (3.1); where any X^* that is invariant with γ will be a fixed point on the curve, and any X^* that varies with γ will move on the curve to the left.

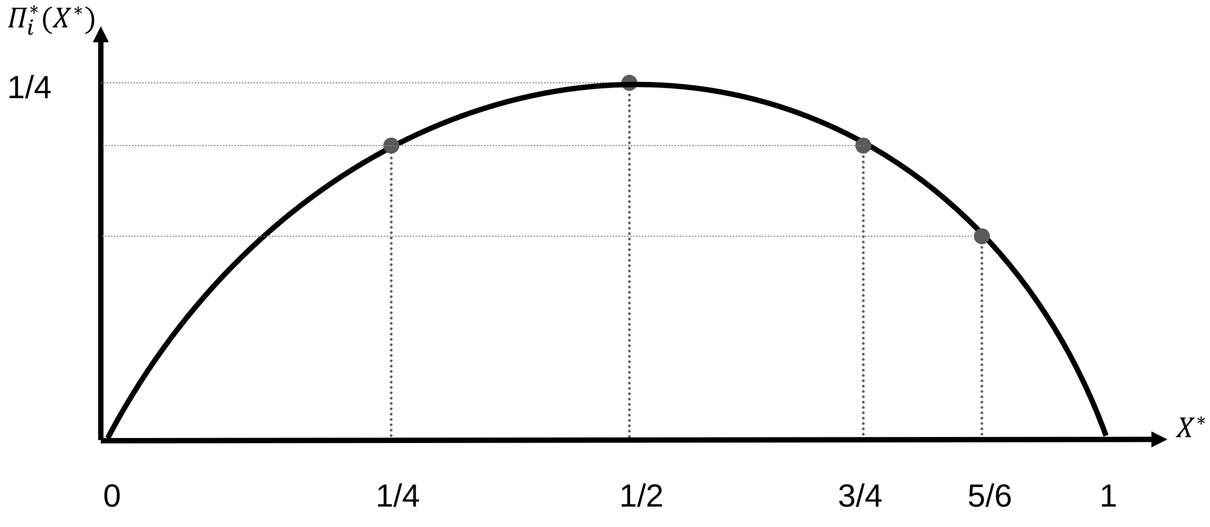

Figure (3.3) Equilibrium profit to network i in each IOT agreement.
- Networks are assumed symmetric, and the expression $\alpha^2/(2\beta)$ is normalized to one, which is responsible for the curve's height.

Therefore, payoffs can be easily compared under any strategy/policy in a comparative static analysis that varies the substitutability parameter γ (or its index θ), which are highlighted in the following remarks.

Remark (3.1). Assume symmetric demand parameters and the equilibrium profit to a network from an IOT agreement is given by Eq. (3.29), with price equilibria given by Table (3.1). Therefore

i. Under the uniform retail policy, all profits are invariant with the substitutability index θ. The international cartel and narrow vertical strategies yield the monopoly profit. The national cartel strategy yields a higher profit than the unilateral strategy, but is lower than the monopoly level.

ii. Under the discriminatory retail policy, the international cartel strategy yields the monopoly profit that is invariant with the substitutability index θ. The national cartel strategy yields a lower profit that is also invariant with θ. When $\theta = 0$, the narrow vertical strategy yields the monopoly profit, while the unilateral strategy yields a profit equivalent to the national cartel strategy. As θ rises, the profit of the unilateral strategy approaches the monopoly level while the profit of the narrow vertical strategy approaches zero.

Proof. By Eq. (3.29), the equilibrium profit to network i from an IOT agreement is $\Pi_i^* = X^*\,(1 - X^*)$, with $\alpha^2/(2\beta)$ normalized to one since it is identical to all networks. From Table (3.1), and given $(0 < X^* < 1)$, the monopoly retail price is ½, and the monopoly profit is ¼, where all net payments are zero. If two X^* solutions under two different strategies add up to one, the payoffs from both strategies will be equal. With the uniform retail policy, there is no effect of γ (or its index θ). The international cartel and narrow vertical strategies yield the monopoly profit since they charge the monopoly retail price. Retail price is higher with the unilateral strategy compared to the national strategy; hence the national cartel strategy yields a higher profit compared to the unilateral strategy ($3/16$ compared to $5/36$), where both profits are less than the monopoly profit. Under the discriminatory retail policy, the international cartel strategy yields the monopoly profit because it charges the monopoly retail price, and the national profit yields a lower profit ($3/16$), where the payoffs from these two strategies are invariant to θ. When $\theta = 0$ (or $\gamma = 0$), the narrow vertical strategy yields the monopoly profit, while the national cartel strategy yields a profit equivalent to the unilateral strategy. As θ rises (or $\gamma > 0$), X^* approaches zero under the narrow vertical strategy leading to zero profit; while X^* approaches the monopoly price under the unilateral strategy leading to the monopoly profit. The profits of the narrow vertical and the unilateral strategies are equal at $\theta^* = 1/2$ (or $\gamma^* = 2$), since X^* in both strategies add up to one. ■

3.3.3 Welfare Implications

We calculate the unweighted total surplus for a country as a proxy for the social welfare under the strategies analysed in this chapter. Take as an example country A which has two networks $A1$ and $A2$ retailing the service for their subscribers who visit country B, and at the same time hosting roamers from country B. The consumer surplus in country A is given by

$$CS_A = U_{A1} + U_{A2}\ , \tag{3.30}$$

where the utility is as given by Eq. (3.1). Denote equilibrium utility for each network's subscriber in country A by U_{Ai}^* $(i = 1{,}2)$. Let us use X^* as in Section (3.3.2) to represent the standardised price under any strategy. The consumer surplus in country A is given by

$$CS_A^* = 2\ U_{Ai}^* = \frac{\alpha^2}{\beta}\ (1 - X^*)^2. \tag{3.31}$$

Notice the derivative of Eq. (3.31) with respect to X^* is negative, which shows that price reduces consumer surplus.

On the other hand, each network has two IOT agreements with the networks in country B. Thus the producer surplus in country A is given by

$$PS_A = \Pi_{A1}^{B1} + \Pi_{A1}^{B2} + \Pi_{A2}^{B1} + \Pi_{A2}^{B2}. \tag{3.32}$$

Let Π_{Ai}^* be the equilibrium profit from an IOT agreement to any network in country A $(i = 1{,}2)$, similar to Eq. (3.29). Therefore, we have

$$PS_A^* = 4\ \Pi_{Ai}^* = 2\ \frac{\alpha^2}{\beta}\ X^*\ (1 - X^*). \tag{3.33}$$

Adding Eq. (3.31) to (3.33), the total surplus for country A is given by

$$TS_A^* = CS_A^* + PS_A^* = \frac{\alpha^2}{\beta}\ (1 - X^{*2}). \tag{3.34}$$

As with the consumer surplus in Eq. (3.31), the total surplus in Eq. (3.34) is unambiguously reduced by the standardised retail price, X^*, where $(0 < X^* < 1)$. Price therefore is a sufficient statistics to identify consumer and total surpluses. Any reduction in wholesale price enhances consumer and total surpluses as long as this would reduce the retail price.

World surplus can be the sum of both countries' total surpluses. However, as Valletti (2004) puts it, national regulators may have distorted incentives towards regulation as each is concerned with the surplus of its own consumers and own networks.

3.4 Discussion

The base model in this chapter aims at modelling pricing behaviours of mobile networks in IOT agreements, comparing equilibria of four different wholesale pricing strategies under two retail pricing policies (discriminatory and uniform). The model uses a demand system which makes the substitutability parameter independent of market size. This substitutability parameter is interpreted in terms of overlapping coverages, in which the roamer can substitute between visited networks. The substitutability parameter is allowed to vary for comparative static analyses.

Under the discriminatory retail policy, all response functions are upward sloping; hence strategic complements. There are two effects on prices: double markups and Bertrand competition. The unilateral retail price lies between the retail prices of the two cartel strategies (national and international). When γ is zero, the relevant wholesale prices for the unilateral and national cartel strategies are the same and thus their retail prices are equivalent. This is the double-markup effect on the retail price. As γ rises, the unilateral wholesale price reduces, approaching the marginal cost, driving the retail price towards the monopoly price (which is also the retail price under the international cartel strategy). This effect is due to wholesale Bertrand competition.

On the other side, the narrow vertical strategy has the Bertrand competition effect only. When γ is zero, the wholesale price equals marginal cost; but as γ rises, the wholesale price becomes negative, dragging down the retail price towards marginal cost to enhance the demand for the IOT partner. Intuitively, mutual wholesale price subsidy is necessary to bring down the retail price.

On the contrary, under the uniform retail policy, the relevant response functions are downward sloping; hence strategic substitutes. The wholesale price equals the marginal cost under the international cartel and the narrow vertical strategies, and is above marginal cost under both the unilateral and the national cartel strategies. Notice the national cartel (cooperative) wholesale price is lower than the unilateral (non-cooperative) price. Because visited networks appear in the demand as perfect complements rather than substitutes, the higher the number of visited networks, the higher is the wholesale price to the home network. Those perfect complementary visited networks can overcome the effect of their horizontal separation problem by charging the monopoly price and share the monopoly profit.

Payoffs under a wholesale pricing strategy may differ depending on the retail pricing policy being used. The retail price does not go below the monopoly level, except for the narrow vertical strategy due to the negative wholesale price if $\gamma > 0$. While γ impacts equilibria under the discriminatory retail policy, it has no impact on the uniform retail policy because it is removed from the demands. All equilibria can be compared on the same curve of Figure (3.3) for any value of γ. When γ is zero, the position of X^* is either on the right side of the monopoly price (i.e. the double markups area), or at the monopoly price. As γ rises, only equilibrium prices of the narrow vertical and unilateral strategies under the discriminatory retail policy move on the curve towards the left. Changes in γ allow us to compare the Pareto optimality of strategies. For instance, a shift in strategy from narrow vertical to unilateral strategy will involve an increase in both wholesale and retail prices. Price increases are noticed in Europe (EC, 2000).

In addition to the comparative static implications, the model shows that a price reduction under any strategy will always enhance both domestic and global unweighted welfares. However, due to the cross-border nature of the service, price regulation requires the cooperation of relevant regulators to jointly control wholesale and retail prices (Hoernig and Valletti, 2012), as in the case of the EC roaming regulation in 2007.

The base model can be extended to oligopoly markets by replacing the own market size ($\alpha/2$) in the profit function of Eq. (3.29) by (α/n), where n is the number of visited networks in each country. This follows from the extension of the demands in Shubik and Levitan (1980). The equilibrium profit from each IOT agreement would reduce by n. Nonetheless, if the equilibrium profit equals the retail revenue and if each network holds monopoly position downstream, the total retail revenues to each network will be unchanged.

The base model compared equilibria under the discriminatory and uniform retail pricing policies. The substitutability parameter is found to place a downward pressure on prices under the discriminatory retail policy. In contrast, it has no impact on equilibria under the uniform retail policy. Equilibria under the uniform retail policy without steering in this chapter are similar to the ones found in the existing literature, which obviously produce equilibria that are inconsistent with wholesale price competition.

The base model does not address asymmetric wholesale price solutions that may arise from preferential IOT agreements. Chapter (4) extends the base model by addressing preferential IOT agreements between cross-owned networks, and between roaming alliance networks. Prior to roaming alliance game, an investment decision in steering technology is played by home networks. Steering is assumed to be effective only if the roamer is in overlapping coverage areas and the retail price is uniform such that the roamer's handset is put on automatic mode[56]. The home network that acquired steering technology can execute steering (i.e. as a supply-substitution) between visited networks, seeking efficiency gains.

56 The existing literature assumes lack of retail price information about visited networks, but the roamer knows the average retail price he pays to his home network; and thus intuitively, the roamer needs not to manually select between visited networks (i.e. leave handset on automatic mode).

Chapter (4). Preferential Wholesale Agreements

In the base model of Chapter (3), all wholesale price equilibria from the Inter-Operator Tariffs (IOT) agreements are symmetric. Symmetry of wholesale prices is a result of assuming symmetric actual marginal costs with all networks. It is also a result of assuming compliance in the cooperative strategies (international cartel, national cartel, and narrow vertical) that perused identical maximization problems in each strategy, without involvement in preferential agreements.

This chapter explores preferential IOT agreements that lead to asymmetry in wholesale prices, in line with the theoretical papers surveyed in Section (2.3), which will be referred to accordingly in this chapter. Similar to this literature, the focus of this chapter is on two wholesale pricing strategies that involve preferential IOT agreements: cross-ownership in Section (4.1); and roaming alliance in Section (4.2). The intuitions from these preferential agreements are discussed in Section (4.3).

4.1 Cross-Ownership Model

Mobile network operators may involve in merger and acquisition across the borders of their NRAs' jurisdictions. Some cross-owned networks may carry the name of the parent company (e.g. Etisalat-UAE and its subsidiary Etisalat-Egypt); or may operate under a different brand (e.g. Etisalat-UAE and its subsidiary Mobily in Saudi Arabia). The first case is typically a merger or a branch of the parent company; and the second is typically shares acquired by the company(s). There are many mobile network operators that engage in cross-border merger/acquisition with existing foreign networks or acquire a license to compete with the existing networks, for example, AT&T, Vodafone, Orange, Zain, and MTN.

Cross-border merger/acquisition is a vertically related cross-ownership, since the engaged networks are licensed by different NRAs to operate in different markets, and terminate cross-border traffics. Nonetheless, foreign merger/acquisition may need to be notified to the authority in charge of merger regulation, which approval decision is normally based on whether or not the merger/acquisition raises competition concerns in the local market.

In this section, we assume a game whereby the engaged (foreign) networks choose the wholesale prices under preferential IOT agreements. Similar to the base model, retail prices are being set independently. The game is a wider vertical strategy, which is an extension of the narrow vertical strategy presented in Section (3.2.8iii) of the base model, for it includes the partners' profit margins from their separate IOT agreements with outsiders.

Salsas and Koboldt (2004) address a vertical merger (or cross-ownership) by one pair of networks assuming uniform retail pricing constraint and retail competition without steering investment. They found merger is unprofitable in this case because the consumer is unaware of prices. If the consumer is fully informed, he will subscribe to the merged entity at home and will choose its subsidiary (manually) in the visited country; hence, merger is profitable in this case, especially with more intense retail competition.

Lupi and Manenti (2009) also consider a similar model to Salsas and Koboldt (2004), but ignored retail competition. They found non-cooperation is the equilibrium (i.e., a prisoner's dilemma case), because the non-cooperating pair can charge a higher price without loosing market share.

In light of these two papers, we follow the uniform retail pricing constraint and compare its results to the case without such constraint. In other words, we compare equilibria under the uniform retail policy to equilibria under discriminatory retail policy. First, the backgrounds of the discriminatory and uniform retail policies are explained. Then, the game is detailed for each policy, where results are compared in the concluding remarks.

4.1.1 Model Background

Similar to the base model in Chapter (3), there are two networks in country A ($A1$ and $A2$); and two networks in country B ($B1$ and $B2$). Each network signs an IOT agreement with each foreign network. Each network is assumed to be a monopolist at the retail level and a duopolist at the wholesale level. Networks are assumed to have symmetric constant marginal costs normalized to zero and no fixed costs. Retail and wholesale prices are assumed to be linear[57].

We use Shubik and Levitan (1980) demand for a visited network given by

$$q_i = \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_i + \frac{\beta\gamma}{2}p_j\right], \qquad (i, j = 1,2), \qquad (i \neq j).$$

If the prices are uniform (i.e. $p_i = p_j = p$), the demands will be symmetric

57 Roaming packages (or bundles) applicable on preferred networks may unnecessarily complicate the model.

$$q_1 = q_1 = q = \frac{1}{2}\ [\alpha - \beta p].$$

All networks are assumed to have symmetric demand parameters (α, β, γ), with $\alpha, \beta > 0$ and with the substitutability parameter $\gamma \geq 0$.

The pricing game is played in two stages. In Stage I, networks decide between vertical cross-ownership and unilateral strategies for their simultaneous setting of wholesale prices. In Stage II, networks set their independent retail prices simultaneously. The subgame perfect Nash equilibrium (SPNE) is solved by backward induction. As in the existing literature, the focus of the game is on whether or not there exists an individual incentive for cross-ownership within the framework of our pricing game.

We assume the NRA in each country does not approve a cross-ownership that involves both its licensed networks and a foreign network, due to competition concerns. Thus, in our case, each network decides to join at most one cross-ownership; in other words, there can be at most two cross-ownership pairs.

The choice on a cross-ownership partner does not matter given networks are symmetric; in other words, asymmetry in demand parameters may result in a preferred cross-ownership partner. Given the vertical relationship and the two-way wholesale charging, we assume cross-ownership once chosen is internally enforceable.

In line with the base model in Chapter (3), the subscript will refer to the network in question and the superscript for its IOT partner. For the sake of simplifying notations, we show the solutions for the case $A1$ and $B1$ engage in cross-ownership, while the other pair ($A2$ and $B2$) either plays non-cooperatively or engages in a counter cross-ownership. The game is detailed for discriminatory and uniform retail pricing policies respectively.

4.1.2 Discriminatory Retail Policy

Assume all networks apply discriminatory retail prices. $A1$ sets its retail price(s) to maximize its total profits from its two IOT agreements

$$\max_{(p_{A1}^{B1}, p_{A1}^{B2})} \Pi_{A1} = \left(p_{A1}^{B1} - w_{B1}^{A1}\right) q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + w_{A1}^{B1}\, q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right)$$
$$+\left(p_{A1}^{B2} - w_{B2}^{A1}\right) q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2}) + w_{A1}^{B2}\, q_{B2}^{A1}\left(p_{B2}^{A1}, p_{B2}^{A2}\right). \quad (4.1)$$

As in the base model, $A1$'s discriminatory retail price mapping functions (RPMFs) are given by[58]

$$p_{A1}^{B1} = \frac{\alpha + \beta\, w_{B1}^{A1}}{2\beta},$$

and

$$p_{A1}^{B2} = \frac{\alpha + \beta\, w_{B2}^{A1}}{2\beta}. \tag{4.2}$$

The joint profit for the cross-ownership ($A1 + B1$) is given by

$$\begin{aligned}\Pi_{(A1+B1)} = {}& p_{A1}^{B1}\; q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + \left(p_{A1}^{B2} - w_{B2}^{A1}\right) q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2}) + w_{A1}^{B2}\; q_{B2}^{A1}\left(p_{B2}^{A1}, p_{B2}^{A2}\right) \\ & + p_{B1}^{A1}\; q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + \left(p_{B1}^{A2} - w_{A2}^{B1}\right) q_{B1}^{A2}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A2}\; q_{A2}^{B1}(p_{A2}^{B1}, p_{A2}^{B2}).\end{aligned} \tag{4.3}$$

The first order conditions (FOCs) for Eq. (4.3) with respect to the wholesale prices charged between $A1$ and $B1$ (the insiders) are given by

$$\frac{\partial \Pi_{(A1+B1)}}{\partial w_{B1}^{A1}} = \frac{\partial \Pi_{(A1+B1)}}{\partial w_{A1}^{B1}} = 0,$$

where w_{B1}^{A1} and w_{A1}^{B1} are embedded in p_{A1}^{B1} and p_{B1}^{A1} RPMFs respectively. Showing the solution for w_{B1}^{A1}, we have

$$\frac{\partial \Pi_{(A1+B1)}}{\partial w_{B1}^{A1}} = \frac{\partial p_{A1}^{B1}}{\partial w_{B1}^{A1}}\; q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + p_{A1}^{B1} \left[\frac{\partial\, q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] + (p_{A1}^{B2} - w_{B2}^{A1}) \left[\frac{\partial\, q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow p_{A1}^{B1} = \frac{\alpha}{\beta(2+\gamma)} + \theta\, p_{A1}^{B2} - \frac{\theta}{2}\, w_{B2}^{A1}, \tag{4.4}$$

where $\theta = \gamma/(2+\gamma)$. By further substituting Eqs. (4.2) in Eq. (4.4) and solving for w_{B1}^{A1}, we have

$$w_{B1}^{A1} = 0,$$

then from Eq. (4.2), we get the retail price solution

$$p_{A1}^{B1} = \frac{\alpha}{2\beta}, \tag{4.5}$$

which is the monopoly price.

The wholesale price charged between the insiders equals (the actual) marginal cost, regardless of the wholesale response function of the outsiders ($A2$ or $B2$), leading to the monopoly retail price for roaming on the insider's network.

58 Similar to the base model, the second order condition is negative in all retail (discriminatory or uniform) and wholesale maximization problems.

The insiders' FOCs for Eq. (4.3) with respect to their wholesale prices to the outsiders are

$$\frac{\partial \Pi_{(A1+B1)}}{\partial w_{B1}^{A2}} = \frac{\partial \Pi_{(A1+B1)}}{\partial w_{A1}^{B2}} = 0.$$

Showing the solution for w_{B1}^{A2}, $B1$'s response function is given by

$$\rightarrow w_{B1}^{A2} = \frac{\alpha}{\beta(2+\gamma)} + \frac{\theta}{2}\, w_{B2}^{A2}\,, \tag{4.6}$$

which is the baseline unilateral response function.

Eq. (4.5) and (4.6) will have different implications on price solutions depending on whether or not the pair $(A2, B2)$ engage in a counter cross-ownership.

Lemma (4.1). With discriminatory retail policy of the model, if only one cross-ownership pair exists and if $\gamma > 0$, *each of its members will receive independently a net payment from the outsiders.*

Proof. Consider the case only $A1$ and $B1$ engage in a cross-ownership. The insiders $A1$ and $B1$ will set the internal wholesale price at marginal cost as per Eq. (4.5), and will use the unilateral response function of Eq. (4.6) in choosing the wholesale prices to the outsiders ($A2$ and $B2$). Since they do not engage in cross-ownership, $A2$ and $B2$ each uses a unilateral response function similar to Eq. (4.6), by which they charge each other $2\alpha/[\beta(4+\gamma)]$ (i.e. the baseline unilateral wholesale price), and each charges $\alpha/[\beta(2+\gamma)]$ to the cross-ownership members. In return, $A2$ and $B2$ will be charged the unilateral wholesale price. The (retail) demands facing an outsider are evaluated at the unilateral retail price $\alpha(6+\gamma)/[2\beta(4+\gamma)]$. For example, $A2$'s demand for Bj ($j = 1,2$) is $q_{A2}^{Bj} = \alpha(2+\gamma)/[4(4+\gamma)]$. By contrast, the demands facing an insider are asymmetric because the insider charges different retail prices: the monopoly price $\alpha/(2\beta)$ to use the insider's network and $\alpha(3+\gamma)/[2\beta(2+\gamma)]$ to use the outsider's network. For example, $B1$'s demand for $A1$ is $q_{B1}^{A1} = \alpha(4+3\gamma)/[8(2+\gamma)]$, while for $A2$, it is $q_{B1}^{A2} = \alpha/8$. The net payment between the insiders is zero; and the net payment between the outsiders is also zero, because the relevant IOT partners set identical wholesale prices and have identical demands. However, if $\gamma > 0$, the net payment between an outsider and an insider is non-zero: the outsider is a net payee to the insider because the outsider charges a lower wholesale price (e.g. $w_{A2}^{B1} < w_{B1}^{A2}$) and has a higher demand (e.g. $q_{A2}^{B1} > q_{B1}^{A2}$). ■

Lemma (4.1) shows asymmetry of prices and demands if one cross-ownership pair exists. For example, the net payment for $A2$ from its IOT agreement with $B1$ is

$$net_{A2}^{B1} = \overbrace{\frac{\alpha}{\beta(2+\gamma)}}^{w_{A2}^{B1}} \overbrace{\frac{\alpha}{8}}^{q_{B1}^{A2}} - \overbrace{\frac{2\alpha}{\beta(4+\gamma)}}^{w_{B1}^{A2}} \overbrace{\frac{\alpha(2+\gamma)}{4(4+\gamma)}}^{q_{A2}^{B1}} = -\frac{\theta(8+3\gamma)\alpha^2}{8\beta(4+\gamma)^2} \leq 0,$$

where $\theta = \gamma/(2+\gamma)$.

Given discriminatory retail policy, the retail price for roaming on the insider's network equals the monopoly price, $\alpha/(2\beta)$, which is lower than $\alpha\,(3+\gamma)/[2\beta(2+\gamma)]$ (the price for roaming on the outsider's network). As a consequence, the demands are asymmetric favouring the insider's network. On the other side, as the outsider is being charged identical unilateral wholesale prices, it will set the unilateral retail price (i.e. $\alpha\,(6+\gamma)/[2\beta(4+\gamma)]$) for the use of either visited network, resulting in equal demands. Each outsider has a higher demand for the insider than vice versa, where the former charges a lower wholesale price than the later. The result is a net payment from the outsider to the insider as long as networks are imperfect substitutes (i.e., $\gamma > 0$).

Lemma (4.2). With discriminatory retail policy of the model, if two cross-ownership pairs exist, net payments are zero.

Proof. Consider the case of two cross-ownership pairs, for example $(A1 + B1)$ and $(A2 + B2)$. In each pair, the insiders will set the internal wholesale price at marginal cost as in Eq. (4.5); and, with the unilateral response function of Eq. (4.6), they will set $\alpha/[\beta(2+\gamma)]$ as the wholesale price to the outsiders. In each IOT agreement, wholesale prices are identical; and demands are identical too (i.e. $\alpha\,(4+3\gamma)/[8(2+\gamma)]$ for the insider, and $\alpha/8$ for the outsider). Therefore, net payments are zero. ■

Lemma (4.2) shows asymmetry in wholesale prices, but with zero net payments because networks engage in two counter cross-ownership pairs. Notice that if $\gamma > 0$, by moving from the case in Lemma (4.1) to the case in Lemma (4.2), the wholesale price charged by $A1$ and $B1$ to outsiders decreases (from $2\alpha/[\beta(4+\gamma)]$ to $\alpha/[\beta(2+\gamma)]$) and the retail price of $A2$ and $B2$ for roaming on $B1$ and $A1$ respectively decreases (from $\alpha\,(6+\gamma)/[2\beta(4+\gamma)]$to $\alpha\,(3+\gamma)/[2\beta(2+\gamma)]$). Lemma (4.1) and (4.2) lead to the following proposition.

Proposition (4.1). With discriminatory retail policy of the model, if $\gamma > 0$, joining a cross-ownership pair is a dominant strategy to each network.

Proof. Let Π^N represent the baseline unilateral profit to a network from its both IOT agreements when no cross-ownership takes place in the market, all networks set wholesale prices unilaterally, and net payments are zero; where $\Pi^N = (2+\gamma)(6+\gamma)\alpha^2/[4\beta(4+\gamma)^2]$. From Lemma (4.1), the insider, for example $B1$, can improve upon its unilateral profit to reach the cross-ownership profit $\Pi^I = (7+4\gamma)\alpha^2/[16\beta(2+\gamma)]$ plus the net payment with $A2$ given by $net = \theta(8+3\gamma)\alpha^2/[8\beta(4+\gamma)^2]$. By contrast, the outsider's unilateral profit is reduced by this net payment only if $\gamma > 0$. From Lemma (4.2), each network gets Π^I and net payments are zero. Therefore, joining cross-ownership is a dominant strategy to each network. ■

The following example demonstrates the dominant strategy as predicted by Proposition (4.1). Let ($A1 + B1$) be a possible cross-ownership pair and ($A2 + B2$) be a possible counter pair. Consider the decision in joining different pairs by $B1$ and $A2$. Assume $\gamma > 0$. As given in the proof of Proposition (4.1), let Π^N, Π^I and net respectively represent the unilateral profit, the cross-ownership profit and the net payment to these two IOT partners, where $\Pi^N < \Pi^I + net$, and Π^I and Π^N can be equal depending on γ values. Table (4.1) shows the payoffs matrix.

Table (4.1) Payoffs matrix for joining a cross-ownership pair under the discriminatory retail policy.

Possible cross-ownership pairs: $(A1+B1); (A2+B2)$		$B1$: Join $(A1+B1)$	$B1$: Don't join
$A2$	Join $(A2+B2)$	$\boldsymbol{\Pi^I, \Pi^I}$	$\Pi^I + net, \Pi^N - net$
$A2$	Don't join	$\Pi^N - net, \Pi^I + net$	Π^N, Π^N

$\Pi^N < \Pi^I + net.$

As can be seen from Table (4.1), the game has a unique equilibrium, which is joining a cross-ownership pair. The non-zero net payment is behind the individual incentive to join a cross-ownership. If one cross-ownership exists, its members can improve their payoffs beyond the unilateral profit, but reduce the unilateral profits of the outsiders by the net payments.

The question of Pareto efficiency of the game depends on γ values, where $\gamma \geq 0$. But there exists a critical γ, which is $\gamma^* = 9.67$, at which $\Pi^I = \Pi^N$; below which, $\Pi^I > \Pi^N$; and above which, $\Pi^I < \Pi^N$. In the limit of γ, Π^I and Π^Nequal the monopoly profit, $\alpha^2/(4\beta)$. At γ^*, the substitutability index given by $\theta = \gamma/(2+\gamma)$ equals $\theta^* = 0.828$. Therefore, the equilibrium of the cross-ownership game is Pareto efficient when substitutability is not very high. As substitutability rises, the profit from the outsider decreases while the profit from the insider increases. In contrast, the baseline unilateral profit rises with substitutability, overcoming the cross-ownership profit when substitutability is too high.

4.1.3 Uniform Retail Policy

Assume all networks apply uniform retail prices without investing in steering technologies. Here, the substitutability parameter is removed from the demands. $A1$ sets its uniform retail price to maximize its total profits from its two IOT agreements

$$\max_{(p_{A1})} \Pi_{A1} = 2\left(p_{A1} - \overline{w}_B^{A1}\right) q_{A1}(p_{A1}) + w_{A1}^{B1} q_{B1}(p_{B1}) + w_{A1}^{B2} q_{B2}(p_{B2}), \tag{4.7}$$

where $q_{A1} = q_{A1}^{B1} = q_{A1}^{B2}$, and $\overline{w}_B^{A1} = \frac{w_{B1}^{A1} + w_{B2}^{A1}}{2}$.

$A1$'s uniform RPMF is given by

$$p_{A1} = \frac{\alpha + \beta \overline{w}_B^{A1}}{2\beta}. \tag{4.8}$$

Rewriting Eq. (4.3) for the uniform retail policy, the joint profit for the cross-ownership ($A1 + B1$) is given by

$$\Pi_{(A1+B1)} = \left(2p_{A1} - w_{B2}^{A1}\right) q_{A1}(p_{A1}) + w_{A1}^{B2}\, q_{B2}(p_{B2}) + (2p_{B1} - w_{A2}^{B1})\, q_{B1}(p_{B1}) + w_{B1}^{A2}\; q_{A2}(p_{A2}). \tag{4.9}$$

The FOCs for Eq. (4.9) with respect to the wholesale prices charged between the insiders are given by

$$\frac{\partial \Pi_{(A1+B1)}}{\partial w_{B1}^{A1}} = \frac{\partial \Pi_{(A1+B1)}}{\partial w_{A1}^{B1}} = 0,$$

where w_{B1}^{A1} and w_{A1}^{B1} are embedded in p_{A1} and p_{B2}RPMFs respectively. Showing the solution for w_{B1}^{A1}, we have

$$\frac{\partial \Pi_{(A1+B1)}}{\partial w_{B1}^{A1}} = 2\frac{\partial p_{A1}}{\partial w_{B1}^{A1}} q_{A1}\left(p_{A1}\right) + \left(2p_{A1} - w_{B2}^{A1}\right)\left[\frac{\partial q_{A1}\left(p_{A1}\right)}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow p_{A1} = \frac{2\alpha + \beta w_{B2}^{A1}}{4\beta}. \tag{4.10}$$

By further substituting Eq. (4.8) in Eq. (4.10) and solving for w_{B1}^{A1}, we have

$$w_{B1}^{A1} = 0. \tag{4.11}$$

The wholesale price charged between the insiders equals (the actual) marginal cost, regardless of the wholesale response function of the outsiders ($A2$ or $B2$).

The insider's FOCs for Eq. (4.9) with respect to their wholesale prices to the outsiders are

$$\frac{\partial \Pi_{(A1+B1)}}{\partial w_{B1}^{A2}} = \frac{\partial \Pi_{(A1+B1)}}{\partial w_{A1}^{B2}} = 0.$$

Showing the solution for w_{B1}^{A2}, $B1$'s response function is given by

$$w_{B1}^{A2} = \frac{\alpha}{\beta} - \frac{w_{B2}^{A2}}{2}, \tag{4.12}$$

which is the baseline unilateral response function.

Eq. (4.11) and (4.12) will have different implications on price solutions depending on whether or not the pair $(A2, B2)$ engage in a counter cross-ownership.

Lemma (4.3). With uniform retail policy of the model, if only one cross-ownership pair exists, each of its members will pay independently a net payment to the outsiders.

Proof. Consider the case only $A1$ and $B1$ engage in a cross-ownership. The insiders $A1$ and $B1$ will set the internal wholesale price at marginal cost as per Eq. (4.11), and will use the unilateral response function of Eq. (4.12) in their wholesale price setting to the outsiders ($A2$ and $B2$). Since they do not engage in cross-ownership, $A2$ and $B2$ each uses a unilateral response function similar Eq. (4.12), by which they charge each other $2\alpha/[3\beta]$ (i.e. the unilateral wholesale price), but each charges α/β to the cross-ownership members. In return, $A2$ and $B2$ will be charged the unilateral wholesale price. The (retail) demands facing an outsider are evaluated at the unilateral retail price $5\alpha/[6\beta]$. For example, $A2$'s demand for Bj $(j = 1,2)$ is $q_{A2}^{Bj} = \alpha/12$. By contrast, the demands facing an insider are evaluated at the retail price $3\alpha/[4\beta]$. For example, $B1$'s demand for Ai $(i = 1,2)$ is $q_{B1}^{Ai} = \alpha/8$. The net payment between the insiders is zero; and the net payment between the outsiders is also zero, because the relevant IOT partners set identical wholesale prices and have identical demands. However, the net payment between an outsider and an insider is non-zero: the insider is a net payee to the outsider because the insider charges a lower wholesale price (e.g. $w_{B1}^{A2} < w_{A2}^{B1}$) and has a higher demand (e.g. $q_{B1}^{A2} > q_{A2}^{B1}$). ■

Lemma (4.3) shows asymmetry of wholesale prices and demands if one cross-ownership pair exists. For example, the net payment for $A2$ from its IOT agreement with $B1$ is positive,

$$net_{A2}^{B1} = \frac{\overbrace{\alpha}^{w_{A2}^{B1}}}{\beta}\frac{\overbrace{\alpha}^{q_{B1}^{A2}}}{8} - \frac{\overbrace{2\alpha}^{w_{B1}^{A2}}}{3\beta}\frac{\overbrace{\alpha}^{q_{A2}^{B1}}}{12} = \frac{5\alpha^2}{72\beta} > 0.$$

Given uniform retail policy, each network will have a uniform retail, even if it engages in a preferential IOT agreement. In other words, retail prices do not reflect preferential wholesale prices, contrast to the case of the discriminatory retail policy. The retail price set by an insider is lower than the one set by the outsider, leading to a higher demand facing the insider compared to the outsider. In addition, given the insider charges a lower wholesale price to the outsider than the other way, a net payment is paid from the insider to the outsider.

Lemma (4.4). With uniform retail policy of the model, if two cross-ownership pairs exist, net payments are zero.

Proof. Consider the case of two cross-ownership pairs, for example $(A1 + B1)$ and $(A2 + B2)$. In each pair, the insiders will set the internal wholesale price at marginal cost as in Eq. (4.11); and, with the unilateral response function similar to Eq. (4.12), they will set α/β as the wholesale price to the outsiders. In each IOT agreement, wholesale prices are identical, and demands are identical too (i.e. $\alpha/8$). Therefore, net payments are zero. ■

Lemma (4.4) shows asymmetry in wholesale prices, but with zero net payments because networks engage in two counter cross-ownership pairs. Notice that by moving from the case in Lemma (4.3) to the case in Lemma (4.4), the wholesale price charged by $A1$ and $B1$ to outsiders increases (from $2\alpha/3\beta$ to α/β) and the retail price of $A2$ and $B2$ decreases (from $5\alpha/6\beta$ to $3\alpha/4\beta$). Lemmas (4.3) and (4.4) lead to the following proposition.

Proposition (4.2). With uniform retail policy of the model, considering the game of joining a vertical cross-ownership, unilateral wholesale pricing is a dominant strategy to each network.

Proof. Let Π^N represent the baseline unilateral profit to a network from its both IOT agreements when no cross-ownership takes place in the market, all networks set wholesale prices unilaterally, and net payments are zero; where $\Pi^N = 5\alpha^2/[36\beta]$. From Lemma (4.3), the insider's profit from cross-ownership, for example $B1$, is $\Pi^I = 3\alpha^2/[16\beta]$ minus the net payment to $A2$ given by $net = 5\alpha^2/[72\beta]$. This is less than the unilateral profit. By contrast, the outsider's unilateral profit is increased by this net payment. From Lemma (4.4), net payments are zero and each network gets Π^I. Therefore, unilateral wholesale pricing (i.e. no-cross-ownership) is a dominant strategy to each network. ■

The following example demonstrates the dominant strategy as predicted by Proposition (4.2). Let $(A1 + B1)$ be a possible cross-ownership pair and $(A2 + B2)$ be a possible counter pair. Consider the decision in joining different pairs by $B1$ and $A2$. As given in the proof of Proposition (4.2), let Π^N, Π^I and net respectively represent the unilateral profit, the cross-ownership profit and the net payment to these two IOT partners; where $\Pi^N < \Pi^I$ and $\Pi^I < \Pi^N + net$. Table (4.2) shows the payoffs matrix.

Table (4.2) Payoffs matrix for joining a cross-ownership pair under the uniform retail policy.

<table>
<tr><td colspan="2" rowspan="2">Possible cross-ownership pairs: $(A1 + B1); (A2 + B2)$</td><td colspan="2">$B1$</td></tr>
<tr><td>Join $(A1 + B1)$</td><td>Don’t join</td></tr>
<tr><td rowspan="2">$A2$</td><td>Join $(A2 + B2)$</td><td>Π^I, Π^I</td><td>$\Pi^I - net, \Pi^N + net$</td></tr>
<tr><td>Don’t join</td><td>$\Pi^N + net, \Pi^I - net$</td><td>$\boldsymbol{\Pi^N}, \boldsymbol{\Pi^N}$</td></tr>
</table>

$\Pi^I < \Pi^N + net.$

As can be seen from Table (4.2), the game has a unique equilibrium, which is non-cooperation (i.e. setting the wholesale price unilaterally). The non-zero net payment is behind the individual incentive not to join a cross-ownership pair. If one cross-ownership exists, the net payment improves the outsider’s profit if they do not form a counter cross-ownership.

The equilibrium is Pareto inefficient as all networks could be made better off if they form two cross-ownership pairs because the profit would be greater compared to baseline unilateral profit (i.e. $\Pi^N < \Pi^I$); hence a prisoner’s dilemma situation. This result matches the result in Lupi and Manenti (2009), and is contrary to the discriminatory retail policy in Section (4.1.2).

Notice with the uniform retail policy, the wholesale price solution (α/β) charged between the outsiders is the price at which the demand equals zero (or reservations price). This is due to the perfect complementarity problem of visited networks in the demand equation: if the insider charges zero, the outsider charges the reservation price. However, the average wholesale price in this case is at the monopoly level (i.e. $\alpha/(2\beta)$).

4.1.4 Concluding Remarks

In this chapter, the two models for cross-ownership, one with discriminatory retail policy and the other with uniform policy, consider a vertically related IOT partners choosing wholesale prices cooperatively, while retail prices are set independently. The discriminatory policy is overlooked in the existing literature, while the uniform is analysed in Salsas and Koboldt (2004) and Lupi and Manenti (2009), where steering is ignored to maintain simplicity.

As can be seen in Table (4.3) below, wholesale price solutions are found asymmetric under both retail policies: the cross-ownership members set the internal wholesale price at marginal cost and the external wholesale price is set above marginal cost. In the case of one cross-ownership pair, prices and demands are asymmetric with the outsiders, resulting in net payments in favour of the cross-ownership pair under the discriminatory policy, but in favour of the outsiders under the uniform policy.

Table (4.3) Standardised prices under discriminatory and uniform retail policies in the cross-ownership game.

Scenario		Pricing with each partner	Discriminatory retail policy		Uniform retail policy	
			Wholesale cost	Retail price	Wholesale cost	Retail price
One cross-ownership pair	The joining network	With insider	$x^* = 0$	$X^* = \frac{1}{2}$	$x^* = 0$	$X^* = \frac{3}{4}$
		With outsider	$x^* = \frac{1}{2+\gamma}$	$X^* = \frac{3+\gamma}{2(2+\gamma)}$	$x^* = 1$	$X^* = \frac{3}{4}$
	The non-joining network	With insider	$x^* = \frac{2}{4+\gamma}$	$X^* = \frac{6+\gamma}{2(4+\gamma)}$	$x^* = \frac{2}{3}$	$X^* = \frac{5}{6}$
		With outsider	$x^* = \frac{2}{4+\gamma}$	$X^* = \frac{6+\gamma}{2(4+\gamma)}$	$x^* = \frac{2}{3}$	$X^* = \frac{5}{6}$
Two cross-ownership pairs	Each network	With insider	$x^* = 0$	$X^* = \frac{1}{2}$	$x^* = 0$	$X^* = \frac{3}{4}$
		With outsider	$x^* = \frac{1}{2+\gamma}$	$X^* = \frac{3+\gamma}{2(2+\gamma)}$	$x^* = 1$	$X^* = \frac{3}{4}$

$w^* = \frac{\alpha}{\beta}x^*$, $p^* = \frac{\alpha}{\beta}X^*$.
$\gamma \in [0, \infty)$.

Based on the findings of the models, joining a cross-ownership pair is a dominant strategy to each network under the discriminatory policy[59]. On the other hand, joining a cross-ownership pair is not a dominant strategy under the uniform policy, as also predicted by Lupi and Manenti (2009).

59 Without detailed modelling, this result is referred to by Salsas and Koboldt (2004).

The equilibrium under the discriminatory policy is Pareto efficient if the substitutability level is not too high. With the uniform policy, the equilibrium is inefficient as networks can be made better off if they form two cross-ownership pairs. This is because with cross-ownership, the average wholesale price is reduced, eliminating some of the double-markup effects.

The discriminatory retail pricing policy relies on the consumer choosing (manually through his handset) the visited network with the cheapest retail price. By contrast, the uniform retail policy applies a uniform retail price. Given absence of steering and consumer's indifference when retail prices are identical (i.e. handset on automatic mode), neither the home network nor the consumer would change the default choice on visited networks, despite the existence of a preferred visited network which charges a lower wholesale price. Therefore, uniform retail is ineffective without steering. Next, we assume uniform retail is the main assumption for the steering model, but we need to explore the impact of market shares asymmetry on results under the uniform retail policy in the next section.

4.2 Uniform Price With Asymmetric Market Shares

This section explores the impact of market share asymmetry on wholesale price solutions when the retail price is uniform. Uniform retail price is assumed necessary for steering to exist, otherwise manual network selection by the roamer overrides steering made by home network. We follow the steps of Salsas and Koboldt (2004), and Lupi and Manenti (2009) who use asymmetric market shares in their modelling of steering, and explain how asymmetry in shares does not impact the final wholesale price charged to the home network, nor the uniform price it sets, which undermines the need for steering.

This section follows the wholesale unilateral pricing strategy assuming uniform retail policy (as in the Sections 3.2.7 and 3.2.8iv) except that we replace the simple average wholesale price with a weighted average wholesale price, where the weights are the market shares of visited networks.

Let us consider the retail maximization problem for $A1$ when its subscriber roams in country B, as in Eq. (3.7), but replace the simple average wholesale price $\overline{w}_B^{A1}$ with this weighted average ($\widetilde{w}_B^{A1} = s_{B1}^{A1} w_{B1}^{A1} + s_{B2}^{A1} w_{B2}^{A1}$), where s_{B1}^{A1} and s_{B2}^{A1} are the market shares of $B1$ and $B2$ respectively in hosting $A1$'s subscriber. By solving for p_{A1}, the RPMF becomes

$$p_{A1} = \frac{\alpha + \beta \widetilde{w}_B^{A1}}{2\beta}. \tag{4.13}$$

The above RPMF is a markup on the weighted average wholesale price. The unilateral wholesale price strategy sets wholesale prices to maximize the unilateral wholesale profit, leading to, as an example, the following unilateral response function for $B1$

$$w_{B1}^{A1} = \frac{\alpha - \beta s_{B2}^{A1} w_{B2}^{A1}}{2\beta s_{B1}^{A1}}. \tag{4.14}$$

Notice Eq. (4.14) equals the baseline unilateral response function if market shares are symmetric (i.e. $w_{B1}^{A1} = (\alpha/\beta) - w_{B2}^{A1}/2$). By substituting symmetrically for w_{B2}^{A1} in Eq. (4.14), we get these solutions

$$w_{B1}^{A1} = \frac{\alpha}{3\beta s_{B1}^{A1}},$$

and

$$w_{B2}^{A1} = \frac{\alpha}{3\beta s_{B2}^{A1}}. \tag{4.15}$$

By taking the weighted average of the solutions in Eq. (4.15), using their market shares as weights, we have

$$\widetilde{w}_B^{A1} = s_{B1}^{A1} w_{B1}^{A1} + s_{B2}^{A1} w_{B2}^{A1} = \frac{2\,\alpha}{3\,\beta}. \tag{4.16}$$

Obviously, the weighted average wholesale price in Eq. (4.16) equals the baseline solution of the unilateral wholesale price. It is clear from Eq. (4.15) that the network's own market share reduces its wholesale price. However, the asymmetry in market shares does not impact the average wholesale price (whether weighted average or simple) charged to the home network. In this case, market shares asymmetry does not change the fact that visited networks appear in the demand as perfect complements. Therefore, the home network's retail price is unchanged.

The above results match the ones found in Salsas and Koboldt (2004), Lupi and Manenti (2009), and Ambjørnsen, et al. (2011); and are also similar to the results found in Gans and King (2000) who modelled fixed-to-mobile access. As noted in Gans and King (2000), with linear demands, the changes in wholesale prices due to changes in market shares exactly offset each other. Therefore, the (uniform) retail price is independent from market shares.

The main problem in this setting, where retail price is uniform and market shares can be asymmetric, is that if the home network is able to steer (and effectively manipulates market shares of visited networks), it does not cause downward pressures on wholesale prices. This undermines the efficiency gains steering investment is assumed to bring.

Another problem in using the uniform retail price in this setting is that the substitutability parameter is removed from the demands. As substitutability does not exist in all relevant solutions, the expressions of market shares do not reflect substitutability. We assumed visited networks are substitutable if their coverages overlap, where steering is possible only in the overlapping areas. In the next section on steering model, the expressions of market shares take into consideration substitutability between visited networks.

4.3 Roaming Alliance Model

Traffic steering techniques allow the home network to manipulate the market shares of its IOT-agreement partners in the visited country. This practice was deemed in the European NRAs analyses, before the EC roaming regulation, as a countervailing buyer power to pay cheaper wholesale prices. Moreover, the nature of the two-way access of IOT agreements enabled the emergence of two-way steering, (hereafter roaming alliance).

In order for steering to exist, three conditions we assume are necessary: a uniform retail price to avoid roamer's overriding selection (i.e. handsets on automatic mode to allow steering); expected efficiency gains (if wholesale prices are high to justify steering investment); and of course overlapping coverages (i.e., substitutability between visited networks).

Salsas and Koboldt (2004) use complex expressions for market shares, exploring the case when all networks steer to the cheapest visited network. Depending on the ability to steer, the authors think wholesale prices will approach marginal costs, dragging down retail prices.

Lupi and Manenti (2009) offer a detailed model for steering. They assume full overlapping coverage, and use a rate of steering success. They concluded that with perfect success rate, wholesale price is driven to marginal cost; if imperfect, there is no equilibrium in pure strategies. That is, there will be asymmetry in wholesale prices: a low price to the home network that commits to steer, and a high price if it steers away. The baseline unilateral price is between these two prices, which is charged to the home network that does not steer to any (i.e. does not acquire steering technology). As a consequence, each visited network offers a menu of wholesale prices: a high and low price, and the unilateral price. In addition, they found steering investment is the equilibrium in pure strategies; which is a waste of resources since it does not impact retail prices that bear the double marginalisation problem.

However, the aforementioned papers rely on uniform retail price in the demand; thus, the weighted average wholesale price to a home network equals the baseline unilateral wholesale price, as demonstrated in Section (4.2). Therefore, retail prices and demands are unaltered, given visited networks appear as perfect complements in this case.

Next section addresses our model backgrounds in the context of the existing literature. Then two games are detailed: a network's choice on steering investment; and a network's choice in joining a roaming alliance. Results are discussed finally.

4.3.1 Model Background

The existing steering models relied on the uniform retail policy. Yet this policy has four problems. First, as explained previously, the uniform policy is inferior to the discriminatory policy in the non-cooperative wholesale price setting. That is, the uniform policy is not optimal for a retailer network with monopoly position. Second, the demand under this policy makes visited networks appear as perfect complements rather than substitutes, which removes upstream competition by removing the substitutability parameter necessary for effective steering. Third, as explained in Section (4.2) and found in Lupi and Manenti (2009), there will be no wholesale price equilibrium in pure strategies since changes in market shares create asymmetric solutions. Fourth, complication of the steering model through market share asymmetry in a two-stage pricing game is unnecessary since the retail price is independent from market shares asymmetry, as also explained in Section (4.2).

We avoid the uniform retail policy assumed in the existing literature because of the above-mentioned problems. Rather, we skip the retail maximization problem in the steering game, and assume instead each home network chooses uniform retail price. It does not matter which uniform price is chosen in this game as long as the status quo net payments are zero. However, if net payments are zero such that the profit equals the retail revenue and given unconstrained retailers, the optimal retail price is the monopoly price. In this case, the unconstrained monopolist gains the monopoly retail revenue. Such monopoly price is uniform by definition as it is common for the use of any visited network.

We maintain the same assumptions as in Section (4.1.1), unless mentioned otherwise. The retail stage, Stage II, is skipped in this game by assuming all networks set the monopoly retail price. For simplicity, the game is split into two static games:

i. A two-stage game, where each network at the retail level decides simultaneously on steering investment, followed by simultaneous wholesale price setting; and

ii. A game whereby each network decides simultaneously on joining a roaming alliance, where an alliance can take at most two vertically-related networks.

Note that, along with symmetry in demand parameters and in the absence of steering investment, the assumption of monopoly retail price provides no incentive for wholesalers to undercut because this does not raise own market share. In this situation, wholesale price is fixed at the monopoly level and net payments are zero. Additionally, as explained in Appendix (C), the assumption on monopoly retail price is in accordance with an infinitely repeated game equilibrium. As a consequence, steering investment is deemed to be feasible in this situation because efficiency gains are possible given wholesale prices are at the monopoly level.

Networks are assumed to incur a common sunk cost, F, for buying the steering technology. Undercutting is given by the unilateral response function (e.g. $w_{B1}^{A2} = \alpha/[\beta(2+\gamma)] + \theta w_{B2}^{A2}/2$), where the baseline unilateral wholesale price is $2\alpha/[\beta(4+\gamma)]$ and $\theta = \gamma/(2+\gamma)$, the substitutability index. Therefore, we can maintain the substitutability parameter, γ, indicating coverage overlapping where steering can be exercised. Additionally, we can insure that market share manipulation does not affect unilateral wholesale price equilibria.

In addition, we assume the home network's success of steering depends only on coverage overlap. Accordingly, there are no random traffics since the level of randomness that exists in overlapping areas is successfully eliminated via steering. Let the visited network that is being steered to receives the market share $(1+\theta)/2$, and the remaining $(1-\theta)/2$ goes to the visited network that is being steered away, where $\theta = \gamma/(2+\gamma)$[60].

Coverages are assumed symmetric[61]. Steering between two visited networks implies preferring only one network, where full steering can only exist in the limit of γ. Nonetheless, given networks are assumed imperfect substitutes, an alliance formed for instance between $A1$ and $B1$ can coexist with the existing roaming agreements with the other partners, $A2$ and $B2$. Furthermore, the choice on an alliance partner does not matter since networks are symmetric. In other words, asymmetry in demand parameters may result in a preferred alliance partner.

Based on the model backgrounds, in the status quo, both the retail and wholesale prices equal the monopoly price, $\alpha/(2\beta)$. Accordingly, the monopoly retail revenues are unaffected by market shares manipulation, because market shares add up to one. Moreover, the

60 These market share expressions are derived from Shubik and Levitan (1980) demand: if firm 1 drives firm 2 out from the market, the demand to firm 1 becomes $q_1 = ((1+\theta)/2))\,[\alpha - \beta p_1]$, where $(1+\theta)/2 = (1+\gamma)/(2+\gamma)$ and $\theta = \gamma/(2+\gamma)$, representing the line ($d' - F'$) in Figure (3.2).

61 Contrary to Ambjørnsen, et al. (2011) who model investment decision to expand coverage in airports for example, we maintain the base model's assumption that networks installed their coverages competing for home subscribers only, not for hosting visitors.

demand for a visited network is given by its market share times $\alpha/2$. We only show net payments as payoffs to simplify presentations.

4.3.2 Steering Investment Game

Assume all home networks set the retail price at the monopoly level and the status quo wholesale prices equal the monopoly price. Assume a two-stage game. In Stage I, home networks decide simultaneously on investing in steering technology, which costs $F > 0$. In Stage II, wholesale prices are set non-cooperatively. The solution method for the Subgame Perfect Nash Equilibrium (SPNE) is backward induction.

Proposition (4.3). In the steering investment game, conditional on $F \leq \gamma\alpha^2/[8(4+\gamma)\beta]$, the SPNE of the game is such that each network invests in steering and sets wholesale prices unilaterally.

Proof. The status quo is when steering investment does not exist, where visited networks sustain the wholesale price at the monopoly level (i.e. $\alpha/[2\beta]$), because undercutting is unattractive as it does not raise market shares. When a home network invests in steering, depending on the substitutability level, it can increase the market share of the cheapest visited network to $(1+\theta)/2$, while the other network gets $(1-\theta)/2$, where $\theta = \gamma/(2+\gamma)$. In this case, each visited network charges the baseline unilateral wholesale price (i.e. $2\alpha/[\beta(4+\gamma)]$), which is the dominant strategy in Stage II. In Stage I, the home network gains from the net payment with each visited network that does not invest in steering due to asymmetry in wholesale prices (i.e., monopoly price by the former compared to baseline unilateral price by the later). The expected gain makes investment a dominant strategy in Stage I, as long as the fixed cost of investment $F \leq \gamma\alpha^2/[8(4+\gamma)\beta]$. ■

Proposition (4.3) can be demonstrated as follows. Let net denotes the net payment from an IOT agreement, with subscript refers to the network in question and the superscript to its partner. If $A1$ invests in steering, $B1$ and $B2$ will set the baseline unilateral price ($w^N = 2\alpha/[\beta(4+\gamma)]$). If $B1$ does not invest, $A1$ will set the monopoly price ($w^M = \alpha/[2\beta]$); hence $A1$ will get a positive net payment as follows

$$net_{A1}^{B1} = w^M \ \frac{\alpha}{4} - w^N \ \frac{\alpha}{4} = \frac{\gamma\alpha^2}{8\beta(4+\gamma)} \geq 0.$$

The incurred fixed cost F must be less than or equal to the expected gain from each IOT agreement. It is clear from the above example that the gain from wholesale price differentials requires positive γ, which allows steering to be effective since visited networks are substitutable.

The above net payment gain increases by γ (i.e. derivative of net with respect to γ is positive). With $\gamma = 0$, net payments are zero since the baseline unilateral wholesale price, w^N, equals the monopoly price, w^M.

Predictably, investing in steering causes downward pressures on wholesale prices in the similar way as the consumer's substitutability with discriminatory retail prices.

Proposition (4.3) shows the prisoner's dilemma at both wholesale and retail levels: the SPNE has unilateral wholesale prices and sunk costs of investments without improving payoffs. In other words, the status quo profit to each network, given by the monopoly retail revenue, is reduced by the investment fixed cost. Next we explore networks' temptations to take advantage of the steering technology.

4.3.3 Roaming Alliance Formation Game

Proposition (4.3) predicts that all networks invest in steering and choose the baseline unilateral wholesale price. In this case, steering does not effectively take place, because wholesale prices are symmetric (at w^N). This section explores incentives to a home network in engaging in steering unilaterally, or mutually with an IOT partner (i.e. forming a roaming alliance). For simplicity, the payoffs shown below regard a network's net payments with its IOT partners, as we ignore the retail revenues and the fixed cost of steering investment, which are common to all networks.

Denote net for the net payment from an IOT agreement. The subscript refers to the network in question and the superscript to its partner, with subscript/superscript ($+s$) for the case steering is made by a network to the partner, or ($-s$) for steering away from that partner. Before we get to the main findings of the game, we state the following Lemmas with their proofs for the different scenarios of roaming alliance formations.

Lemma (4.5). Assume all networks invested in steering and charged the unilateral wholesale price. If $\theta > 0$, where $\theta = \gamma/(2+\gamma)$, and if only one network unilaterally steers, it will not improve its payoffs.

Proof. Assume only $A1$ steers unilaterally to $B1$. $A1$'s payoffs are

$$net_{A1+s}^{B1} = w^N \frac{1}{2}\frac{\alpha}{2} - w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} = -\frac{\theta\alpha^2}{2\beta(4+\gamma)},$$

and

$$net_{A1-s}^{B2} = w^N \frac{1}{2}\frac{\alpha}{2} - w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} = \frac{\theta\alpha^2}{2\beta(4+\gamma)}.$$

The net gain to $A1$ is zero. ■

Lemma (4.6). Assume all networks invested in steering and charged the unilateral wholesale price. If $\theta > 0$, where $\theta = \gamma/(2+\gamma)$, and if only two networks engage in mutual steering, they will improve their payoffs.

Proof. Assume only $A1$ and $B1$ engage in mutual steering (i.e. form a roaming alliance). $A1$'s payoffs, for example, are

$$net_{A1+s}^{B1+s} = w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} - w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} = 0,$$

and

$$net_{A1-s}^{B2} = w^N \frac{1}{2}\frac{\alpha}{2} - w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} = \frac{\theta\alpha^2}{2\beta(4+\gamma)}.$$

The net gain to $A1$ is positive. ■

Lemma (4.7). Assume all networks invested in steering and charged the unilateral wholesale price. If $\theta > 0$, where $\theta = \gamma/(2+\gamma)$, and if two pairs of networks engage in mutual steering, the payoffs will be zero to each network.

Proof. Assume $A1$ and $B1$ form a roaming alliance and $A2$ and $B2$ form another roaming alliance. $A1$'s payoffs, for example, are

$$net_{A1+s}^{B1+s} = w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} - w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} = 0,$$

and

$$net_{A1-s}^{B2-s} = w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} - w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} = 0.$$

The net gain to $A1$ is zero. ■

Lemma (4.8). Assume all networks invested in steering and charged the unilateral wholesale price. If $\theta > 0$, where $\theta = \gamma/(2+\gamma)$, and if one network unilaterally deviates from a mutual steering, it will not improve its payoffs.

Proof. Assume $A1$ and $B1$ form a roaming alliance and $A2$ and $B2$ form another roaming alliance, similar to the case in Lemma (4.7). First, assume $A1$, for example, deviates by steering away from $B1$. $A1$'s payoffs are

$$net_{A1-s}^{B1+s} = w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} - w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} = \frac{\theta\alpha^2}{\beta(4+\gamma)},$$

and

$$net_{A1+s}^{B2-s} = w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} - w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} = -\frac{\theta\alpha^2}{\beta(4+\gamma)}.$$

The net gain to $A1$ is still zero. Second, assume $A1$ deviates by the refrain from steering. $A1$'s payoffs are

$$net_{A1}^{B1+s} = w^N \frac{(1+\theta)}{2}\frac{\alpha}{2} - w^N \frac{1}{2}\frac{\alpha}{2} = \frac{\theta\alpha^2}{2\beta(4+\gamma)},$$

and

$$net_{A1}^{B2-s} = w^N \frac{(1-\theta)}{2}\frac{\alpha}{2} - w^N \frac{1}{2}\frac{\alpha}{2} = -\frac{\theta\alpha^2}{2\beta(4+\gamma)}.$$

The net gain to $A1$ is also zero. Similarly, if only one roaming alliance exists, say between $A1$ and $B1$, the deviant will not improve its payoffs. ■

All results of the Lemmas (4.5) to (4.8) require $\theta > 0$, which is the case where steering can be effective because visited networks have overlapping coverages. From Lemma (4.5), one can see that if a network's unilaterally manipulate visited networks' market shares, it affects the payoff with each, but does not improve its total gains. From Lemma (4.6), a mutual steering improves the payoffs to each member of the roaming alliance at the expense of the non-members which did not form a counter alliance. From Lemma (4.7), with two roaming alliances, all gains/losses from net payments cancel out, so the payoffs are zero to each network. From Lemma (4.8), there is no incentive to a network to deviate from a mutual steering with its roaming alliance member, whether deviation is by steering away from its member or by the refrain from steering. Of course, such deviation harms the complying member.

We conclude from Lemmas (4.5) and (4.8) that only mutual steering can be profitable, which can sustain roaming alliance cooperation. Members will break even in their own net payment, where each expects a positive net payment with the non-member due to market share asymmetry (buying less through steering away compared to selling more at default market share). Lemmas (4.5) to (4.8) lead to the following proposition.

Proposition (4.4). Assume all networks invested in steering and charged the unilateral wholesale price. If $\theta > 0$, where $\theta = \gamma/(2+\gamma)$, then joining a roaming alliance is a dominant strategy to each network.

Proof. From Lemmas (4.5) and (4.8), mutual steering is sustained within the roaming alliance members. From Lemmas (4.6), any network that does not join an alliance will pay a net payment to its IOT partner that joined an alliance. From Lemmas (4.7), joining an alliance provides non-negative payoffs to each network. ■

The following example demonstrates the dominant strategy as predicted by Proposition (4.4). Let $(A1+B1)$ be a possible roaming alliance and $(A2+B2)$ be a possible counter alliance. Consider the decision in joining different alliances by $B1$ and $A2$. Let net represents their non-zero net payment from their IOT agreements. Table (4.4) shows the payoffs matrix.

Table (4.4) Payoffs matrix for joining a roaming alliance.

Possible roaming alliances: $(A1+B1), (A2+B2)$		$B1$	
		Join $(A1+B1)$	Don't join
$A2$	Join $(A2+B2)$	$\mathbf{0, 0}$	$net, -net$
	Don't join	$-net, net$	0,0

In Proposition (4.4), θ, the substitutability index, is assumed positive; hence $net > 0$.

This game has zero-sum payoffs, where joining a roaming alliance is its unique equilibrium. The non-zero net payment if one network joins while the other does not is an externality that makes joining an alliance a dominant strategy. If only one pair forms an alliance, its members can improve their statues quo payoffs at the expense of the counter pair. Therefore, two alliances are formed in equilibrium, and their net gains are zero.

4.3.4 Concluding Remarks

The roaming alliance model in this chapter is based on assuming all networks apply the same uniform retail price, which is assumed to be the monopoly price. If steering is absent, the wholesale price also equals the monopoly level. Through investment in steering, a home network can cause downward pressures on wholesale prices, seeking a gain from the net payment due to asymmetry in wholesale prices if its IOT-agreement partner does not invest in steering. The equilibrium of this two-stage game is such that each network invests in steering and wholesale prices are set non-cooperatively (see Table 4.5 below).

Table (4.5) Standardised prices when all networks apply the monopoly retail price in the steering investment game.

Home network decision to invest in steering	Wholesale cost	Retail price
Do not invest in steering	$x^* = \frac{1}{2}$	$X^* = \frac{1}{2}$
Invest in steering	$x^* = \frac{2}{4+\gamma}$	$X^* = \frac{1}{2}$

$w^* = \frac{\alpha}{\beta} x^*$, $p^* = \frac{\alpha}{\beta} X^*$.
$\gamma \in [0, \infty)$.

Therefore, the game does not predict unilateral menu prices as in Lupi and Manenti (2009) who used a uniform retail pricing different from our model, nor it predicts above marginal cost pricing as in Bühler (2010) who looked at the impact of wholesale prices on retail two-part tariffs set by home networks competing for home subscribers.

In the game of joining a roaming alliance, we found only mutual steering is profitable, and alliance networks can sustain cooperation. Thus, steering is necessary for alliance formation, as predicted in Bühler (2010) and Hualong and Shoulian (2009). The model shows that the higher is the substitutability parameter, the higher will be the expected gains from steering, reflecting the role of coverage overlapping in steering effectiveness. Each network has a dominant strategy to join an alliance in order to gain from the net payment, or to balance its net payment with the outsider which joined a counter alliance. The model predicts two alliances are formed in equilibrium, but do not lead to exclusive IOT agreements because the substitutability parameter is bounded. With two roaming alliances formed in equilibrium, the monopoly retail revenues are reduced by steering investment. Such investment is then a waste of resources as predicted by Lupi and Manenti (2009), and by Ambjørnsen, et al (2011).

4.4 Discussion

Cross-ownership and alliance models are inspired by the existing literature that addresses the impact of IOT preferential agreements on game equilibria. In this chapter, our results are all based on the implications of net payments. In the situation whereby only one pair of networks has a preferential agreement, the net payment of an IOT agreement between an insider and outsider is non-zero because of asymmetric demands; and, in the cross-ownership case, because of asymmetric wholesale prices.

In the cross-ownership model, the potential gain from the net payment with the outsider provides the incentive to join a cross-ownership pair if discriminatory retail policy is assumed and networks are imperfect substitutes. But the opposite is true with the uniform retail policy without steering investment: the potential gain from the net payment exists for the outsider when it does not join a cross-ownership pair. Therefore, with discriminatory policy, vertical cooperation through cross-ownership is a dominant strategy to each network; while with uniform policy, non-cooperation is the dominant strategy.

In the alliance model, monopoly retail price is assumed. Each network has a dominant strategy to invest in steering to induce wholesalers to set unilateral wholesale prices. Each network expects a gain from the net payment with its IOT partner through wholesale price differential had that partner did not invest in steering.

With all networks acquiring steering technology and charging wholesale prices non-cooperatively, a unilateral steering by a home network does not improve its payoffs. Unless engaged in mutual steering (i.e. roaming alliance), the home network does not improve its payoffs. Each network has a dominant strategy to join an alliance in order to gain from the net payment with the non-member IOT-agreement partner had this partner did not join a counter alliance. Such gain requires visited networks to be substitutable, and rises with substitutability reflecting the effectiveness of steering.

In this chapter, we found a dominant strategy in each game (cross-ownership and alliance), which are all driven by the implications of net payments. In all models, networks are assumed symmetric; thus the choice on a preferred partner does not matter.

Yet since net payment plays a role in each model, a relatively larger network (e.g. with higher market size) will always be a net payee in its IOT agreements. Therefore, under the preferential agreements where vertical cooperation is a dominant strategy (i.e. the cross-ownership with discriminatory retail prices and the roaming alliance), each network will prefer to choose the largest network as a partner. At the same time, a large network is better off choosing, as a preferential partner, the largest network amongst its IOT-agreement partners, in order to minimize negative net payments. We expect the choices of preferential partners in this case would be: large networks against small networks. Our expectation contradicts with the scenarios analysed in Shortall (2010) and Lacasa (2011), who found small networks would prefer to form an alliance.

Next chapters will use a dataset on outbound roaming by Etisalat. The dataset contains wholesale prices and market shares of visited networks. It also contains information on the visited networks that are cross-owned by Etisalat, as well as the networks that are roaming alliances to Etisalat. The dataset will be used to test empirically the predictions of the theoretical models in Chapters (3) and (4) about the base model and its extension.

Chapter (5). Dataset Description

In this chapter, we describe the dataset on Etisalat[62] (the incumbent mobile network operator in the UAE) outbound roaming that shall be used for empirical estimations. The purpose is to introduce the reader to the specifics of the dataset. The dataset contains information which is relevant in understanding upstream competition, complementary to the theoretical predictions of previous chapters.

Section (5.1) discusses the applicability of the dataset to the theoretical models of previous chapters. Section (5.2) provides a brief on Etisalat retail prices. Section (5.3) details the available information on visited networks. Data collection procedures and dataset description are provided in Sections (5.4) and (5.5) respectively. We conclude in Section (5.6) with linking the dataset to the empirical models of next chapters.

5.1 Relevance Of Dataset

The theoretical models in Chapters (3) and (4) focus on wholesalers' competition in hosting the visiting subscriber of their Inter-Operator Tariffs (IOT) agreement partner. The home network is assumed to be a monopolist at the retail level. The games assumed retail price is either discriminatory (i.e. differs by visited network in the same visited country) or uniform. The substitutability between visited networks is interpreted as the visited networks coverage overlap, whereby roamers can choose between visited networks through manual-network-selection feature of their handsets. Alternatively, home networks can steer to their preferred networks had they invested in steering technology and set the uniform retail price such that roamers put their handsets on automatic mode. Preferred IOT agreements are assumed under cross-ownership or roaming alliance strategies.

The dataset in hand allows us to investigate some of the theoretical predictions of the previous chapters. It contains all foreign networks that were visited by Etisalat's travelling subscribers (hereafter roamers) around the world during the years 2008-2011. It includes average wholesale prices for the relevant roaming traffics (hereafter quantities), where wholesale prices are unregulated and hence should represent the market outcome.

62 Etisalat was ranked 140th among the Financial Times Top 500 Corporations in the world in terms of market capitalization, expanding in 18 countries (Gulfnews.com, 2009).

In addition, visited networks did not price discriminate at the wholesale level between Etisalat[63] roamers (e.g. postpaid versus prepaid), which is expected given a visited network's knowledge is supposed to be limited to knowing the home network of the visitors. Therefore, visited networks are thought to treat an Etisalat roamer as a representative consumer of all Etisalat roamers.

The study period witnessed Etisalat's retail policy shift from generally discriminatory retail prices during the years 2008-2009 to uniform during the years 2010-2011. This policy shift is supposed to allow Etisalat to steer its roamers to its preferred visited networks as long as roamers are indifferent between visited networks. We gathered information on visited networks' relationships with Etisalat in order to explore the impact of such relationships with Etisalat on market outcome.

In the UAE, there has been hardly any room for new subscribers when Du, the second mobile operator, launched its services in 2007, as the market was saturated with mobile penetration exceeding 100% (Dam, R. 2011). Since there was no mobile number portability in the UAE during the study period, an Etisalat subscriber would not retain his mobile number had he switched to Du. If international roaming is mainly about the convenience of using the same mobile number abroad, we can assume Etisalat subscribers do not switch to Du for roaming purposes. Therefore, based on the above, we can carry on the theoretical assumption that the retailer (Etisalat) holds a monopoly position downstream.

5.2 Brief On Etisalat Retail Prices

The NRA of the UAE issued a directive obliging its licenced operators (Etisalat and Du) to send free SMS to their travelling subscribers informing them about the applicable retail prices for making and receiving calls. This directive entered into force by the end of 2007 (NRA-UAE, 2007). Therefore, in our dataset, Etisalat's subscribers are assumed to be aware of applicable retail prices.

International roaming had been exclusive to postpaid subscribers, but then Etisalat extended it to prepaid subscribers as the Customized Applications for Mobile Enhanced Logic (CAMEL) technology has been implemented by Etisalat and many of its IOT-agreement partners. At the retail level, Etisalat discriminates between its postpaid and prepaid

63 This statement was communicated verbally by Etisalat.

subscribers: Etisalat generally charges higher prices to prepaid subscribers compared to the postpaid. Retail prices vary across roaming services: outgoing and incoming calls, outgoing SMS and data roaming, whilst incoming SMS is free.

Mobile retail prices are subject to regulation by the NRA of the UAE. Etisalat would submit a price control request to the NRA, an ex-ante price regulation procedure, only if Etisalat plans to introduce or renovate prices and packages. However, a retail price change due to changes in wholesale prices would not be notified to the NRA, including for example retail international roaming.

Recently, a regional regulation agreement was reached between the GCC member states, known as the Intra-GCC Roaming Charges. The regulation imposes retail and wholesale price caps for outgoing calls when roaming within the GCC. The NRA at the UAE side issued a directive that set a cap on both wholesale and retail prices for outgoing calls regardless of contract type (postpaid or prepaid) (NRA-UAE, 2010). However, we will show later in this chapter that wholesale price caps were ineffective during our study period.

From the beginning of the last decade till February 2010, Etisalat offered international roaming based on discriminatory retail prices, i.e. differentiated by visited networks. The available discriminatory retail prices are summarized in Table (5.1). For comparison purposes, the regions are divided into three: the neighbouring GCC countries, the remainder of the Arab countries and the rest of the world.

Table (5.1) Etisalat international roaming average retail prices in AED for postpaid roamers in 2009.

Region	Incoming call	Outgoing local call	Outgoing call to UAE	SMS*
GCC	2.55 (0.35)	1.80 (1.20)	3.43 (1.26)	0.98 (0.43)
Arab countries	3.46 (1.24)	2.54 (1.31)	7.35 (3.35)	1.26 (0.56)
Rest of the world	4.62 (2.36)	2.78 (1.65)	10.26 (4.33)	1.13 (0.57)
All	4.49 (2.31)	2.74 (1.63)	9.89 (4.40)	1.13 (0.57)

*The prices of SMS made to local and international destinations are averaged out for each visited network, which are very similar with most visited networks. The standard deviation in parentheses is then taken for each region.
- Standard deviations in parentheses.
Source: Adapted from Etisalat (2009).

The standard deviations in the above table give us a hint on how Etisalat set its retail prices across visited networks within a region. It is obvious that retail prices vary substantially for outgoing calls (to local or to UAE). This is generally true because, within the region, prices of outgoing calls vary by visited networks in a given country. With respect to incoming calls, there is variation between regions, but retail price is uniform within most countries, which is also true with SMS.

Since February 2010, Etisalat applied uniform retail prices by regions: GCC, Arab countries and the rest of the world (Gulfnews.com, 2010). Table (5.2) shows the (uniform) retail prices in 2010[64] for Etisalat postpaid[65]. As can be seen, prices of incoming and outgoing local calls tend to be similar, which are about half the prices of outgoing calls to UAE.

Table (5.2) Etisalat international roaming retail prices in AED for postpaid roamers in 2010.

Region	Incoming call	Outgoing local call	Outgoing call to UAE	SMS
GCC	1.25	1.30	3.00	1.00
Arab countries	3.00	3.00	6.00	1.50
Rest of the world	4.00	5.00	10.00	2.00

Prices for international outgoing calls to non-GCC destinations are variable.
- Any international outgoing call has a setup charge of 2.5 AED.
- Optional roaming packages are available for incoming calls and data roaming.
Source: Adapted from Etisalat (2010b).

We face difficulties combining information on retail prices with our dataset. First, the information on retail prices is incomplete. For example, the retail prices in 2008 are not available; and data roaming retail prices are not available in the years 2008-2009. Second, retail prices are complex, as they may involve call setup charges and optional roaming packages (such as for incoming calls and data roaming). Third, for outgoing calls, the available retail prices differ by call destination (e.g. to local or to international; international to UAE or to third country), which makes it impossible to combine with our dataset that does not breakdown the wholesale prices for outgoing calls by destination. Finally, the dataset would not have enough variations for empirical estimations if we are to use the uniform (zonal) retail prices in the period 2010-2011.

To overcome the above-mentioned problems, one should use average retail prices (or revenue per unit). This was requested, but was not supplied as explained next.

64 If Table (5.2) has standard deviations similar to the case in Table (5.1), they would be zero because of uniform retail pricing.
65 Prepaid prices are also uniform (Etisalat, 2010c).

5.3 Data Collection

In 2012, we approached the NRA of the UAE for information regarding mobile international roaming. The NRA shares our interest in knowing whether or not mobile networks compete in this service, given unjustified high prices that led regional regulators to consider regulation similar to the EC roaming regulation. In addition, the NRA is interested in knowing the effectiveness of its existing policies regarding the service, as mentioned in Section (5.2).

We agreed to focus on information regarding UAE outbound roaming; that is, the UAE subscribers travelling abroad. Such information should be provided at the visited network level. The choice on years was agreed to be the year after the entry of Du (i.e., 2008), to the most recent year, which was 2011. Moreover, because international roaming is known to be seasonal (e.g. summer holiday travels), we agreed to look for annualized data to avoid seasonality effects. Monetary data was requested to be converted to AED for the relevant year.

The period 2008-2011 was of relevant importance to the retail pricing policies by Du and Etisalat: Du began offering uniform retail pricing for some of its services from late 2008 (EITC, 2008); and Etisalat implemented similar retail policy since the beginning of 2010 (Gulfnews.com, 2010).

The NRA issued the following requests for information to its licensed mobile operators, Etisalat and Du. The requests contain the following items, for each visited network in each year over the period 2008-2011:

1. Quantities per mobile service (e.g. outgoing calls, incoming calls, etc.);
2. Wholesale total charges in AED;
3. Listed wholesale prices in AED as stated in IOT-agreement;
4. Retail revenues in AED;
5. Listed retail prices in AED as communicated to subscribers (e.g. in website, SMS notification, etc.); and
6. Number of distinct outbound roamers by subscription type (prepaid and postpaid).

Du’s response was limited to the visited networks in the neighbouring GCC countries for the period 2010-2011. On the other hand, Etisalat’s response included all visited networks around the world. However, Etisalat did not provide any information on the retail side. Moreover, neither Etisalat nor Du provided accurate numbers of distinct outbound roamers.

The data provided in Etisalat response[66] constitutes our dataset that will be used for the empirical estimations in the next chapters. Etisalat dataset is comprehensive with regards to the wholesale level, for it includes all outbound roaming quantities and their respected average wholesale prices at the visited network level for each of the years 2008-2011. Such dataset should be relevant for testing the impact of Etisalat's retail policy shift (from discriminatory to uniform) on wholesale price competition.

5.4 Information On Foreign Networks

The only information provided in the dataset about foreign networks visited by Etisalat roamers are the names of those networks, countries in which they operate, and the TAP code used for billing in international roaming. It is important to note that country information is not always accurate as some names either had changed, or they did not specify regions within a country if the country has regional licensing[67].

We redefined geographic markets to ensure any derivation on the market-level, such as market shares, is as accurate as possible. Each visited network is rechecked, through its website or search engine using its given name and Tap code[68], in order to ensure it operates in the correct geographic market[69].

We considered visited networks that have ties with Etisalat (i.e. preferred by Etisalat) for analytical purposes. We relied on information contained in Etisalat's response to the NRA and from Etisalat's website. In an attachment to its response to the NRA, Etisalat states its roaming alliance networks (thereafter Alliance networks). By roaming on alliance networks, Etisalat roamers can buy roaming packages (for incoming calls and data roaming). In addition, some networks are partially or fully cross-owned by Etisalat (thereafter Cross-owned networks) (Etisalat, 2011).

66 Disclaimer: Etisalat had an IOT agreement with each visited network in the dataset, which is confidential. Therefore, access to the dataset is restricted to the UAE NRA's employees. We can show summary statistics and estimation results without disclosing price and quantity information at the visited network level.
67 Regional markets were adjusted for: India (into 23 regions); Iran (into Kish island and Iran); UK (into Great Britain, Isle of Man, Jersey, and Guernsey); Finland (into Alands and Finland); and the disputed region of Karabakh. We lack information to adjust any possible regional markets (e.g. Brazil, Russia and USA).
68 The TAP code is used as a network identifier, which usually differs from the MCC-MNC code (a combination of the Mobile Country Code and the Mobile Network Code) used to hunt information on mobile network operators.
69 See Appendix (G) for full list of visited networks and their geographic markets.

Etisalat preferred networks are listed in Table (5.3). Notice that Etisalat cross-owned networks are in developing countries. Given low mobile penetration, perhaps Etisalat seeks investment opportunities in markets where potential subscription growth is possible. Moreover, Etisalat has no more than one cross-owned network in a given market, due probably to local merger control.

On the other side, most alliance networks are in developed countries, where Etisalat has more than one alliance in some markets. Given that Etisalat roamers come from the UAE, one of the world's highest GDP per capita, perhaps Etisalat seeks efficiency gains in markets visited frequently by its subscribers.

In addition, we considered visited networks with CAMEL technologies, as they can allow prepaid roaming. As of 2010, there are 165 visited networks that have CAMEL technologies and allow roaming by Etisalat prepaid subscribers (thereafter networks With CAMEL) (Etisalat, 2010a). Table (5.4) lists the countries in which these networks operate.

Furthermore, while gathering information on visited networks, we found that some mobile operators own more than one network in the same geographic market (e.g. CEDMA and 3G networks operated by KT in South Korea). This might be a result of network licensing procedures in some jurisdictions. We also found some visited networks involved in horizontal merger or acquisition. All such networks are considered as multinetworks within their markets (thereafter Multinetwork).

An observation in the dataset represents a visited network in a given year, where all visited networks are segregated by the TAP codes. We do not change how visited networks appear in the dataset; rather, we control for Multinetwork with the use of a dummy variable[70] (one if a visited network has multinetworks within the market; zero otherwise). Table (5.5) lists visited networks that have multinetworks.

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70 This was suggested by Professor Summit Majumdar, where in Majumdar (2010) and Majumdar et al (2012) a dummy variable equals one if the firm experienced a merger event.

Table (5.3) Etisalat roaming alliance and cross-owned visited networks by country.

Country	Alliance network(s)*	Cross-owned network** (Effective year in parenthesis)
Afghanistan	-	Etisalat (license since 2006)
Armenia	Orange	-
Austria	Orange & T-Mobile	-
Bahrain	Batelco	-
Belgium	Mobistar	-
Benin	-	Moov (acquisition since 2005)
Bulgaria	Globul	-
Burkina Faso	-	Telecel (acquisition since 2005)
Central African Republic	-	Moov (acquisition since 2005)
Czech	T-Mobile	-
Egypt	Etisalat Misr	Etisalat Misr (license since 2006)
France	Orange	-
Gabon	-	Moov (acquisition since 2005)
Germany	T-Mobile	-
Greece	Cosmote	-
Hungary	T-Mobile	-
India	Vodafone India	Etisalat DB (acquisition since 2008)
Indonesia	-	Excelcomindo (acquisition since 2007)
Italy	Vodafone Italia	-
Ivory Coast	-	Moov (acquisition since 2005)
Jordan	Umniah	-
Kuwait	Zain	-
Luxembourg	Orange	-
Malaysia	Maxis	-
Moldova	Orange	-
Netherlands	T-Mobile	-
Niger	-	Moov (acquisition since 2005)
Nigeria	-	Etisalat (license since 2007)
Oman	Omantel	-
Pakistan	-	Ufone (acquisition since 2005)
Poland	Orange & T-Mobile	-
Romania	Cosmote & Orange	-
Saudi Arabia	Mobily	Mobily (license since 2004)
Slovakia	Orange & T- Mobile	-
Spain	Orange	-
Sri Lanka	-	Etisalat (acquisition since 2009)
Switzerland	Orange	-
Tanzania	-	Zantel (acquisition since 1999)
Thailand	AIS & DTAC	-
Togo	-	Moov (acquisition since 2005)
Turkey	Turkcell	-
UK	O2, Orange & T-Mobile	-
USA	Cingular & T-Mobile	-

* Alliance networks were provided as of August 2012.
** Cross-owned networks were provided till the end of 2011 (Etisalat, 2011).

Table (5.4) Number of visited networks with CAMEL technologies by country as of 2010.

Country	Networks with CAMEL	Country	Networks with CAMEL
Afghanistan	3	Macedonia	1
Albania	1	Malaysia	2
Algeria	1	Maldives	1
Argentina	1	Mauritania	1
Armenia	2	Mauritius	1
Australia	3	Moldova	1
Austria	1	Morocco	2
Azerbaijan	1	Netherlands	1
Bahrain	2	Niger	1
Bangladesh	4	Nigeria	2
Belgium	3	Oman	2
Benin	1	Pakistan	4
Brazil	3	Palestine	1
Bulgaria	2	Philippines	1
Burkina Faso	1	Portugal	1
Cameroon	1	Qatar	1
Canada	1	Romania	1
Croatia	2	Russia	2
Cyprus	1	Saudi Arabia	3
Czech Republic	3	Serbia	1
Egypt	3	Singapore	1
Estonia	1	Slovenia	1
France	2	South Africa	1
Germany	3	Spain	3
Greece	2	Sri Lanka	3
Hong Kong	1	Sudan	2
Hungary	2	Switzerland	3
Iceland	1	Syria	2
India*	21	Tajikistan	1
Indonesia	5	Tanzania	3
Iraq	3	Thailand	3
Isle of Man	1	Tunisia	2
Italy	3	Turkey	1
Ivory Cost	1	Uganda	2
Japan	1	UK	3
Jordan	3	Ukraine	1
Kazakhstan	2	USA	1
Kuwait	3	Uzbekistan	1
Kyrgyzstan	1	Yemen	2
Libya	1	Zambia	1
Luxembourg	1	Total	165

Source: Etisalat (2010a).
* Indian networks with CAMEL operate in 11 regional markets.

Table (5.5) Visited networks with Multinetwork by country.

Country	Networks which have Multinetwork
Austria	3G & Vodafone merged in 2009
Brazil	Brasil Telco & TNL merged in 2009
Hong Kong	CSL & NW merged in 2006
	H3 operates two distinct networks: 2G & 3G
	PCCW operates two distinct networks: 2G & 3G
India	In Karnataka market: Spice merged with Idea in 2008
	In Punjab market: Spice merged with Idea in 2008
	In Rajasthan market: Airtel acquired Hexacom in 2004
	In Chennai market: Airtel acquired Skycell in 2000
Iraq	Zain acquired Iraqna in 2008
Netherlands	Orange & T-Mobile merged in 2007
South Korea	KT operates two distinct networks: CDMA & 3G
Taiwan	Far East acquired KG in 2003
Tajikistan	Tcell operates two distinct networks: North & South; which had operational merger in 2011
UK	Orange & T Mobile merged in 2009
Ukraine	URS acquired Golden Telecom in 2008, forming Beeline
	Beeline & Kyivstar merged in 2010

Source: Information from multiple search engines.

5.5 The Dataset

In our aggregated dataset, we observe foreign networks that were visited by Etisalat roamers during the years 2008-2011: Etisalat is the home network; and visited networks are the wholesalers. Visited networks billed Etisalat for the use of their networks. The dataset includes average wholesale prices (computed by dividing the billed charges by the used units) for each of the four roaming services: minutes of outgoing calls (to any destination), minutes of incoming calls, originated SMS (to any destination) and MB of data roaming. Wholesale prices are available in AED.

These IOT bills are assumed to include any payment discounts given to Etisalat[71]. Nevertheless, these bills are not the net IOT payments between Etisalat and visited networks; rather, they are part of Etisalat net payments. More specifically, they represent Etisalat wholesale costs, or visited networks' wholesale revenues.

There are few observed visited networks[72] that offer mobile telephony via satellite or other enabling technologies on airplanes or ships, which charged excessive wholesale prices. As

71 Value added tax (VAT) is also included in these bills if imposed by the visited country. However, such tax does not affect wholesale competition because it would be applied similarly to all networks in a given country.

72 Namely, AeroMobile, Maritime Communications, Maritime Seanet, Oceancel, OnAir, Telecom Italia Maritime, Thuraya and Digicel Maritime.

they operate in wider geographic markets that include more than one jurisdiction, networks of this type were removed from the dataset in order to focus on conventional mobile networks.

We make use of the information provided in Tables (5.3 to 5.5). This information indicates the relationship between Etisalat and the visited networks in terms of possible preferential IOT agreements that lead to preferential wholesale pricing and/or steering arrangements. In addition, we control for multinetworks, because such visited networks may enjoy market power in their wholesale price setting. Therefore, we created the following dummy variables to be used for empirical estimations:

- Cross-owned by Etisalat: a dummy variable that equals one if the visited network is cross-owned by Etisalat, zero otherwise. This variable can vary over time (see Table 5.3).

- Alliance to Etisalat: a dummy variable that equals one if the visited network is recognized by Etisalat as an alliance network, zero otherwise. We have this information for 2012 (see Table 5.3), but lack information for the years 2008-2011[73]. We consider such networks to be alliances during the full study period; hence the variable is time invariant.

- With CAMEL: a dummy variable that equals one if the visited network allows Etisalat prepaid roamers, zero otherwise (see Table 5.4). We have information for 2010, but lack information for other years[74]. We consider such networks to be with CAMEL during the full study period; hence the variable is time invariant.

- Multinetwork: a dummy variable that equals one if the visited network experienced a horizontal merger or acquisition, or owned more than one network in the same market, zero otherwise (see Table 5.5)[75]. The dummy variable takes the value of one for each visited network that has multinetworks. For the merger/acquisition events, the year in effect is considered; hence the variable varies by year. For example, in the merger event in the UK between Orange and T-Mobile in 2009, the dummy value is zero in 2008 and

73 In fact, the number of Etisalat alliance networks rose from 38 networks in 2012 as in Table (5.3) to 143 as of July 2013 (Etisalat, 2013b).
74 In fact, the number of networks with CAMEL that allow Etisalat prepaid roamers rose from 165 networks in 2010 as in Table (5.4) to 280 as of May 2013 (Etisalat, 2013a).
75 In Indian regional markets, we noted four merger/acquisition events in Table (5.5). However, our dataset shows the event partners as one network, contrary to other countries where the dataset would still show the event partners as distinct networks. We conclude that those merger/acquisition events took place across-regions, not within region, perhaps to allow one network to enter a regional market. Because such events do not affect the number of existing networks or horizontal competition, none of the Indian networks is considered to have multinetworks.

one in 2009-2011 for each network. For the ownership of more than one network (due to probably licensing reasons) the dummy variable takes the value of one in the full study period, zero otherwise. For example, in Hong Kong, H3 owns 2G and 3G networks, so the dummy value is one for the years 2008-2011 for each network.

Summary statistics are provided in Table (5.6) for the dataset variables. We have 552 visited networks observed over the years 2008-2011; thus the dataset has 2,208 observations. The number of (active) visited networks that sold any roaming unit increases from 438 in 2008 to 539 in 2011.

Any difference between active networks and the number of observed visited networks, 552, should mean some networks did not host Etisalat subscribers in the given year. This can be due to not being licensed that year, or due to other reasons such as Etisalat roamers chose not to roam on them or Etisalat did not have an IOT agreement with them. It is also possible that these networks were in markets not visited by the Etisalat roamers in the given year.

The increase in the number of active networks over time indicates the expansion of Etisalat IOT agreements. This is true despite the existence of Etisalat's preferred networks (Alliance or Cross-owned). Therefore, the existence of preferred networks did not lead to exclusivity, which confirms conventional assumptions that mobile networks are not perfect substitutes.

Our dataset identified 204 distinct visited markets in 182 countries, where some countries (e.g. India) have regional markets. Etisalat roamers visited 191 in 2008, 193 in 2009, 201 in 2010, and 202 in 2011. Notice on average, each market has 2.7 observed visited networks. This reflects the oligopoly nature of the mobile industry.

The means in Table (5.6) do not change for Alliance or CAMEL because the dummy variable does not change over time. In contrast, Cross-owned and Multinetwork vary overtime, but as can be seen, the mean does not vary by much. Overall, on average, cross-owned networks represent 5.4% of observations, roaming alliance networks represent 8%, networks with CAMEL represent 29.9%, and 5.3% of networks own multinetworks within their markets.

Table (5.6) also shows a downward trend in average quantity of outgoing and incoming calls[76]. With SMS, apart from the spike in 2009, a downward trend is also apparent. On the other hand, there is an upward trend in data roaming.

76 The total of outgoing/incoming calls also has a downward trend.

Table (5.6) Dataset summary statistics.

Summary statistics		2008	2009	2010	2011	All
Observations		552	552	552	552	2208
No. of active visited networks		438	448	516	539	1941
Mean of Cross-owned networks by Etisalat (1 if Yes; 0 otherwise)		0.053	0.054	0.054	0.054	0.054
Mean of Alliance networks to Etisalat (1 if Yes; 0 otherwise)		0.08	0.08	0.08	0.08	0.08
Mean of networks with CAMEL allowing Etisalat prepaid (1 if Yes; 0 otherwise)		0.299	0.299	0.299	0.299	0.299
Mean of Multinetwork (networks horizontal ownership) (1 if Yes; 0 otherwise)		0.043	0.054	0.056	0.06	0.053
Outgoing calls	Mean of Quantity (1000'minutes)	Redacted	Redacted	Redacted	Redacted	Redacted
	Mean of Price (AED/minute)*	Redacted	Redacted	Redacted	Redacted	Redacted
Incoming calls	Mean of Quantity (1000'minutes)	Redacted	Redacted	Redacted	Redacted	Redacted
	Mean of Price (AED/minute)*	Redacted	Redacted	Redacted	Redacted	Redacted
SMS	Mean of Quantity (1000'SMS)	Redacted	Redacted	Redacted	Redacted	Redacted
	Mean of Price (AED/SMS)*	Redacted	Redacted	Redacted	Redacted	Redacted
Data roaming	Mean of Quantity (1000'MB)	Redacted	Redacted	Redacted	Redacted	Redacted
	Mean of Price (AED/MB)*	Redacted	Redacted	Redacted	Redacted	Redacted

* Constant prices, using 2007 as the base year (NBS, 2013).
- Data redacted as per NRA-UAE's data confidentiality policy.

Etisalat roamers travelled to many countries, as the following map suggests. However, visited markets have high variations in their total quantities sold to Etisalat roamers. Based on outgoing calls per visited market during the study period, the mean is around 786 thousand minutes, while the median is around 126 thousand minutes. In the next chapter, we will show how heterogeneity of visited markets, (which is assumed to be a sampling problem), impacts our estimations. The shading areas of the world map in Figure (5.1) illustrate the highly visited markets.

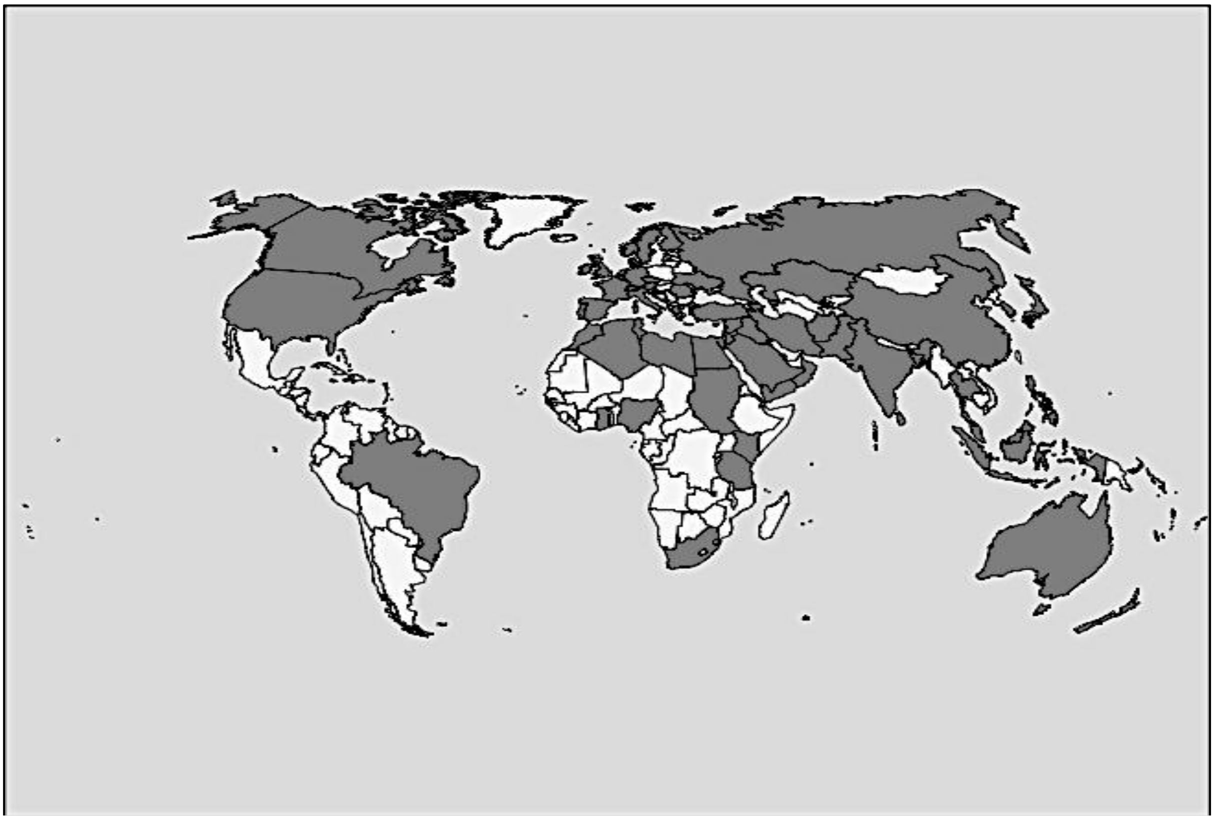

Figure (5.1) Map for highly visited markets by Etisalat roamers during the years 2008-2011.
- Based on market total minutes of outgoing calls above the median.
- The map does not show small size countries or regions such as the Indian regions.

We use CPI deflator[77] to adjust prices for inflation. There is no substantial change in the price movement if, instead, current prices were used[78].

In Table (5.6), the (average wholesale) prices a visited network charged to Etisalat for a minute of outgoing call and a MB of data roaming show a downward trend. The year 2010 witnessed an increase in the means for a minute of incoming call and an SMS. Wholesale prices differ by roaming service due to probable differences in marginal costs. The highest price is for a MB of data roaming, followed by a minute of outgoing call.

There are a few price outliers. The main outlier is an Etisalat cross-owned visited network that charged a very high price for outgoing calls and SMS. The other outliners involve zero pricing, which can be due to pricing policies. Few visited networks did not charge Etisalat when usage was very low. This practise is a known bill-and-keep arrangement in interconnection agreements.

77 The price in year *t* is multiplied by 100/CPI_t.
78 The CPI is 100 in 2007 (the base year), where inflation rose afterwards due to rising property prices. However, during our study period (2008-2011), inflation grew by less than 2%, as follows: CPI is 112.25 in 2008, 114.0 in 2009, 115.0 in 2010, and 116.01 in 2011 (NBS, 2013).

However, there are many observations with zero pricing for incoming calls despite high quantities. This might be due to the fact that with incoming calls, foreign networks are already compensated by international settlement rates because a roaming incoming call requires international calling: Etisalat pays such settlement rates to route the call back to the visited network. This explains why Etisalat sets a positive retail price despite a very low (IOT) wholesale price.

Visited networks in the GCC charged lower wholesale prices for outgoing and incoming calls than the average in Table (5.6); while they sold more units than the average in each of the four roaming services. Although the Intra-GCC Roaming Charges regulation is supposed to reduce wholesale prices charged between networks in the GCC, we show in Figure (5.2) that such regulation is ineffective during our study period.

In Figure (5.2), clearly the GCC networks charged Etisalat wholesale prices for outgoing calls above the GCC caps, except for one network[79]. This finding shows how regulation across different jurisdictions is difficult to enforce. Therefore, we can carry on the assumption that wholesale prices in the dataset are free from regulation.

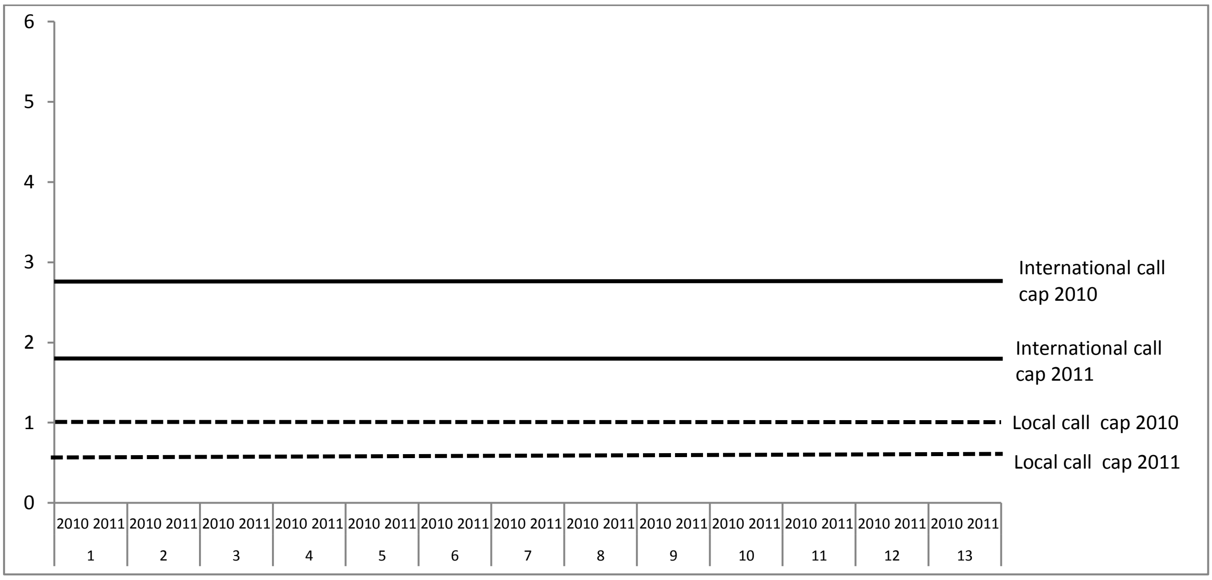

Figure (5.2) Wholesale price for a minute of outgoing call by GCC visited networks by year.
- The horizontal lines represent wholesale price caps set by the Intra-GCC Roaming Charges for outgoing calls[80].
- The years 2010-2011 are considered because they are relevant in the NRA-UAE's directive (NRA-UAE, 2010).
- Data redacted as per NRA-UAE's data confidentiality policy.

79 The wholesale price of network 10 in Figure (5.2) is still above the local call price cap. Charging below the international call price cap is not a response to regulation; rather, it is in line with prior periods (before regulation): network 10 increased its wholesale price compared to the previous two years before regulation (i.e. 2008-2009).

80 GCC price caps are converted from SDR to AED according to the effective dates in the NRA-UAE directive (NRA-UAE, 2010), using the SDR Valuation History for the exchange rate of the US dollar ($0.27=1 AED) from the International Monetary Fund website (www.imf.org).

For later use, we will create a dummy variable for Etisalat uniform retail policy (one for the years 2010-2011; zero otherwise). This variable will be used as an explanatory variable for estimating the impact of Etisalat retail policy shift (from discriminatory to uniform) on wholesale pricing of visited networks and steering by Etisalat.

Furthermore, we look at correlations between the four roaming services in terms of prices, quantities and market shares (computed by dividing a visited network's quantity by the total quantities of the relevant geographic market). This is done to know how interdependent the services are, especially outgoing and incoming calls, following the EC (2006).

In Table (5.7), there are missing observations in wholesale prices due to some networks being inactive in some of the years. The missing observations in market shares are due to some geographic markets having a zero total quantity for some roaming services in some of the years, mainly for MB of data roaming.

Table (5.7) Correlations between roaming services.

Correlation of quantities (2,208 observations)	Outgoing calls	Incoming calls	SMS	Data roaming
Outgoing calls	1	-	-	-
Incoming calls	0.986	1	-	-
SMS	0.305	0.320	1	
Data roaming	0.566	0.526	0.082	1

Correlation of average wholesale prices (1,344 observations)	Outgoing calls	Incoming calls	SMS	Data roaming
Outgoing calls	1	-	-	-
Incoming calls	0.018	1	-	-
SMS	0.310	0.478	1	-
Data roaming	0.284	0.117	0.419	1

Correlation of market shares (1,851 observations)	Outgoing calls	Incoming calls	SMS	Data roaming
Outgoing calls	1	-	-	-
Incoming calls	0.982	1	-	-
SMS	0.972	0.971	1	-
Data roaming	0.834	0.811	0.800	1

As seen in Table (5.7), all correlations are positive; this concurs with our preliminary intuition that the four services are non-substitutes. Notice the high significant correlation between the quantities of outgoing and incoming calls, while the correlation of their wholesale prices is very low, reflecting the gap in prices (i.e., in Table (5.6), the average wholesale price is 6.36 AED for a minute of outgoing call compared to 0.88 AED for a minute of incoming call). We relate the gap in prices to the involvement of another wholesale price agreement, which is international settlement rate agreement, as follows.

If an Etisalat roamer makes an outgoing call, the visited network bears the cost of call origination. In addition, the visited network bears the cost of call termination, which is paid as an access price if the call is destined to another network. If the terminating network is located in a different country, such as Etisalat, the visited network has to pay an access price called international settlement rate, which tends to be above the actual cost of terminating the call. To cover such costs, the visited network sets high IOTs for outgoing calls.

In comparison, if an Etisalat roamer receives an incoming call, the visited network bears the cost of call termination on its own network, without paying any access price. Instead, the visited network receives an international settlement rate from Etisalat[81]. Therefore, the visited network charges low IOTs for incoming calls. This explains the gap in wholesale prices between outgoing and incoming calls.

With roaming incoming calls, Etisalat pays the settlement rates, thus it charges a positive retail price for incoming calls. If Etisalat does not charge for incoming calls, its subscribers may view incoming and outgoing calls as substitutes; and we would expect a negative correlation between quantities of incoming and outgoing calls. The EC (2006) believes that a home network has an incentive to keep a high retail price for incoming calls; otherwise, consumers would prefer to receive the call instead of originating it.

Furthermore, the low correlations between the prices suggest differences in actual marginal costs between the four roaming services. Notice the high correlations between market shares, suggesting visited networks would have similar market shares across the roaming services they provide to roamers.

81 This is because the call is routed from Etisalat in the UAE to the visited country. The visited network that handles the incoming call either receives the full settlement rate from Etisalat, or a portion of it if a third party is involved (e.g. the call is routed through another network in the same country which has an international gateway).

5.6 Discussion

We will be using the dataset described in this chapter for the empirical estimations in the proceeding chapters, for the sake of understanding visited networks wholesale competition.

Given that most interconnection prices (including international settlement rates with foreign networks) are widely regulated, our dataset has information on wholesale prices (IOTs) assumed to be set freely by market forces. Additionally, the dataset is comprehensive as it includes all foreign networks visited by subscribers of the same home network. Etisalat witnessed a shift from discriminatory retail policy to uniform. Such a policy shift is assumed to make roamers shift the network-selection-modes of their mobile handsets from manual to automatic, by which steering by Etisalat is assumed possible.

Etisalat retail policy shift is assumed to influence the demands for outgoing calls because outgoing calls experienced price restructuring as compared to the rest of roaming services. In addition, outgoing calls were not offered in roaming packages; thus the roamer is assumed to leave his handset on automatic mode, enabling steering by Etisalat.

In contrast, incoming calls and SMS generally experienced uniform retail (within visited countries) prior to the policy; while information is unavailable on retail prices for data roaming prior to the policy. Incoming calls and data roaming are offered in roaming packages that can be purchased only from alliance networks, thus they may involve network manual selection by roamers. Moreover, at the wholesale level, outgoing calls have positive wholesale prices compared to incoming calls that widely involve a zero-pricing policy. Furthermore, quantities and prices for outgoing calls seem to be less affected by the time trend in Table (5.6), compared to the rest of roaming services.

The next chapters will focus on quantities and wholesale prices of outgoing calls, similar to the studies done by the NRAs in the EU. We will test how wholesale competition is affected by the shift in Etisalat's retail policy and by the fact that Etisalat has preferred visited networks. More specifically, we will estimate the demand for visited networks by Etisalat roamers; and test for the impact of Etisalat's uniform retail policy shift on wholesale prices and market shares. The last part will investigate whether steering by Etisalat was exercised, and to what extent it enabled Etisalat to cause downward pressures on the wholesale prices it paid to visited networks.

Chapter (6). Demands For Visited Networks

International roaming services are governed by Inter-Operator Tariff (IOT) agreements, which are a type of two-way access/interconnection wholesale agreements. Such agreements entitle the subscribers of a home network to use their mobile phones while roaming on foreign networks.

For the aim of understanding wholesale competition under IOT agreements, we make use of the dataset described in Chapter (5) for empirical estimations in this chapter and the next two chapters. The dataset has usages and wholesale prices (IOTs) of all foreign networks visited by Etisalat roamers.

The study period witnessed Etisalat shifting from discriminatory retail pricing policy (during 2008-2009), whereby prices would differ by visited networks, to uniform policy (during 2010-2011). The two different retail policies[82] are the main theme of the theoretical modeling in Chapters (3) and (4); thus this dataset will be used to test the hypotheses derived from the theoretical predictions.

In this chapter, we estimate the demand by Etisalat roamers for visited networks to understand their responsiveness in a foreign land to price and non-price characteristics of visited networks before and after Etisalat uniform retail policy. The results from demand estimation will be compared to results from policy-impact analyses of policy on market outcomes in the next two chapters, where we will explore the relationship of wholesale pricing (IOTs) and market structure, and the effectiveness of steering in the presence of the policy.

This chapter is planned as follows. Section (6.0) introduces the structural model to be used in this chapter. Section (6.1) introduces the dataset. Section (6.2) outlines the empirical methodology. Demand estimation results are discussed in Section (6.3). The chapter concludes in Section (6.4).

82 Retail prices are discriminatory or uniform across visited networks, not across roamers.

6.0 Simple Logit Demand

In this chapter, we use a structural model to estimate Etisalat roamers' demands for visited networks, borrowing from discrete choice models of product differentiation. The simple logit demand model assumes that demand can be described by a discrete choice model where prices are endogenously determined by price-setting firm(s). The implied mean utility level from product *i* is found by inverting the market share equation, which is then used as the dependant variable acting in similar way as the observed output quantities of homogenous goods (Berry, 1994). Consumers' tastes are assumed homogenous, so the marginal utilities of product characteristics are identical for all consumers.

The following explanation borrows from section (5.4.2) in Belleflamme and Peitz (2010). Suppose the consumer can choose between *n* products in a given market and an outside good, $\overline{v_0}$, which gives him zero utility. Market share for product *i* can be written as

$$s_i = \frac{exp\{\overline{v_i}\}}{1 + \sum_{j=1}^{n} exp\{\overline{v_j}\}},$$

where all consumers have the same mean utility level, $\overline{v_i}$. The mean utility takes the form

$$\overline{v_i} = -\,\alpha p_i + \beta x_i + \xi_i\,,$$

where p_i is the price of product i, x_i is a vector of observed product characteristics, and ξ_i contains all unobservable product characteristics. ξ_i is considered the error term in the following transformed market share equation,

$$ln(s_i) - ln(s_o) = -\,\alpha p_i + \beta x_i + \xi_i\,, \tag{6.0.1}$$

where s_o is share of the outside good. Eq. (6.0.1) represents the simple logit demand, which can be estimated using linear regression. The price elasticities are given by

$$\eta_{ij} = \frac{\partial s_i}{\partial p_j}\frac{p_j}{s_i} = \begin{cases} -\alpha p_i\,(1 - s_i) & \text{if } i = j \text{ (i.e. own price elasticity),} \\ \alpha p_j s_j & \text{otherwise (i.e. cross price elasticity).} \end{cases} \tag{6.0.2}$$

Two major limitations of the simple logit model lie in its estimation of elasticities. With respect to the own price elasticity, the functional form implies that the lower-price firm must enjoy a higher markup (i.e. elasticity is low if price is low, and high if price is high). In addition, the substitution pattern among products may be unrealistic (i.e. a product can have identical cross price elasticities).

Alternative discrete models of product differentiation, for instance the random coefficients logit, overcome the limitation on cross price elasticity. Given our lack of information on visited networks' nests/groups [83], brands fixed effects [84], and on Etisalat roamers demographics[85], we will follow the simple logit demand model.

6.1 The Dataset

The dataset[86] has aggregated traffics (hereafter quantities) used by Etisalat roamers while roaming on foreign networks, which were annualized to remove the seasonality effects in the data. These quantities are provided on the visited network level per year for each of the four roaming services (minutes of outgoing calls and incoming calls, SMS and MB of data roaming), along with their relevant average wholesale prices.

The dataset has all foreign networks visited by Etisalat subscribers (prepaid and postpaid) around the world during the years 2008-2011. There are 552 visited networks, and thus we have 2208 observations. The number of active visited networks is less than 552, which means some visited networks did not sell any roaming unit in a given year, due to entry/exist or other unknown reasons.

The four roaming services (outgoing calling, incoming calling, SMS and data roaming) are assumed to be separate services (i.e. non-substitutes to one another)[87], where the roamer can buy each service from any visited network.

During the study period, Etisalat shifted its retail policy from (generally) discriminatory retail prices (in the years 2008-2009) to a uniform retail policy (by region or zone) (in the years 2010-2011). We assume outgoing calling is exposed to the effects of the uniform retail policy. The other services, to a great extent, experienced retail price uniformity during the whole study period[88]. Furthermore, incoming calls and data roaming were offered in optional

83 Possible nests can be the radio technology used by visited networks in a given market (e.g. CDMA and GSM; or 2G and 3G). However, any technology would typically handle roaming outgoing calls with similar quality.
84 It is difficult to know the brands for the 552 mobile networks visited by Etisalat roamers, mainly because of language barriers to access their information. Moreover, many mobile networks have multiple names/brands; and we found many networks rebranded themselves (e.g. Orange and T-Mobile to Everything Everywhere in UK; Vimpelcom to Beeline in Russia, etc…).
85 Such information may help to account for the heterogeneity of Etisalat roamers in different visited markets (e.g. in market r, roamers distribution by postpaid/prepaid, business/consumer, male/female, etc…), which is unavailable in our case. For this information to be relevant, it must be provided per visited market.
86 See Chapter (5) for a description of the dataset.
87 See Section (1.1) on definition of roaming and Chapter (2) on literature review.
88 See Section (5.2) on Etisalat retail prices.

roaming packages that would apply on alliance networks and hence may require manual network selection, which would override steering by Etisalat. Therefore, for the sake of all estimations in this chapter and the next two chapters, we only focus on the data related to outgoing calls.

In our dataset, we observe average wholesale prices[89]. During the discriminatory policy period, retail prices are assumed to be a markup over the (observed) wholesale prices; thus variation in retail prices should reflect variations in wholesale prices. During the uniform policy period, retail prices became uniform based on three zones (GCC neighbouring countries, the rest of the Arab states, and the rest of the world).

We do not use the zonal retail prices in demand estimation because they do not have enough variation for analysis[90]. Therefore, we will rely on wholesale prices provided in the dataset because they vary by visited networks. With respect to the choice between visited networks in the case of uniform retail price, roamers may be steered by Etisalat to preferred visited networks.

Visited networks are assumed unconstrained by regulation in choosing their wholesale prices to Etisalat, because, during the study period, no wholesale regulation existed that involve Etisalat[91]. Moreover, visited networks did not price discriminate between Etisalat's subscribers (e.g. postpaid versus prepaid)[92].

Etisalat roamers are assumed to be aware of retail prices, since Etisalat is obliged by NRA in the UAE to send SMS to its travelling subscribers informing them of the applicable retail prices in a given visited market[93].

Etisalat retail policy shift is assumed to make its roamers indifferent in choosing between visited networks based on price, allowing Etisalat to steer to its preferred networks. That is, if roamers are indifferent, their handsets would be on automatic mode which allows for steering.

89 Wholesale prices were provided to us in averages: total IOT bill divided by total quantity for each roaming service.

90 A better way is to get average retail prices (total retail revenues divided by total quantity), which was not provided to us. See Section (5.3) on the original data requested from Etisalat.

91 Intra-GCC Roaming Charges regulation within the GCC countries, which addresses wholesale prices charged to Etisalat, was ineffective during the study period (see Section 5.5).

92 This statement was communicated verbally by Etisalat. Visited networks charge Etisalat for the total usage of its roamers. On the other side, Etisalat price discriminates at the retail level, where the retail price is usually lower for postpaid subscribers (see Section 5.2).

93 In line with the thesis focus on wholesale competition, the empirical chapters ignore retail competition in the UAE. In light of the non-existence of mobile number portability in the UAE during our study period, we assume retail competition is absent because the main purpose of international roaming is to use the same home number abroad.

6.1.1 Visited Networks Characteristics

Additional to the variables in the dataset of wholesale prices and quantities, we included dummy variables on visited networks characteristics that are available in Etisalat's website. These characteristics are assumed to be the key non-price information relevant to roamers' decisions in choosing between (foreign) visited networks.

The first characteristic is the networks that are cross-owned by Etisalat, which represent 5.4% of visited networks. These networks usually bear the name of Etisalat (e.g. Etisalat-Egypt and Etisalat-Nigeria), and thus roamers are assumed to be familiar with cross-owned networks.

In addition, roamers may care about cross-owned networks during the discriminatory retail price period. This is because, as predicted in the cross-ownership model (Section 4.1.2), a cross-owned network should charge wholesale price equivalent to its marginal cost, which should translate into lower retail prices.

All cross-owned networks operate in developing countries. Among which is Etisalat-DB, which by itself represents half of cross-owned networks. Etisalat DB operated in 15 regional markets in India, and has very low market share in each Indian regional market. This is a structural problem for this specific network as it is new in the Indian mobile industry. The rest of cross-owned networks were acquired recently by Etisalat or launched with a new mobile licence. Therefore, cross-owned networks should be in the early phase of operation, where expansion of coverage rollout might be their priority.

The second characteristic is the networks that are roaming alliance to Etisalat, representing 8% of visited networks. These networks operate in different markets that seem to be frequently visited by Etisalat roamers. Etisalat would include the name of its alliance networks in the SMS sent to roamers, and thus roamers are assumed to be familiar with alliance networks.

By roaming on alliance networks, Etisalat roamers can buy roaming packages (at better retail prices) for incoming calls and data roaming. Nonetheless, these packages do not apply to outgoing calls, which is the focus of all empirical estimations. Given independence between roaming services, when Etisalat shifted from discriminatory retail policy to uniform, roamers should be indifferent regarding the prices of outgoing calls. We proceed by assuming limited take-rate for roaming packages, and thus as far as outgoing calls are concerned, the impact of such packages on roamers' choice between visited networks during the uniform policy should be very limited[94].

The third characteristic is the networks that allow Etisalat prepaid roaming, which represent around 30% of visited networks. Etisalat prepaid roamers can only roam on these networks, and such networks must have a CAMEL technology[95]. As the service is costly to the home network[96], Etisalat charges a higher retail for prepaid roamers compared to postpaid; while visited networks do not price discriminate at the wholesale level[97].

Furthermore, two time related variables are used as non-price characteristics. The first is the year discrete variable that helps to capture the effect of time. Time may affect demand if technological improvement improves the quality of network (e.g. coverage). The second is a dummy variable for the existence of Etisalat uniform retail policy. This policy is likely to be associated with consumer discretion in demand across visited networks: demand-side substitution before the policy and supply-side substitution via steering after the policy. In other words, the policy should help us know why a visited network is chosen[98].

6.1.2 Variables

The dataset has 2208 observations, consisting of 552 visited networks in each of the four years (2008-2011) in 204 different markets. The relevant notations and variables used in demand estimations are listed in Table (6.1) below.

The year variable, *YEAR*, is used to control for the effect of time. The policy dummy variable, *POLICY* (1 if uniform; 0 otherwise), will be used to estimate the impact of Etisalat shift in its retail policy (from discriminatory to uniform) on outcomes. *POLICY* will be interacted with networks characteristic dummy variables to understand the impact of the characteristics on demand before and after the uniform policy.

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94 For example, the roamer can make outgoing call while roaming on network 1 and receive a call while roaming on network 2. His selection is assumed to be manual when price mattered during the discriminatory policy period. Under uniform policy, the only plausible way not to choose automatic mode based on prices would be for opting in roaming packages. Our assumption regarding the independence between roaming services still hold, but once the roamer manually selected a network to buy a roaming package (which does not include outgoing calls), it is implausible to assume he would switch his handset to automatic in order to make outgoing calls. However, we need the independence of roaming services to hold in order to simplify the modelling; so we proceed with assuming limited take-rate for roaming packages.
95 CAMEL technology is a real-time system that requires the communications of both home network and the visited network to deduct instantly from the balance of the prepaid roamer according to his usage (European Parliament, 2006).
96 This is according to a study by European Parliament (2006).
97 This statement was communicated verbally by Etisalat.
98 The choice between visited networks after the policy will be studied in depth in Chapter (8), where the effectiveness of steering is investigated through interacting the policy with the relative price of the visited network to the market arithmetic mean.

For demand estimation, we derive the market shares for the inside good (visited networks in a given market) and the outside good in the market, using the multiplier explained in Section (6.2.2).

Table (6.1) Notations and variables related to estimations.

Notation	**Description**
j	Subscript for visited networks, where (*j=1,…,552*).
t	Subscript for year, where (*t=2008,2009,2010,2011*).
r	Subscript for geographic market, where (*r=1,…,204*).
Time variables	**Description**
YEAR	Discrete variable for the study years, where *(1=2008, 2=2009, 3=2010, 4=2011)*.
POLICY	Dummy variable equals 1 for the years 2010-2011 (when Etisalat implemented its uniform retail policy); 0 otherwise.
Price variables	**Description**
$PRICE_{jt}$	*j*'s average wholesale price per minute of outgoing call in year *t* (in constant AED with 2007 as base year).
Visited network's characteristic variables	**Description**
$CROSSOWNED_{jt}$	Dummy variable equals 1 if *j* is cross-owned by Etisalat in year *t*; 0 otherwise.
$ALLIANCE_j$	Dummy variable equals 1 if *j* is a roaming alliance to Etisalat; 0 otherwise.
$CAMEL_j$	Dummy variable equals 1 if *j* allows Etisalat prepaid roaming; 0 otherwise.
Market shares variables	**Description**
s_{jrt}	*j*'s market share in minutes of outgoing calls in market *r* and year *t*.
s_{ot}	Outside good market share in year *t*.

All prices provided in nominal AED are converted to constant prices using 2007 as the base year (NBS, 2013). All results do not statistically change if we use other base years, or if we use nominal prices because inflation is very low during the study period[99]. In addition, three observations have extreme price values: two observations have zero prices due to the bill-and-keep arrangement for very low quantity; and one observation for a cross-owned network by Etisalat with an abnormal price. These three observations will be excluded in all estimations of this chapter and the next chapters.

99 Inflation during the study period grew annually by less than 2% (see Section 5.5).

6.1.3 Sampling Problem

During the years 2008-2011, Etisalat roamers visited 204 different geographic markets (in 182 countries)[100]. There are high variations between visited markets in the total quantities roamers consumed. With outgoing calls, the mean per visited market is around 786 thousand minutes while the median is around 126 thousand.

Later in the chapter, we will compare results for observations below or equal the median (labeled Low Visited Markets) to results above the median (labeled High Visited Markets), where we find opposite predictions with regards to roamers' price sensitivity.

Roamers seem to be price insensitive in the low visited markets, which may suggest that those markets are hosting a different type of roamers, for example diplomats or businessmen. Therefore, we are concerned that our dataset includes heterogeneous observations arising from having two different samples.

To include all observations in a demand estimation, one should consider the use of a good exogenous[101] variable to weight the dataset. Tourism statistics in those visited markets may not necessarily tell us about the travelling behaviors of the UAE people. According to our dataset for example, the Afghani market sold more roaming quantities than the markets of the Channel Islands. In addition, judging from distance to the UAE can be misleading. For example, the UK market sold more roaming quantities than the Iranian market. By looking at visited markets, it is not obvious if a macro-level statistics (e.g. GDP per capita) can explain why markets differ in hosting Etisalat roamers.

The number of UAE travelers per visited markets seems to be a good weight if we are to include all observations to estimate demand, but is currently unavailable. In the demand estimation, we will be focusing on highly visited markets.

6.2 Empirical Methodology

This section outlines the empirical methodology used in demand estimation. First, market definition is explained. Second, the estimation model and hypotheses to be tested are

100 Some countries (e.g. India) have regional markets.
101 Thanks to Professor Eugenio Miravete for this point.

presented. Finally, the endogeneity problem is addressed, where instrumental variables are proposed.

6.2.1 Market Definition

This section defines the relevant market in order to derive market-related variables (e.g. market size and market shares). We rely on the EC's definition of this market, which is "*wholesale national market for international roaming on public mobile networks*"[102] (O.J., 2003).

In the dataset, we recognize 204 geographic markets[103] visited by Etisalat roamers over the span of the study period. The public mobile networks are the licensed networks in a given market that provide wholesale roaming services to home networks.

The source of roaming utility for an Etisalat subscriber is assumed to come from consuming minutes of outgoing calls while roaming abroad with the same home phone number. His outside options include, for example, calling from public payphones/hotel, or calling with visitor-SIM cards. Outside options also include the refrain from making roaming outgoing calls. All such outside options are included in the outside good which gives the roamer zero utility.

A precondition to making an outgoing call is to first roam on a visited network. Because the unit of observation in our dataset is the visited network, the product market for Etisalat roamers is the visited network that sold outgoing call minutes. Etisalat roamers can substitute between visited networks in the relevant geographic market based on price and non-price characteristics.

Therefore, for Etisalat roamers, the geographic market is the visited market, and the visited networks are the product market. Notice our market definition involves Etisalat as the home network. This is to say that for the same visited networks and market, the demands by Etisalat roamers is different from the demands by another home network, where the difference can be, for example, in market sizes and incomes of the roamers. Visited network j is assumed to set different wholesale prices to different home networks, depending on their different demands and j's two-way vertical relationships (i.e. IOT agreement) with each home

102 This definition was known as Market (17) in the EC list of recommendation on relevant markets. In 2007, the EC removed Market (17) from this list after it issued roaming regulation (see Section 2.1.2).
103 See Section (5.4) about the method used to define geographic markets. See also Appendix (G) for a list of all visited networks along with their relevant geographic markets.

network, which may involve preferential wholesale prices. This point will be revisited in details when possible instrumental variables are proposed in Section (6.2.4).

6.2.2 Market Size

Because the aim of all estimations is to understand upstream competition, the market, as defined in Section (6.2.1), is related to the visited networks in each visited market. Therefore, market size is the sum of the quantities (i.e. all minutes of outgoing calls) in a given market and year[104].

The outside good is included in the market size for demand estimation. We lack information on Etisalat roamers' outside options. Therefore, we use a multiplier to calculate market size. Due to high variations in quantities between visited geographic markets[105], market sizes need to differ according to visited markets.

In order to calculate market size, we use a multiplier, $m_{t,}$, to multiply the market quantity in a visited market, $q_{rt,}$, which gives the market size in that market, M_{rt} (r indexes market and t indexes year). Market share for the outside good will be the same across all geographic markets.

The choice on the multiplier is justified as follows. First, we look at the typical usage inside the home country, the UAE, which we consider as what roamers would consume had they stayed inside the UAE (i.e. did not travel). We use aggregate minutes of mobile-to-mobile calls made by Etisalat subscribers inside the UAE for each of the study years, denoted by MTM_t. The difference between the typical usage inside the UAE, MTM_t, and the aggregate roaming usage, denoted by Q_t, is deemed to be the outside good. The outside good should reflect what roamers consumed of the outside options (e.g. calling from public payphones abroad) or their refrain from making roaming outgoing calls. m_t is thus derived by dividing MTM_t by Q_t.

However, we must attribute some of MTM_t for international roaming, because not all Etisalat subscribers can be assumed to have travelled abroad. A proportion v_t of MTM_t is attributed to roaming, where v_t is the estimated proportion of roamers in Etisalat total subscribers.

104 If, instead, market size is considered as the aggregate quantities of all the 204 markets, then the demand estimation would focus on demands for visited markets (e.g. hot destinations), not for visited networks which is the focus in understanding upstream competition.
105 See the sampling problem in Section (6.1.3).

We use the weights of postpaid/prepaid subscribers in roaming usage[106]: around 85% of quantity was made by postpaid subscribers. For each year, we weight the number of Etisalat subscribers by roaming behaviours (e.g. 85% postpaid; 15% prepaid) and divide them by Etisalat total subscribers to get v_t.

Table (6.2) summarizes the calculations related to market size. As can be seen from the table, around 22% of Etisalat subscribers are estimated to be roamers during the study period, which is plausible. The outside good market share varies in each year, and its difference from one represents the inside good market share for any visited market.

Table (6.2) Calculations related to market size.

Relevant calculations	2008	2009	2010	2011
Estimated proportion of roamers in total subscribers, v_t	0.216	0.224	0.226	0.230
Market size multiplier: $m_t = \frac{v_t \times MTM_t}{Q_t}$	18.50	20.58	19.54	19.40
Outside good market share: $s_{ot} = \frac{m_t - 1}{m_t}$	0.946	0.951	0.949	0.948

6.2.3 Estimation Model

Etisalat roamers' mean utility from roaming on visited networks is regressed on price and visited networks' characteristics (cross-owned, alliance and with CAMEL), which are observed by the roamers and by the econometrician. Other characteristics of visited networks observed by the roamers but not by the econometrician enter the error term of the model. The regressors will also include time variables (year and Etisalat uniform policy dummy variable), and the characteristics interacted with the policy.

The model for the simple logit demand is given by Eq. (6.1), which is estimated by Ordinary Least Squares (OLS) and Second Stage Least Squares (2SLS). Subscript for year is dropped as data is pooled, and market subscript is dropped for convenience.

$$\begin{aligned} ln(s_j) - ln(s_o) = {} & \beta_0 + \beta_1 YEAR + \beta_2 POLICY + \beta_3 PRICE_j \\ & + \beta_4 CROSSOWNED_j + \beta_5 ALLIANCE_j + \beta_6 CAMEL_j \\ & + \beta_7 POLICY \times CROSSOWNED_j + \beta_8 POLICY \times ALLIANCE_j + \beta_9 POLICY \times CAMEL_j + \xi_j, \\ & (j = 0, 1, \ldots, 552). \end{aligned} \tag{6.1}$$

106 This information does not belong to our dataset. It is provided by NRA-UAE's for Etisalat roamers in GCC countries.

$ln(s_j)$ is the natural log of the market share of visited network j; $ln(s_0)$ is the natural log of the outside good share; and ξ_j is the error term. All variables are as explained in Table (6.1). The product $j = 0$ refers to the outside good.

The price used in Eq. (6.1) is the wholesale price charged by visited network j to Etisalat in year *t*. Any retail price markup, due to probably retail price discrimination between postpaid/prepaid, is unobserved and hence enter the error term.

As shall be see in the results, the price coefficient is only negative and significant in the highly visited markets, due the sampling problem discussed in Section (6.1.3). Price endogeneity problem and proposed instrumental variable are discussed in the next section.

We expect visited networks that are preferred by Etisalat (i.e. cross-owned or roaming alliance) to charge Etisalat lower wholesale prices, and have higher market shares through demand-side substitution when retail price is discriminatory. Because steering is assumed relevant only if retail price is uniform, we expect Etisalat after the policy, if its steering is effective, to raise the market shares of its preferred networks (i.e. supply-side substitution).

We also expect visited networks that allowed Etisalat prepaid roaming (i.e. with CAMEL), to have higher market share because they host Etisalat prepaid roamers in addition to its postpaid.

The choice on the market size multiplier affects the constant term in Eq. (6.1). Nonetheless, the own price elasticity is sensitive to the definition of the market. If the market is defined more broadly, the own market share decreases, and, as a result, own price elasticity increases in absolute value (Slade 2009).

After estimating Eq. (6.1), the own price elasticity is given by

$$\eta_{jj} = \widehat{\beta_3}\, PRICE_j \left(1 - s_j\right), \quad (j = 0, 1, \ldots, 552). \tag{6.2}$$

6.2.4 Endogeneity Problem

This section addresses the endogeneity problem known in demand estimations, such as in Eq. (6.1), and proposes possible instrumental variables (IVs) to overcome this problem.

In estimating a demand model using OLS estimator where price is used as a regressor, the covariance of price and the error term of the model is not zero. This is because quantity and price are determined simultaneously in the market, such that a shock in demand or supply will affect the equilibrium quantity and price. In this case, price is not exogenous, which means OLS provides inconsistent estimates for the model.

Our dataset lacks a possible instrument for price. Market structure variables, such as the number of visited networks, affect market shares (e.g. the higher the number of visited networks, the lower should be the own market share). The error term in Eq. (6.1) involves the unexplained variations in market shares, which can be affected by the number of networks. Therefore, the number of networks[107] can be correlated with the error term; hence does not suit to instrument for price.

Another reason that the number of networks can be correlated with the error term of demand comes from our assumptions on the error term. The unobserved network's characteristics by the econometrical are assumed to be captured by the error term. Quality of network coverage is an example of unobserved characteristics, which can be affected by the number of networks as a response to competition; hence correlated.

Furthermore, regional dummies, such as GCC and Europe, have effects on prices[108]. They can be a proxy for cost at the region-level (i.e. group of markets), but not on the market-level or network-level[109]. We sought external information for a better cost proxy, as explained next.

In industrial organization literature, the price of a product in market (or city) A can be an instrument for the price of the same product in market B (Hausman et al., 1994)[110]. This requires the prices of the products in markets A and B to be correlated through cost, and the price in market A (B) must be uncorrelated to the error term of the demand in market B (A).

The justification is as follows. On the supply-side, the product being sold in two different markets has a common marginal cost such that a cost shock will shift the prices in both markets[111.] On the demand-side, the fact that the product is being sold in different markets

107 Chapter (7) explores market structure impact on wholesale pricing.
108 Chapter (7) explores the impact of networks operating in Europe on their wholesale pricing for non-European networks (Etisalat in this case) for the possibility of a spill-over effect caused by the EC roaming regulation.
109 In fact, if we use region dummies as IVs similar to Etisalat zonal retail prices (GCC, rest of Arab and rest of the world), we get very similar results to the 2SLS in model (6f) of this chapter, but with less significance level for price coefficient (10% level when regional dummies are used compared to 1% level in model 6f).
110 Nevo (2001) uses a similar instrument approach.
111 This may require controlling for market specific supply shifters (e.g. local wages).

means the demands are independent, such that a demand shock in one market does not affect the demand in the other market[112].

In our case, we deal with visited networks selling roaming outgoing call minutes. The product is the visited network in market *r* (the geographic market) in time *t*, composing the observations in our dataset. In order to maintain the same product, we should consider an IV related to the same visited network. In addition, we assume the visited network faces a common marginal cost in providing one minute of outgoing call.

We propose that a good instrument for *j*'s wholesale price per minute of outgoing call (or IOT, our endogenous regressor) is any other price *j* charges per minute that involves call origination. On the wholesale level, examples include the wholesale price per minute *j* charges to domestic network *k* for national roaming by *k*'s subscriber (governed by national roaming agreement[113]), or to foreign network *g* other than Etisalat for international roaming by *g*'s subscriber (governed by international roaming agreement). On the retail level, examples include retail price per minute *j* charges to its subscriber for any outgoing call (domestic or international). Another retail-side example is the retail price per minute *g* charges (where *g* is a foreign network other than Etisalat) to its roamer when using *j's* network.

The proposed instrument is justified on two grounds. First, there is common marginal cost to network *j* for any minute of an outgoing call. For example, the cost per minute to originate a call on network *j* is similar whether it is done by *j*'s own subscriber (under any standard retail service), *j*'s rival subscriber (under national roaming agreement), or by a visitor roaming on *j*'s network (under international roaming agreement). Therefore, the proposed IV and the endogenous IOT would be correlated via the common cost of call origination.

Second, the proposed IV is assumed to be uncorrelated with the demands of Etisalat roamers. If the IV is for retail prices for international roaming by a home network other than Etisalat, then roamers of Etisalat and roamers of that IV's home network are assumed to differ in their incomes, market sizes, and marginal utilities[114] regarding *j*'s (the visited network) price and non-price characteristics. These two justifications need to hold in order to proceed with the proposed IV.

112 This may require controlling for market specific demand shifters (e.g. demographics).
113 See Section (1.1) for the difference between national and international roaming agreements.
114 In the simple logit demand, roamers are assumed to have identical marginal utilities within the home network.

Among the examples for possible IV, we propose the retail prices of international roaming by another home network than Etisalat, as they are publically available and can be found at the network level (which is the product in our case).

The NRA in the Sultanate of Oman provided us with the retail prices of one of its licensed operator, Nawras, as of August 2013 (NRA-Oman, 2013). Oman has another mobile network operator, Oman-Mobile, on which we also gathered similar information (Oman-Mobile, 2013). We explored the two Omani networks as IVs for the endogenous regressor (i.e. for wholesale prices charged to Etisalat).

In line with our focus on wholesale prices charged to Etisalat for outgoing calls (which is not provided by call destination, e.g. local call versus international call), we choose the retail prices charged by the Omani networks for calling Oman[115] while roaming abroad. This is because calling Oman should involve more cost components (e.g. international settlement rates) that reflect cost asymmetry between visited networks and markets. For instance, since Oman and the UAE are neighbouring countries, routing the international call to Oman or to the UAE may involve similar costs for the visited networks in a given market. Therefore, visited networks in a given market are assumed to have similar costs compared to networks in other markets.

The retail prices of the Omani networks, converted to AED currency, are provided at the network level for postpaid roamers. In each visited market, Nawras charges uniform retail price, while Oman-Mobile charges discriminatory retail (i.e. differs by visited networks). Oman-Mobile retail pricing policy is similar to Etisalat's policy during the years 2008-2009, while Nawras is similar to Etisalat's policy during the years 2010-2011, except that Nawras does not involve in zonal prices. The retail prices of both Omani networks vary across markets.

The (observed) wholesale price Etisalat pays to visited network *j* is assumed to be correlated with the retail price of an Omani network through the underlying costs *j* faces (e.g. call origination cost), but the demands (of Etisalat and an Omani network) for *j* are assumed to be uncorrelated.

115 The Omani networks provide retail price information by destination of the call (local within the visited market, or international call to Oman). Nawras also provides information for calling to the rest of the world.

The wholesale price *j* sets is assumed to equal its actual marginal cost[116] plus its wholesale markup. This wholesale markup should be affected by wholesale competition or/and demand of the home network (e.g. roamers income). The markup may also depend on the relationship of *j* and the home network[117].

A good IV should be correlated with the endogenous regressor through the common cost. This crucial assumption is exposed to bias caused by the existence of possible preferential IOT agreements. As shall be seen in Chapter (7), visited networks' characteristics demonstrate IOT preferential agreements (e.g. Etisalat alliance networks charge lower wholesale prices). However, given our data limitation, we cannot fully control for the bias with the available information on the characteristics. There can be other causes for preferential agreements such as the net payments from IOT[118] and international settlement rate agreements, which are not available to us.

One possible way to remove the bias of preferential IOT agreements is to consider, as an IV, retail prices that are uniform within the visited market, because such prices are neutral to preferential wholesale agreements within the market. An IV including uniform retail prices should tell us about cost asymmetries across markets, but it tells nothing regarding cost asymmetries within the market. However, it should overcome the bias caused by possible IOT preferential agreements.

On the contrary, an IV including discriminatory retail prices reflects the embedded wholesale prices. Although it reflects wholesale asymmetries within markets, it is not clear if such asymmetries correspond to actual cost asymmetries in the presence of preferential IOT agreements. Put differently, it cannot overcome the bias at the wholesale level stemming from preferential agreements (e.g. alliance discounts).

In our case, we have retail prices of Nawras, which applies uniform retail policy, and Oman-Mobile, which applies discriminatory policy. We tried using both as IVs, separately and jointly, for wholesale prices charged to Etisalat (the endogenous regressor). In First Stage Least Squares (1SLS) regressions, each Omani network has a positive and significant coefficient at 1% level, reflecting probably common underlying costs. However, we found

116 Marginal cost includes the actual cost of call origination as explained previously. In addition, it includes the actual cost of termination if the call is terminated on *j*'s network, or the perceived cost of termination (e.g. mobile termination rate or international settlement rate) if the call is terminated on another network.
117 Section (2.1.1) describes how international roaming came into existence. In 1996, the GSM Association issued its Standard International Roaming Agreement (STIRA), which states that wholesale prices are non-discriminatory. This means *j* should charge same wholesale price to Etisalat or any other home network. Nevertheless, as found in EC (2000), networks involve in wholesale discounts, such as preferential prices between roaming alliance members.
118 Our dataset only includes one side of the IOT net payment, which is Etisalat wholesale costs, or visited networks' wholesale revenues.

that only Nawras can be used as an IV in the 2SLS[119]. Therefore, Nawras retail prices will be used as the IV for the endogenous regressor.

6.3 Results And Discussion

This section presents and discusses the results for estimating Eq. (6.1) and (6.2). First, we compare between price results for all observations, low and high visited markets. Second, we look at the effect of time related variables. Third, we discuss price effect and own price elasticity of demand. Finally, we discuss the results of visited networks characteristics. Estimation results are presented in Table (6.3), and marginal effects of policy interaction terms are presented in Table (6.4).

In Table (6.3), OLS estimator is used for all observations (model 6a) and for observations in low visited markets (model 6b) to demonstrate the sampling problem, using price and time related variables as regressors. We then use OLS for observations in highly visited markets with different specifications (models 6c-6e). Finally, we use 2SLS estimator for the highly visited markets (model 6f), using Nawras retail price as the IV for the (observed) wholesale prices charged to Etisalat.

One can see the contradiction of the price coefficients under low versus high visited markets (models 6b-6c). The coefficient is positive and significant[120] at 5% level for low visited markets, and negative and significant at 5% level for high visited markets. With all observations, the coefficient is insignificant (model 6a).

Given our data limitations to find a good weight that should solve the sampling problem described in Section (6.1.3), we proceed in this section with models related to the highly visited markets, with focus on comparing results under OLS (mainly model 6e) to 2SLS (model 6f).

Results for the 1SLS used in estimating the 2SLS are deferred to Chapter (7) which includes wholesale price estimations. All can be said about 1SLS in this section is that Nawras IV has a positive and significant coefficient at 1% level (with t-value equals 23.46) in explaining the

119 See Appendix (D) for the evaluation of the two IVs.
120 We found the significance of the positive sign in the price coefficient is caused by not controlling for network' characteristics. In other words, if we include the characteristics in the OLS for low visited markets, the price coefficient is positive but insignificant (see Appendix E).

(endogenous) wholesale prices. The positive sign indicates the correlation between the two variables rooted in the common (actual) marginal costs faced by the visited network.

As shown in Table (6.3), time is found insignificant in all models. Etisalat uniform retail dummy variable is negative and significant at 10% level with OLS (model 6e) after including policy interaction terms. The policy is also significant at 5% level in 2SLS (model 6f). The significance of the policy in the demand is not clear here, but its impact will become clear in Chapter (8) as it is related to the effectiveness of steering.

The price coefficient increases in significance and magnitude under 2SLS (6f) compared to the OLS models. In other words, Nawras IV improves the coefficient on price[121]. The uniform retail prices of Nawras might resemble roamers' perception on retail prices, as compared to the given wholesale prices[122].

In model (6f), we have 273 observations with inelastic demand, representing around one third of the observations. This contradicts with profit maximizing wholesale price decisions[123]. Nevertheless, it is an improvement compared to model (6e), where almost all the observations have inelastic demands. This follows from using the larger price coefficient in absolute value with 2SLS compared to OLS, which increases the own price elasticity given by Eq. (6.2).

121 This improvement is in spite of the loss of observations in model (6f) since Nawras prices are not available for each visited network in the dataset.

122 Etisalat roamers are assumed to be aware of retail prices. Prior to 2010, when prices were discriminatory, if some roamers were aware of only one retail price for using a given visited network, they might consider the same price for using the rest of networks in the same market. If so, then these roamers would act as if the retail had been uniform. In this case, Nawras uniform retail prices better resemble roamers' perception on prices.

123 Comparison between OLS and 2SLS in terms of the number of inelastic demands are used in Table III of Berry, et al. (1995).

Table (6.3) Simple logit demand models.

Dependent variable: $\boldsymbol{ln(s_j) - ln(s_o)}$	**OLS**					**2SLS**
	All Observations	Low Visited Markets	High Visited Markets	High Visited Markets	High Visited Markets	High Visited Markets
	(6a)	**(6b)**	**(6c)**	**(6d)**	**(6e)**	**(6f)**
CONSTANT	-4.266***	-3.856***	-4.305***	-5.112***	-5.006***	-3.865***
	(0.168)	(0.201)	(0.253)	(0.245)	(0.252)	(0.332)
YEAR	-0.043	-0.102	-0.028	-0.006	-0.007	-0.060
	(0.082)	(0.095)	(0.125)	(0.116)	(0.116)	(0.129)
POLICY	-0.349*	-0.310	-0.379	-0.328	-0.526*	-0.639**
(Dummy=1 for 2010-2011)	(0.184)	(0.212)	(0.282)	(0.262)	(0.290)	(0.319)
$PRICE_{jt}$	0.012	0.038**	-0.056**	-0.055***	-0.052**	-0.203***
(Network own price)	(0.014)	(0.016)	(0.023)	(0.021)	(0.021)	(0.037)
Network characteristics:						
$CROSSOWNED_{jt}$	-	-	-	-0.912***	-0.003	-0.342
(Dummy=1 if network is cross-owned by Etisalat)	-	-	-	(0.285)	(0.504)	(0.552)
$ALLIANCE_j$	-	-	-	0.621***	0.465*	0.439
(Dummy=1 if network is alliance to Etisalat)	-	-	-	(0.177)	(0.248)	(0.274)
$CAMEL_j$	-	-	-	1.328***	1.092***	1.042***
(Dummy=1 if network allows Etisalat prepaid)	-	-	-	(0.119)	(0.174)	(0.195)
Interaction with *POLICY*:						
$CROSSOWNED_{jt}$	-	-	-	-	-1.286**	-1.103*
	-	-	-	-	(0.610)	(0.659)
$ALLIANCE_j$	-	-	-	-	0.293	0.133
	-	-	-	-	(0.353)	(0.390)
$CAMEL_j$	-	-	-	-	0.407*	0.563**
	-	-	-	-	(0.240)	(0.266)
Observations	1,927	932	995	995	995	831
R^2	0.015	0.039	0.017	0.158	0.164	-
R^2 Adjusted	0.0137	0.0360	0.0141	0.153	0.157	-
Observations with Inelastic Demands	-	-	-	-	993	273

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

With 2SLS (model 6f), the mean of own price elasticity is (-1.185), where the absolute value of elasticity declines over the four years (2008-2011). This is caused by higher density of inelastic observations over the years[124]. As a consequence, the distribution of elasticity is flatten overtime as shown in Figure (6.1).

The negative trend of own price elasticity can be read as a shift towards inelastic demands, which is accompanied by wholesale price decline as demonstrated in Chapter (5) and found in Chapter (7).

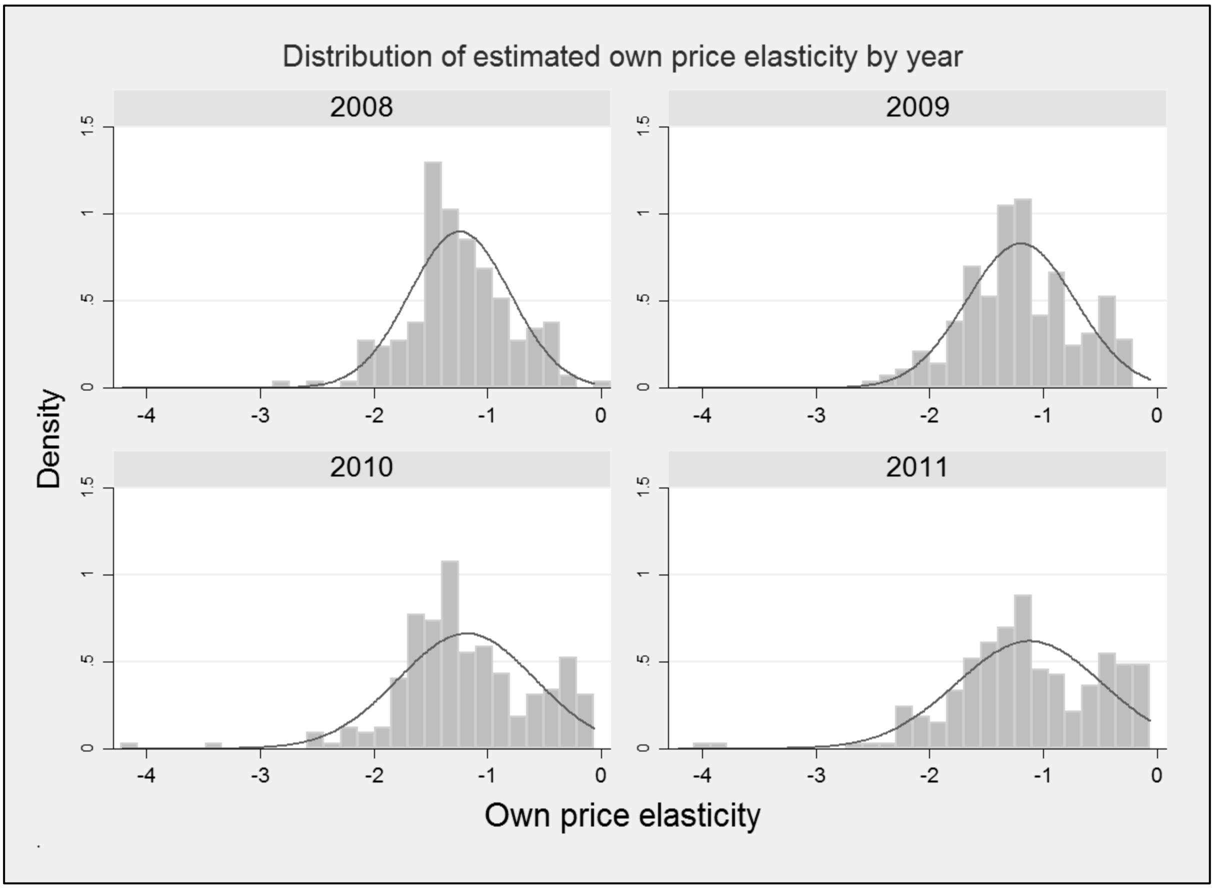

Figure (6.1) Own price elasticity by year.
- Based on Eq. (6.2) using the price coefficient in model (6f).

The results regarding visited networks cross-owned by Etisalat imply that cross-owned networks reduce the mean utility of Etisalat roamers. The coefficient of the dummy variable is negative and significant at 1% level in model (6d). In models (6e) and (6f), where the interaction terms enter the model, we found that before the policy, the coefficient is insignificant, while after the policy, the coefficient becomes negative and significant at 1% level (see Table 6.4).

124 The number of observations with inelastic demands is 273. By breaking it by year, we have 51 in 2008, 61 in 2009, 72 in 2010, and 86 in 2011.

The intuition here is that, only after the policy, Etisalat roamers have less mean utility when roaming on Etisalat cross-owned networks[125].

A possible explanation for the negative utility is that most cross-owned networks are in the expansion stage since they are either new or have very low market share due to structural problems (unrelated to roaming). The reduction in mean utility is probably caused by roaming on networks that have low-coverage (i.e., low quality).

Table (6.4) Marginal effects on visited networks' characteristics post Etisalat uniform retail policy.

Network's Characteristic	Null Hypothesis	Relevant model	F-statistics	P-value
Cross-owned by Etisalat	$\widehat{\beta_4} + \widehat{\beta_7} = 0$	OLS (6e)	14.05	0.000***
		2SLS (6f)	16.00	0.001***
Alliance to Etisalat	$\widehat{\beta_5} + \widehat{\beta_8} = 0$	OLS (6e)	9.14	0.003***
		2SLS (6f)	4.28	0.039**
With CAMEL	$\widehat{\beta_6} + \widehat{\beta_9} = 0$	OLS (6e)	83.02	0.000***
		2SLS (6f)	78.68	0.000***

* p<0.10, ** p<0.05, *** p<0.01
- Based on Table (6.3) results.

The alliance dummy variable has a positive and significant coefficient at 1% level in model (6d). When the interaction terms enter model (6e), the significance level of alliance becomes 10% before the policy and 1% level after the policy (see Table 6.4). On the other side, in the 2SLS (model 6f), alliance is positively related to mean utility, but only significant after the policy (at 5% significance level as shown in Table 6.4).

The intuition here is that alliance networks increased the mean utility of Etisalat roamers, mainly after the policy. A possible interpretation of this result is that Etisalat chose roaming alliance networks that have strong coverage, such that steering towards them (after the policy) raises roamers' utilities[126].

The findings regarding alliance networks are similar to the ones regarding networks with CAMEL that allow Etisalat prepaid roaming. However, the magnitude of the effect is much

125 We shall see in the next chapters that Etisalat steers towards its cross-owned networks; despite they do not give Etisalat wholesale discounts.
126 It could be also possible that roamers choose alliance networks to buy roaming packages for incoming calls and data roaming, even if the price for outgoing call is identical for any network in the market. Interdependence between roaming services is assumed away as explained in Section (6.1.1).

larger with CAMEL, as can be seen in the size of the coefficient in Table (6.3). The dummy variable for CAMEL accounts for visited networks that can host Etisalat roamers with prepaid subscriptions; thus it increases demand through raising the market size.

6.4 Concluding Remarks

In the structural demand model, we focus on highly visited markets because of our concern that the dataset has sampling problems. Roamers are found price sensitive in highly visited markets. These markets seem to be visited by many Etisalat roamers of different types. We found visited networks with CAMEL raise the mean utility of roamers more significantly than the rest of networks' characteristics, indicating the presence of prepaid roamers.

On the other hand, the low visited markets have probably certain types of consumers, who seem to be price insensitive. In fact, when visited networks' characteristics are included in the estimation for low visited markets, CAMEL is found insignificant before the uniform policy, and significant after the policy with positive but small coefficient compared to the highly visited markets (see Appendix E). This suggests that low visited markets do not significantly host prepaid roamers. We conclude that roamers in those markets have mainly postpaid phones, who might be businessmen, journalists or diplomats.

Furthermore, Etisalat preferred networks (alliance and cross-owned) have opposite effects on mean utility, where they matter only after the policy. Alliance networks raise mean utility; while cross-owned networks reduce it. As the policy enables steering, Etisalat might be steering its roamers towards its preferred networks, despite reducing its roamers utility when they roam on cross-owned networks.

We used Nawras retail prices to instrument for wholesale prices charged to Etisalat. Nawras applies uniform retail prices that vary across markets, and this variation is assumed to proxy cost differentials between markets. We think an IV with uniform price overcomes the bias in wholesale prices caused by preferential wholesale agreements or any other non-cost based reasons, compared to discriminatory retail price.

We employed a structural model to estimate demand for visited networks. The mean own price elasticity is found to be (-1.185) in the highly visited markets. For the EEA networks, the figure is (-1.295). Appendix (F) lists the mean own price elasticity of demand for the EEA markets, where the majority of those markets have elastic demands.

These results regarding Etisalat roamers' own price elasticity suggest demand for outbound roaming is more elastic than the industry crude studies by EC (2006), GSMA (2008), Europe Economics (2008) and CMT (2009) surveyed in Section (2.3.3). However, the focus of those industry studies is outbound roaming within the EEA networks, which excludes Etisalat.

Next chapters will explore visited networks' wholesale prices and steering by Etisalat, taken into account visited networks' characteristics. We make use of the panel structure of the data to understand the effect of Etisalat uniform retail price policy.

Chapter (7). Visited Networks Wholesale Pricing

In the theoretical chapters (3) and (4), we present pricing games for networks with IOT agreements, assuming two countries, each with two networks. With discriminatory retail policy, the unilateral wholesale price is predicted to decline by visited networks' substitutability level; and between vertically cross-owned networks, wholesale price is set at marginal cost. If the uniform retail policy chosen at the monopoly level, all networks are predicted to invest in steering when the substitutability level is high enough to reduce wholesale prices, which brings efficiency gains. Then networks form roaming alliances in vertical pairs, where each pair engages in reciprocal steering to raise members' market shares.

This chapter tests empirically for the theoretical predictions regarding the IOTs (or wholesale prices). The chapter studies the effect of market structure, as a measure of competition, on wholesale prices charged by visited networks to Etisalat. In addition, the chapter studies the impact of visited networks' characteristics on pricing, especially how Etisalat is charged by its preferred visited networks before and after the existence of its uniform retail policy that would enable its traffic steering.

In this chapter, the dependent variable is wholesale price; hence the model shares similarity with the 1SLS used in Chapter (6). The model in this chapter does not re-estimate the supply model (1SLS), because it is concerned with the effect of market structure on prices; therefore, it will consider all observations (both high and low visited markets).

Furthermore, we are interested to see if visited networks operating in the EEA were overcharging Etisalat, compared to the rest of networks in the dataset. This is because EEA networks experienced the EC roaming regulation, and given unregulated wholesale prices charged to Etisalat, EEA networks might involve in spill-over (or waterbed) effect due to their regional regulation[127].

This chapter is planned as follows. In Section (7.1), the estimation model and hypotheses to be tested are presented. Then estimation results are discussed in Section (7.2). The chapter concludes in Section (7.3).

127 Thanks to Professor Tommaso Valletti for this suggestion.

7.1 Empirical Methodology

The aim of this chapter is to test the theoretical predictions in light of the impact of Etisalat uniform retail policy, relaying on the same dataset described in Chapter (5) and used in Chapter (6) for demand estimation. Therefore, we will be using panel regressions. The random-effect regression will be looking at the effect of time invariant variables; for instance, to test for the spill-over effect in the EEA. Fixed-effects and random-effects models will be compared using Hausman test. Due to visited networks entry and exist, the panel is (weakly) unbalanced.

The relevant variables used in the estimations of this chapter are listed in Table (7.1) below. We use two variables for market structure. The first variable is $NETWORKS_{rt}$, which is the number of active visited networks in market *r* and year *t*. This variable is calculated for each market by summing up all visited networks (in each year) that sold any roaming unit to Etisalat roamers.

The second variable is $MULTINETWORK_{jrt}$, which is a dummy variable with value one if visited network *j* in market *r* and year *t* experienced horizontal merger/acquisition event, or if it owns more than one network in the same market[128]; zero otherwise[129].

Networks which own more than one network in the same market (or have multinetworks) represent 5.3% of visited networks in the dataset. The dummy variable controls for local synergy and thus it is assumed to have the opposite effect to the number of visited networks.

The wholesale price estimation model is given by the following equation.

$$
\begin{gathered}
ln\left(PRICE_{jt}\right) = \beta_0 + \beta_1 YEAR + \beta_2 POLICY + \beta_3 EEA_j \\
+ \beta_4 CROSSOWNED_j + \beta_5 ALLIANCE_j + \beta_6 CAMEL_j \\
+\beta_7 POLICY \times CROSSOWNED_{jt} + \beta_8 POLICY \times ALLIANCE_j + \beta_9 POLICY \times CAMEL_j \\
+\beta_{10} NETWORKS_{rt} + \beta_{11} MULTINETWORK_{rt} + \varepsilon_{jt}, \\
(j = 1, \dots, 552), \qquad (t = 2008, 2009, 2010, 2011), \qquad (r = 1, \dots, 204),
\end{gathered} \tag{7}
$$

128 This is probably due to licensing reasons in the market. For example, a network has two licensed networks, one with 2G technology and one with 3G technology.

129 As explained in Chapter (5), the data given to us breaks down observations by the name of visited network (which has unique TAP code) and years. We do not change how the data looks; instead, we control for multinetworks with a dummy variable as suggested by Professor Summit Majumdar.

where the $ln(PRICE_{jt})$ is the natural log of price; and ε_{jt} is the error term. All variables are as listed in Table (7.1).

Table (7.1) Notations and variables related to estimations.

Notation	**Description**
j	Subscript for visited networks, where (*j=1,…,552*).
t	Subscript for year, where (*t=2008,2009,2010,2011*).
r	Subscript for geographic market, where (*r=1,…,204*).
Time variables	**Description**
YEAR	Discrete variable for the study years, where *(1=2008, 2=2009, 3=2010, 4=2011)*.
POLICY	Dummy variable equals 1 for the years 2010-2011 (when Etisalat implemented its uniform retail policy); 0 otherwise.
Price variables	**Description**
$PRICE_{jt}$	*j*'s average wholesale price per minute of outgoing call in year *t* (in constant AED with 2007 as base year).
Visited network's characteristic variables	**Description**
$CROSSOWNED_{jt}$	Dummy variable equals 1 if *j* is cross-owned by Etisalat in year *t*; 0 otherwise.
$ALLIANCE_{j}$	Dummy variable equals 1 if *j* is a roaming alliance to Etisalat; 0 otherwise.
$CAMEL_{j}$	Dummy variable equals 1 if *j* allows Etisalat prepaid roaming; 0 otherwise.
Market structure variables	**Description**
$NETWORKS_{rt}$	Number of active visited networks in market *r* and year *t*.
$MULTINETWORK_{jrt}$	Dummy variable equals 1 if *j* owns more than one network in market *r* and year *t*; 0 otherwise.
Region variables	**Description**
EEA_{j}	Dummy variable equals 1 if *j* operates in the European Economic Area (EEA); 0 otherwise.

Eight regressors in Eq. (7) appear also in the demand estimation of Eq. (6.1). We will be reading the results of Eq. (7) in light of the 1SLS results used in demand estimation of Eq. (6.1). In other words, the price model in Eq. (7) can be compared to the reduced form of the supply model used as the 1SLS. However, there are two main problems that may lead to un-similar results.

First, the 1SLS pools the data, whereas the price model in Eq. (7) uses panel regression. Second, the market structure variables, $NETWORKS_{rt}$ and $MULTINETWORK_{jrt}$, are not assumed relevant in the 1SLS (see Section 6.2.4); but they are assumed relevant in this chapter for testing the effect of market structure on wholesale competition. We will present results of the 1SLS next to the random-effect panel regressions that uses same specification[130].

The coefficients related to market structure are assumed to be measures of wholesale competition. As $NETWORKS_{rt}$ (the number of visited networks) increases, wholesale price is expected to decrease, reflecting the rise in the bargaining position of the buyer (Etisalat).

In contrast, $MULTINETWORK_{jrt}$ dummy variable (one if the network owns more than one network in the same market; zero otherwise) is expected to do the opposite effect on wholesale price, because a mobile network operating multiple networks should relatively enjoy more market power.

Furthermore, we explore whether EEA networks overcharged Etisalat due to possible spill-over effect of the EC roaming regulation.

In addition, we expect the coefficients related to Etisalat preferred networks (cross-owned or alliance networks) to be negative. That is, preferred networks are assumed to lower their wholesale prices to their affiliate, Etisalat.

Moreover, the fact that some visited networks have CAMEL technology (and allow Etisalat prepaid roaming) is expected to be irrelevant in wholesale pricing decision. That is, visited networks do not involve in price discrimination at the wholesale level between prepaid and postpaid roamers.

7.2 Results And Discussion

This section discusses the results from estimating the wholesale price model for Eq. (7). First, results from the 1SLS regression are discussed, and compared to the random-effect panel regressions. Then we expand the analysis to focus on wholesale price competition by including the market structure variables and the EEA dummy variable using random and fixed effect panel regressions.

130 Fixed-effect panel regression will drop Nawras IV because Nawras IV does not vary by time (i.e. observed in 2013).

Table (7.2) presents the 1SLS in model (7a), which uses pooled OLS for observations in highly visited markets. The table also presents the random-effect panel regressions for comparison purposes (model 7b for highly visited markets and 7c for all observations). In all these models, we use the given wholesale price (in level-form) as the dependent variable, which is also used in the 1SLS. Additionally, we include Nawras IV (as a market-level cost proxy) [131] and the other explanatory variables used in the 1SLS.

It seems that model (7a) differs because of the choice on the estimator (Pooled OLS versus random-effect panel regression) or because of the choice on observations based on type of market (highly visited or all markets). The only discrepancy is in the coefficient related to cross-owned networks before the policy, which is negative and significant at 10% level. We found this is caused by the functional form of the dependant variable. That is, if wholesale price is in log-form instead, the coefficient becomes insignificant[132].

More importantly, Nawras IV is positive and significant at 1% level in all models of Table (7.2). The positive relation confirms the assumption that the two home networks (Etisalat and Nawras) are correlated through the actual costs borne by visited networks to handle outgoing calls.

Next we expand model (7c) by including the market structure variables and the EEA dummy variable to estimate Eq. (7), where the results are presented in Table (7.3). The marginal effects of policy interaction terms are presented in Table (7.4). Notice the results from model (7c) are similar in significance to model (7d) of Table (7.3).

---

131 Explanation for using Nawras retail prices as an IV is provided in Section (6.2.4).
132 The log makes price outliers less significant. Since cross-owned networks are all in developing countries (see Section 5.4), the significance of their price perhaps reflects price outliers.

Table (7.2) Wholesale price models with wholesale price in level-form.

Dependent variable: *$PRICE_{jt}$*	High Visited Markets		All observations
	OLS (1SLS) (7a)	**Random-effect** (7b)	**Random-effect** (7c)
CONSTANT	2.733*** (0.314)	2.784*** (0.331)	2.505*** (0.262)
YEAR	-0.251* (0.148)	-0.252** (0.102)	-0.284*** (0.073)
POLICY (Dummy=1 for 2010-2011)	0.655* (0.369)	0.685*** (0.256)	0.462*** (0.177)
Network characteristics:			
$CROSSOWNED_{jt}$ (Dummy=1 if network is cross-owned by Etisalat)	-1.050* (0.635)	-0.208 (0.650)	-0.456 (0.578)
$ALLIANCE_j$ (Dummy=1 if network is an alliance to Etisalat)	0.671** (0.315)	0.713* (0.389)	0.370 (0.351)
$CAMEL_j$ (Dummy=1 if network allows Etisalat prepaid)	0.575** (0.225)	0.471* (0.267)	0.154 (0.222)
Interaction with *POLICY*:			
$CROSSOWNED_{jt}$	1.513** (0.760)	0.584 (0.574)	1.073** (0.499)
$ALLIANCE_j$	-1.124** (0.448)	-1.114*** (0.307)	-1.057*** (0.244)
$CAMEL_j$	-0.489 (0.307)	-0.400* (0.217)	-0.212 (0.160)
NAWRAS IV*:*			
$NAWRAS_j$ (Nawras retail price in AED in 2013 for roaming on *j*)	0.262*** (0.011)	0.259*** (0.018)	0.327*** (0.015)
Observations	831	831	1,403
Visited Networks	241	238	396
R^2	0.413	-	-
R^2*adjusted*	0.406	-	-
rho	-	0.541	0.611

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01.

In Table (7.3) below, one can see that time has a negative and significant coefficient at 1% level, which shows the negative trend in real wholesale prices. In model (7g) for instance, price declines by 5.2% a year.

Table (7.3) Wholesale price models with wholesale price in log-form for all observations.

Dependent variable: *Ln(PRICE$_{jt}$)*	**Random-effect**			**Fixed-effect**
	(7d)	**(7e)**	**(7f)**	**(7g)**
CONSTANT	1.410*** (0.074)	2.031*** (0.049)	2.069*** (0.047)	2.252*** (0.047)
YEAR	-0.068*** (0.016)	-0.056*** (0.013)	-0.056*** (0.013)	-0.052*** (0.013)
POLICY (Dummy=1 for 2010-2011)	0.091** (0.040)	0.078** (0.032)	0.078** (0.032)	0.091*** (0.031)
Network characteristics:				
CROSSOWNED$_{jt}$ (Dummy=1 if network is cross-owned by Etisalat)	0.135 (0.142)	-0.058 (0.119)	-0.091 (0.119)	0.099 (0.333)
ALLIANCE$_j$ (Dummy=1 if network is an alliance to Etisalat)	0.120 (0.094)	0.036 (0.097)	0.096 (0.095)	- -
CAMEL$_j$ (Dummy=1 if network allows Etisalat prepaid)	0.035 (0.057)	-0.009 (0.056)	-0.013 (0.057)	- -
Interaction with *POLICY*:				
CROSSOWNED$_{jt}$	0.277** (0.113)	0.079 (0.078)	0.079 (0.078)	0.028 (0.078)
ALLIANCE$_j$	-0.343*** (0.055)	-0.303*** (0.048)	-0.303*** (0.048)	-0.298*** (0.047)
CAMEL$_j$	-0.034 (0.036)	-0.020 (0.029)	-0.020 (0.029)	-0.017 (0.029)
Market structure:				
NETWORKS$_{rt}$ (Number of networks)	-0.120*** (0.011)	-0.087*** (0.009)	-0.088*** (0.009)	-0.146*** (0.013)
MULTINETWORK$_{jrt}$ (Dummy=1 if network owns more than one network)	0.360*** (0.089)	0.383*** (0.082)	0.374*** (0.082)	0.241** (0.115)
European Economic Area (EEA)*:*				
EEA$_j$ (Dummy=1 if network operates in EEA)	0.040 (0.066)	0.179*** (0.062)	- -	- -
NAWRAS IV*:*				
NAWRAS$_j$ (Nawras retail price in AED in 2013 for roaming on *j*)	0.059*** (0.004)	- -	- -	- -
Observations	1,403	1,927	1,927	1,927
Visited Networks	396	549	549	549
rho	0.695	0.778	0.780	0.823

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01.

Table (7.4) Marginal effects on visited networks' characteristics post Etisalat uniform retail policy.

Network's Characteristic	Null Hypothesis	Relevant model	F-statistics	P-value
Cross-owned by Etisalat	$\widehat{\beta_4} + \widehat{\beta_7} = 0$	Random-effect (7d)	14.11	0.000***
		Random-effect (7e)	0.04	0.838
		Random-effect (7f)	0.01	0.915
		Fixed-effect (7g)	0.15	0.700
Alliance to Etisalat	$\widehat{\beta_5} + \widehat{\beta_8} = 0$	Random-effect (7d)	5.58	0.018**
		Random-effect (7e)	7.68	0.006***
		Random-effect (7f)	4.78	0.029**
With CAMEL	$\widehat{\beta_6} + \widehat{\beta_9} = 0$	Random-effect (7d)	0.00	0.977
		Random-effect (7e)	0.27	0.600
		Random-effect (7f)	0.33	0.564

* p<0.10, ** p<0.05, *** p<0.01
- Based on Table (7.3) results.

On the other hand, the uniform dummy variable has a positive and a negative coefficient in all models, with 5% level in the random-effect models and 1% with the fixed-effect model. In model (7g) for instance, wholesale price rises by 9.1% after the policy, which undermines the effectiveness of Etisalat steering to bring visited networks to the negotiation table.

It is clear from Table (7.3) that all visited networks characteristics are insignificant in explaining the wholesale price before the policy. After the policy, some of the preferred networks become significant (cross-owned and alliance), while networks with CAMEL are still insignificant.

After the policy, cross-owned networks are only significant in model (7d), with 1% significance level (see Table 7.4). Model (7d) suggests that cross-owned networks overcharged Etisalat. We can see that this result holds only when Nawras IV is included in the regression. A possible interpretation is provided below.

We think cross-owned networks were in the expansion phase of their network roll-out, so their priority should be getting financed. Model (7d) suggests that once we control for market-level costs (with the help of Nawras IV), some cross-owned networks, perhaps with more need for finance, overcharged Etisalat when Etisalat became in charge of substitution between visited networks (i.e. via steering after the policy).

All results regarding cross-owned networks in Table (7.3) point to one conclusion: cross-owned networks do not offer wholesale discount to Etisalat. This suggests non-cooperative pricing behaviour by the cross-owned networks, which is contrary to our theoretical predictions, despite Etisalat's ability to steer after the uniform policy[133].

On the other hand, after the policy, Etisalat alliance networks lowered their wholesale prices significantly in the random-effect models (at least with 5% level as in Table 7.4). This is confirmed by the fixed-effect model, which shows that after the policy, the alliance networks reduced wholesale prices by 29.8% (at 1% significance level). The institution here is that alliance networks involved in preferential wholesale pricing with Etisalat when Etisalat is able to steer.

With respect to networks with CAMEL, we conclude that allowing prepaid roaming does not matter in the setting of wholesale prices, before or after the policy. This result is in accordance with the fact that visited networks did not price discriminate at the wholesale level for hosting Etisalat prepaid/postpaid subscribers.

Table (7.3) suggests that market structure matters in the setting of wholesale prices. The number of active visited networks decreases the wholesale price at 1% significance level in all the models. This result reflects wholesale price competition between (substitutable) visited networks, because Etisalat can increase its bargaining position. In model (7g) for example, we conclude that the price declines by 14.6% for each extra visited network.

On the other hand, the coefficient on the dummy variable for horizontal multinetworks (one if visited network owns more than one network within same market; zero otherwise) has a positive coefficient, which is significant at 1% level with all the random-effect models, and 5% with the fixed-effect model. Owning more than one network in the same market is assumed to raise market power, which does the opposite effect of the number of visited networks. In model (7g) for example, we conclude that the price rises by 24.1% for visited networks with horizontal ownership.

The coefficient on the EEA dummy variable (one if EEA; zero otherwise) is positive and significant in model (7e) at 1% level[134]. The positive relation associated with being an EEA network and wholesale price might reflect spill-over effect.

133 In spite of not getting wholesale discount, Etisalat steers towards its cross-owned networks, as predicted by the steering model in Chapter (8).

134 The sing and significance level of the coefficient do not change at different specifications, starting from the specifications as in model (7e), then gradually removing each regressor except EEA.

However, comparing to model (7d), the above result is true only if Nawras IV is excluded from the model. Nawras IV is a market-level cost proxy, but at the same time Nawras is not immune from possible EEA spill-over effect, because, similar to Etisalat, Nawras operates outside the EEA[135].

The high wholesale price associated with EEA networks might reflect higher actual marginal costs in EEA markets, for which we have no cost data to control for. An ideal way to test for spill-over in EEA networks is to compare wholesale prices before the EC roaming regulation to after the regulation. This would require data on prices before 2007, the year when regulation entered into force. Given the study period in our dataset is post EU regulation, we cannot judge if EEA networks involved in spill-over.

Finally, we compare between the random and fixed effect models (7f and 7g)[136]. The Hausman test (with the null hypothesis that no difference between the estimated coefficients of fixed-effect and random-effect models) has a chi2 of 29.5 (significant at 1% level). Hence, we reject the null hypothesis and conclude the fixed-effect model is preferred over the random-effect model. Nevertheless, as obvious in Table (7.3), there is no contradiction in the significance level or sign of the coefficients under both the random and fixed effect models.

7.3 Concluding Remarks

This chapter studies the effects of market structure on wholesale prices (IOTs) set by visited networks to Etisalat. The chapter also explores the effects of visited networks characteristics on wholesale pricing, and whether EEA networks overcharged Etisalat.

A key finding is that wholesale prices decline by the number of visited networks. An additional network reduces price by 14.6%, reflecting the increase in Etisalat negotiation ability. This finding confirms our theoretical models (in Chapters 3 and 5) that networks are substitutes, where substitutability is our measure of competition that drives down wholesale

135 If, instead, Nawras IV (weather logged or non-logged) is regressed on EEA (with or without the rest of regressors), EEA is found to be have a positive and significant coefficient, at 1% level.
136 These results do not change in significance level if $ALLIANCE_j$ and $CAMEL_j$ are excluded from model (7f) such that models (7f) and (7g) have the same regressors.

price. On the contrary, the existing theoretical literature predicts that wholesale price would rise with the number of visited networks[137].

Wholesale competition in IOT agreements is also found in some of the competition analyses carried out by the European NRAs (i.e., Austria, Italy, and Spain), as summarized in Table (2.1).

In addition, we found merger/acquisition or any form of horizontal ownership permits overcharging. Moreover, networks operating in EEA are associated with higher wholesale price, which can be caused by waterbed effect due to the EC roaming regulation, or due to having higher actual costs.

Within all visited networks' characteristics, only alliance networks offer wholesale price discount, where the discount is offered only after the policy. This result may suggest that steering by Etisalat is effective, as shall be explored next chapter. Wholesale discount is also found by the NRAs in Austria and Spain, where the Austrian NRA found significant wholesale discounts given to alliance networks (see Table 2.1).

Unlike alliance networks, cross-owned networks do not lower their wholesale prices. Such non-cooperative pricing might be explained by their financial needs for network-expansion. In addition, CAMEL technologies do not matter in wholesale pricing. This is interpreted as a reflection of non-price discrimination at the wholesale level that is known in this industry.

137 See Section (2.3.1), where theoretical models in existing literature use demand that makes visited networks appear as perfect complements.

Chapter (8). Effectiveness Of Steering

When a home network obtains traffic steering technology, it can affect the market shares of visited networks. We think three conditions are necessary for steering to be effective. The first is that the roamer does not obstruct steering, which means his handset must be on automatic mode. This is assumed to be the case when the retail price is uniform[138], and the roamer cares mainly about the final price he pays. Second, the roamer is in coverage overlapping areas, where visited networks are substitutable. Third, there are efficiency gains to justify the home network's investment decision in the steering technology.

In Section (4.3), we modelled a game whereby all the three conditions are met. When visited networks are substitutable and home networks set uniform retail price at the monopoly level, wholesale prices equal the monopoly price since undercutting does not raise market share. In equilibrium, all home networks invest in steering for efficiency gains, and wholesale prices decline as a consequence. The game also predicts forming roaming alliances in vertical pairs, where each pair engages in reciprocal steering to raise the market shares of alliance members.

Given data before and after the uniform retail pricing policy, the aim of this chapter is to help us explore the steering behaviours by Etisalat, which affects visited networks market shares. Although Etisalat owns steering technologies[139], we lack prior information on its success and thus we try to explore the effectiveness of steering in this chapter.

Because steering manipulates the market shares of visited networks, the dependent variable in this chapter is market share. The model in this chapter does not re-estimate the demand for visited networks (as in Chapter 6), because it is concerned with the effectiveness of steering by the home network in response to relative price; henceforth it can consider all observations.

This chapter is planned as follows. Section (8.1) presents the estimation model and hypotheses to be tested. Section (8.2) discusses the estimation results. The chapter concludes in Section (8.3).

138 If the retail price is discriminatory, the rational consumer can select manually between visited networks based on price and non-price characteristics.
139 This statement was communicated verbally by Etisalat.

8.1 Empirical Methodology

The aim of this chapter is to test the theoretical predictions in light of the impact of Etisalat uniform retail policy, relaying on the same dataset described in Chapter (5) and used in Chapters (6) and (7). The dependent variable in this chapter is market shares.

The market shares are calculated without the assumptions made on market size used in Section (6.2.2). That is, *j*'s market share equals the quantity of *j* divided by *j*'s market quantities, in each year. We will use fixed and random effect panel regressions for all observations. The relevant variables used in the estimations are listed in Table (8.1) below.

The market shares variable is a proportion variable distributed on the interval [0,1]. We make use of the logistic transformation in order to map the variable to the real line. The transformed shares will remove observations with extreme values (i.e. zero and one), which is in line with the aim of the model to understand market share allocation within markets. The market share model for estimation is given by

$$\begin{gathered} ln\left(\frac{s_{jrt}}{1-s_{jrt}}\right) = \beta_0 + \beta_1 YEAR + \beta_2 POLICY + \beta_3 RPRICE_{jrt} \\ + \beta_4 CROSSOWNED_j + \beta_5 ALLIANCE_j + \beta_6 CAMEL_j \\ +\beta_7 POLICY \times CROSSOWNED_{jt} + \beta_8 POLICY \times ALLIANCE_j + \beta_9 POLICY \times CAMEL_j \\ +\beta_{10} POLICY \times RPRICE_{jrt} + \epsilon_{jt}, \\ (j = 1, \dots, 552), \qquad (t = 2008, 2009, 2010, 2011), \qquad (r = 1, \dots, 204), \end{gathered} \tag{8}$$

where ϵ_{jt} is the error term; and all variables are as listed in Table (8.1).

Notice the use of price relative to the market arithmetic[140] mean, instead of the given price. In Appendix (E), we found that changes in market share (after the uniform retail policy, assumingly due to Etisalat steering) depend on the relative market price, not on the given price[141]. Therefore, the relative price is assumed to matter for relative quantities, from which market share is derived.

140 Results are very similar if, instead, the geometric mean is used.
141 We tried the estimation with the given price instead of relative price, and found the price coefficients insignificant. In Appendix (E), we re-estimate the demand model as in Eq. (6.1) with the interaction term of price and uniform policy dummy variable. The given price is only significant before the policy for networks operating in highly visited markets, and insignificant (before or after the policy) for networks in low visited markets and for all observations. However, with the relative price instead, price is insignificant (before or after the policy) in the highly visited markets, but significant only after the policy in the low visited markets and in all observations. To conclude, we think the given price suits the demand model as it represents roamers' response to price (i.e. demand-side substitution), while relative price suits the steering model as it represents Etisalat's response to price (i.e. supply-side substitution).

Table (8.1) Notations and variables related to estimations.

Notation	Description
j	Subscript for visited networks, where (*j=1,…,552*).
t	Subscript for year, where (*t=2008,2009,2010,2011*).
r	Subscript for geographic market, where (*r=1,…,204*).
Time variables	**Description**
YEAR	Discrete variable for the study years, where *(1=2008, 2=2009, 3=2010, 4=2011)*.
POLICY	Dummy variable equals 1 for the years 2010-2011 (when Etisalat implemented its uniform retail policy); 0 otherwise.
Price variables	**Description**
$RPRICE_{jrt}$	*j*'s average wholesale price per minute of outgoing call relative to the arithmetic mean of its market *r* in year *t* (in constant AED with 2007 as base year).
Visited network's characteristic variables	**Description**
$CROSSOWNED_{jt}$	Dummy variable equals 1 if *j* is cross-owned by Etisalat in year *t*; 0 otherwise.
$ALLIANCE_j$	Dummy variable equals 1 if *j* is a roaming alliance to Etisalat; 0 otherwise.
$CAMEL_j$	Dummy variable equals 1 if *j* allows Etisalat prepaid roaming; 0 otherwise.
Market shares variables	**Description**
s_{jrt}	*j*'s market share in minutes of outgoing calls in market *r* and year *t*.

The use of relative price should help in interpreting the effectiveness of steering. If market shares respond to changes in relative price during the uniform policy, then steering by Etisalat is effective, given roamers are not overriding steering with manual network selection. That is, if Etisalat effectively steers (after the policy), then the coefficient on the interaction of policy and relative price is expected to be significant and negative. This hypothesis is explained below.

With discriminatory retail pricing policy, the retail price to roam on network *j* reflects *j*'s wholesale price. If the wholesale price is negatively related to market shares, then roamers demand-side substitution is effective[142]. With uniform retail pricing policy, the retail price to roam on network *j* does not reflect *j*'s wholesale price; hence the roamer is indifferent

142 However, demand-side substitution is related to the given price as in Eq. (6.1), not to the relative price.

between networks price-wise. In this case, visited networks have no reason to undercut if steering is absent because undercutting does not raise market shares.

Based on the above, the effectiveness of a home network's steering should be measured by how much it is able to replace its roamers' demand-side substitution with its supply-side substitution through its ability to steer roamers to the cheapest network. In our case, the effectiveness of Etisalat steering should be known by how much Etisalat is able to cause downward pressures on relative wholesale prices during the years when the retail price is uniform.

The coefficients of the interaction terms related to visited networks' characteristics are also relevant in knowing if Etisalat steers to its preferred networks. The hypotheses in this regard are made in light of Chapter (7) results, where we learned how visited networks charged Etisalat. Etisalat pays lower wholesale prices to its alliance networks after the policy. Thus, we expect the coefficient of the interaction of policy and alliance to be positive. On the contrary, Etisalat gets no wholesale discount from its cross-owned networks. Thus, we expect the coefficient of the interaction of policy and cross-ownership to be negative.

On the other hand, networks that allow Etisalat prepaid roaming (with CAMEL) are expected to have higher market shares, regardless of steering, because they affect market size. For example, Etisalat cannot steer its prepaid roamers to a visited network that does not have CAMEL technology.

Market structure variables are not included in Eq. (8) because, similar to the demand given by Eq. (6.1), they are assumed to be correlated with the error term. Nonetheless, Eq. (8) may still have endogeneity problem because the relative price enters as a regressor and can be correlated with the error term. We will try instrumenting for it with the use of Nawras IV.

8.2 Results And Discussion

Results for market share estimations are provided in Table (8.2); where the marginal effects post the uniform policy are presented in Table (8.3). The Hausman test results recommend the fixed-effect models over the random-effect models. The Chi2 is (1598.59) for models (8a) and (8c); and (61.37) for models (8b) and (8d); which are both significant at 1% level[143]. We discuss the results of model (8d) below, with reference to the other models only if they differ significantly.

As can be seen in Table (8.2), time is insignificant, reflecting no trend in market shares. In model (8d), the dummy for Etisalat uniform retail policy and the relative price are separately insignificant, but their interaction term has a negative coefficient which is significant at 1% level[144] (see Table 8.3).

Notice that the policy and the relative price, independently, are significant only if their interaction term is excluded, (i.e. models 8a and 8c, where their coefficients are negative and significant at least at 5% level). In other words, the interaction term of those two variables (i.e. their combination) is what only matters in market shares compared to the variables independently.

The above results on relative price suggest that only during the policy, a visited network's market share is responsive to the wholesale price it chooses[145]. The question here is why the choice between visited networks (i.e. market shares) is responsive to wholesale prices only after the retail price became uniform, where roamers became assumingly indifferent price-wise. One possible answer is that Etisalat exercised steering. If it did not, the relative price should remain insignificant. Therefore, we conclude that, after the policy, Etisalat can effectively steer.

To demonstrate the effect of steering on market shares after the policy, consider the case of a hypothetical market with three visited networks. Assume the networks are symmetric in marginal costs and all characteristics. Assume the status quo is such that each network sets the price per minute at 1 AED.

If network j offers a 10% wholesale discount to Etisalat, j's relative price is reduced by 7% (from 1 to 0.93). The marginal effect of such action is 0.052, which is the product of the change in relative price (i.e. -7%) and the coefficient of the relative price interaction term (-0.761) in model (8d). By adding 0.052 to the logistically transformed market share (the

143 These results do not change in significance level if $ALLIANCE_j$ and $CAMEL_j$ are excluded from model (8a and 8b) such that all models have the same regressors.
144 This result does not change significantly with or without controlling for visited networks characteristics.
145 This can mean roamers did not care about prices when it was discriminatory. The demand models provided in Appendix (E) show that the relative price is insignificant in highly visited markets, but significant in low visited markets and in all observations only after the policy. However, when the given price is used instead, the given price is significant only before the policy in highly visited markets, but insignificant in low visited markets and in all observations. We conclude that roamers care about prices during the discriminatory period, assuming the given price suits demand estimation because roamers are sensitive to the level of prices.

dependent variable in Eq. (8)), we predict that network *j* will raise its market share by 3.5%. Table (8.4) demonstrates this hypothetical example.

Table (8.2) Market share models for all observations.

Dependent variable:	**Random-effect**		**Fixed-effect**	
$ln\left(\frac{s_{jt}}{1-s_{jt}}\right)$	**(8a)**	**(8b)**	**(8c)**	**(8d)**
CONSTANT	-1.197*** (0.207)	-1.834*** (0.269)	-0.818*** (0.187)	-1.366*** (0.251)
YEAR	0.018 (0.050)	0.016 (0.049)	0.008 (0.049)	0.006 (0.049)
POLICY (Dummy=1 for 2010-2011)	-0.364*** (0.120)	0.498* (0.263)	-0.338*** (0.118)	0.427 (0.263)
$PRICEAR_{jrt}$ (Network own price relative to arithmetic mean)	-0.491*** (0.146)	0.151 (0.227)	-0.404** (0.161)	0.144 (0.233)
Network characteristics:				
$CROSSOWNED_{jt}$ (Dummy=1 if network is cross-owned by Etisalat)	-2.056*** (0.457)	-1.826*** (0.460)	1.255 (1.168)	1.423 (1.165)
$ALLIANCE_{j}$ (Dummy=1 if network is alliance to Etisalat)	0.386 (0.355)	0.355 (0.354)	- -	- -
$CAMEL_{j}$ (Dummy=1 if network allows Etisalat prepaid)	1.120*** (0.218)	1.110*** (0.217)	- -	- -
Interaction with *POLICY*:				
$CROSSOWNED_{jt}$	0.707** (0.295)	0.506* (0.299)	1.059*** (0.295)	0.873*** (0.300)
$ALLIANCE_{j}$	0.239 (0.169)	0.237 (0.169)	0.264 (0.168)	0.259 (0.167)
$CAMEL_{j}$	0.186* (0.108)	0.186* (0.108)	0.141 (0.107)	0.141 (0.107)
$PRICEAR_{jrt}$	- -	-0.858*** (0.233)	- -	-0.761*** (0.234)
Observations	1,706	1,706	1,706	1,706
Visited Networks	499	499	499	499
rho	0.805	0.806	0.860	0.860

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table (8.3) Marginal effects on networks' characteristics and relative prices post Etisalat uniform retail policy.

Network's Characteristic And Relative Price	Null Hypothesis	Relevant model	F-statistics	P-value
Cross-owned by Etisalat	$\widehat{\beta_4} + \widehat{\beta_7} = 0$	Random-effect (8b)	10.66	0.001***
		Fixed-effect (8d)	3.96	0.047**
Alliance to Etisalat	$\widehat{\beta_5} + \widehat{\beta_8} = 0$	Random-effect (8b)	2.80	0.094*
With CAMEL	$\widehat{\beta_6} + \widehat{\beta_9} = 0$	Random-effect (8b)	36.80	0.000***
$PRICEAR_{jrt}$	$\widehat{\beta_3} + \widehat{\beta_{10}} = 0$	Random-effect (8b)	20.37	0.000***
		Fixed-effect (8d)	12.69	0.000***

* p<0.10, ** p<0.05, *** p<0.01
- Based on Table (8.2).

Table (8.4) Hypothetical example of wholesale undercutting in a market with three visited networks.

Relevant variables	Status quo	Undercut by 10%
$PRICE_{jt}$ (Network's own wholesale price)	1.00	0.90
Market arithmetic mean price	1.00	0.97
$PRICEAR_{jrt}$ (Network's own wholesale price relative to the market arithmetic mean)	1.00	0.93
s_j (Network's own market share)	0.33	0.35
$s_j/(1-s_j)$	0.50	0.53
$ln(s_j/(1-s_j))$	-0.69	-0.64
Gain in market share	-	3.5%

Turning to visited network's characteristics, model (8d) suggests that cross-owned networks are insignificant in the model before the policy; but become significant after the policy. In fact, after the policy, their market shares are raised at 5% significance level (see Table 8.3). The result is similar in the other fixed-effect model, (8c).

Similarly, it is obvious that after the policy, the random effect models show an improvement in market share for the cross-owned networks (e.g. significant at 1% level in model 8b; see Table 8.3).

As found in Chapter (7), cross-owned networks do not offer wholesale discount to Etisalat. Nevertheless, the results on cross-owned networks after the policy suggest that Etisalat steers towards its cross-owned networks after the policy. Etisalat probably steers to its cross-owned networks to help financing them in their expansion stage. There can be other reasons for which we have no information to control for, related probably to reciprocal IOT agreements where we observe only one side of it.

However, the contradiction in results between fixed and random effect models is for cross-owned networks before the policy. The fixed-effect models, before the policy, suggest that cross-owned dummy variable is insignificant; while the random-effect models suggest it is significant at 1% level, with negative coefficient. An interpretation is provided below.

We believe there is heterogeneity in visited networks market shares, especially by knowing that some networks, such as Etisalat cross-owned, inherited very low market shares because of structural reasons that are unrelated to roaming. For example, cross-owned networks have either a new license or have very low market share in local subscribers. The random-effect estimator assumes the intercept is a random variable, which is common to all networks. Therefore, the heterogeneity problem in market shares magnifies under the random-effect estimator. This is reflected in the highly significant negative coefficient of the cross-owned networks (before the policy) in the market share model, which is large in magnitude.

In contrast, the fixed-effect estimator allows each network to have its own intercept; hence heterogeneity in market shares is taken into account. This is reflected in the insignificant coefficient of the cross-owned networks (before the policy) in the market share model.

In addition, the fixed-effect models (8c) and (8d) show the coefficient related to the alliance dummy variable as insignificant; but we cannot compare the effect to the case before the policy (i.e. alliance dummy variable is time invariant). In contrast, the random-effect models (8a) and (8b) show a significant coefficient for the interaction term of the policy and the alliance dummy variable (at 10% level in model 8b; see Table 8.3). After the policy, the random-effect models show an improvement in alliance networks' market shares, which might be caused by Etisalat steering, given the roamer is indifferent price-wise and alliance networks significantly charge lower wholesale price as found in Chapter (7).

With regards to visited networks with CAMEL, the fixed-effect models show no impact of this characteristic on market shares after the policy. In the random-effect models, the policy slightly improves the coefficient's size of the CAMEL dummy variable. The related coefficients have the same significance (1%) level before and after the policy (see model 8b in Table 8.3). This is interpreted as networks with CAMEL can raise market size by hosting prepaid roamers; and if steering exists (after the policy), steering would be limited to prepaid roamers and the networks with CAMEL.

Furthermore, similar to the treatment for the price endogeneity problem in the demand estimation (Section 6.2.4), we tried instrumenting for the relative price used in Eq. (8) with Nawras IV in the random-effect models (8a and 8b)[146]. In the 1SLS regressions, Nawras IV is found insignificant in explaining the relative price. Predictably, Nawras IV does not suit as an instrument for the relative price[147].

In our case, given no other available instruments, it is not feasible to solve the endogeneity problem when relative price is used as an endogenous regressor. We maintain the relative price in estimating Eq. (8) because the relative price is assumed to test if market share allocation (via steering) responds to wholesale price undercutting[148].

8.3 Concluding Remarks

In this chapter, we modelled market shares to explore for steering, taking advantage of the dataset on market shares and wholesale prices which are assumed to matter in steering and roaming alliance formation. Additionally, given uniform retail enables steering, the panel structure of the dataset makes use of the uniform retail policy to infer about steering.

The existing empirical literature overlooked the importance of the uniform retail in inference about steering or roaming alliance (see Section 2.3.3). Rieck et al (2005) found that only Vodafone roaming alliance networks involve in strategic alliance, relying on retail price information. In the European NRAs competition analyses, the surveys by the NRAs in Finland and Spain found steering is effective (see Table 2.1).

146 The IV is time invariant; hence it cannot be used with fixed-effect model. Nawras IV interaction with the policy was also tried out for model (8b).

147 This is not surprising, because the IV is supposed to pick up cost differentials that are reflected in prices, but in the case of relative prices, price differentials are minimized (i.e. price is standardised as it is divided by the mean). To confirm, we re-estimated the 1SLS for the demand given by Eq. (6.1) using the relative price instead of the given price. In this case, Nawras IV does not work neither.

148 As explained in Section (8.1), relative price is what matters for relative quantities.

In the steering model of this chapter, before the policy (when the retail price is discriminatory), roamers choice between visited networks does not matter with regards to the relative price. After the policy (when the retail price is uniform), the choice between visited networks is significantly sensitive to relative wholesale pricing. We believe steering by Etisalat is behind this result, as explained below.

With uniform retail price, wholesale undercutting by visited network *j* does not raise *j*'s market share through roamers' demand-side substitution because the retail price for roaming on *j* does not reflect *j*'s wholesale price. This leaves us with the possibility that the supply-side substitution (i.e. Etisalat steering) exists and is effective because reduction in relative wholesale price significantly raises market share.

Steering by Etisalat is found noticeable towards its alliance and cross-owned networks. After the policy, Etisalat preferred networks (alliance and cross-owned) experienced improvements in their market shares, particularly the cross-owned networks.

Chapter (9). Conclusion

Mobile international roaming is a hot topic in the telecommunications industry, particularity in the EU where international roaming raised competition concerns that led to price regulation. The NRAs that studied their wholesale market concluded that the market was competitive; however, the EC was concerned that reductions in wholesale prices were not passed on to consumers. The EC was also concerned that prices (retail and wholesale) remained unjustifiably high with no sign of decline.

A possible reason for the competition concerns is the high consumers' switching costs that made retail prices unjustifiably high. Sources of switching costs include the inconvenience to use the outside options (e.g. public payphones or visitor-SIM card), the absence of mobile number portability at the retail market, and probably the roamers' temporary nature of visit. However, the European NRAs competition analyses and the theoretical literature mainly focused on the wholesale market, which is also the focus of this thesis.

This thesis studies the economics of mobile international roaming with emphasis on visited networks' wholesale competition in hosting the visiting subscriber of their IOT-agreement partners. Areas tackled in the thesis are similar to the ones tackled by the existing theoretical literature. In addition, the thesis uses a dataset on Etisalat outbound roaming to test the theoretical predictions.

All the existing published papers on the economics of international roaming assume uniform retail price. This thesis demonstrates that using such assumption in visited networks' optimization problems leads to results that are inconsistent with wholesale competition, for example the number of visited networks increases wholesale price. The source of such inconsistency is the fact that visited networks appear in the demand as (perfect) complements.

We compare equilibria under the two different assumptions on retail pricing policy (uniform and discriminatory). As found in Proposition (3.1), the discriminatory retail price suits for modelling wholesale competition, because visited networks appear in the demand as substitutes and price equilibria are in accordance with competition models.

Wholesale competition is found in our empirical estimations on the effect of market structure on wholesale price (Chapter 7). We found that the number of visited networks, as a measure of wholesale competition, significantly reduces wholesale prices. In addition, horizontal ownership (e.g. merger) enables visited networks to raise wholesale prices.

In addition, our base model predicts that a nation's (unweighted) welfare can be enhanced by (retail and wholesale) price reduction, supporting the argument for price regulation. Nonetheless, because of the cross-border nature of the IOT agreements, price regulation requires the cooperation of the relevant NRAs.

Another policy implication is the use of a structural model for demand estimation (Chapter 6), similar to our simple logit model, to derive the own price elasticity that is crucial in industry's impact assessment analyses on the EC roaming regulation. A future industry assessment can consider a European home network, say Vodafone-UK, to study quantities and prices[149] related to its outbound roamers within the EU. Of course, including information on Vodafone-UK's retail pricing policy (discriminatory or uniform) and information on Vodafone-UK's relationship with visited networks (e.g. cross-owned or roaming alliance) will help in estimating the demands for visited networks.

Our market size calculation can be used in future demand estimation, but with better information on, for example, the demographics of Vodafone-UK's roamers in each visited market. Better information can allow for sophisticated demand estimation models, such as the random coefficients logit.

The instrumental variable method used in our demand estimation can be suited for future research. In our experiment, we found that uniform retail prices are better instruments compared to discriminatory prices, which is interpreted as uniform prices overcoming the bias in wholesale preferential agreements.

The two assumptions on the retail policy (discriminatory or uniform) lead to opposite results with regards to the incentive for vertical cross-ownership. At one hand, with discriminatory policy, the incentive for cross-ownership exists (Proposition 4.1). But with the uniform policy on the other hand, such incentive does not exist (Proposition 4.2). In the cross-ownership games (either with discriminatory or uniform retail policy), it is predicted that vertically cross-owned networks charge internally preferential wholesale prices.

149 Data on wholesale prices charged to Vodafone-UK may better suit the demand estimation for visited networks compared to Vodafone-UK's retail prices if those retail prices are based on zones (e.g. a price to roam in EU and a price to roam outside EU) such that they lack enough variation for analysis.

However, empirically (Chapter 7), we found that Etisalat cross-owned networks do not offer preferential wholesale prices to Etisalat. We looked for the nature of cross-owned networks to seek an interpretation. All of these networks operate in developing countries, where penetration is relatively low; and many of them are new in their markets or/and have low market shares in local subscription. Therefore, these networks may be in the expansion phase; hence behaving non-cooperatively.

After Etisalat uniform retail policy, Etisalat roamers are found to have negative mean utility by roaming on cross-owned networks, probably due to their low-quality of coverage. Paradoxically, after the policy, cross-owned networks significantly improved their market shares. This suggests that Etisalat exercise steering towards its cross-owned networks. Given data limitation, we do not know why Etisalat would steer towards its cross-owned networks despite, in return, not getting wholesale discount.

By Proposition (4.3), all home networks are predicted to invest in steering technology for efficiency gains when substitutability is high enough to drive down wholesale prices. The roaming alliance model predicts that mutual steering between allied networks can be self-sustained given no incentive to deviate. Proposition (4.4) predicts that networks will engage in roaming alliance pairing, because joining a roaming alliance is a dominant strategy to each network. The equilibrium is a prisoner dilemma situation where the status quo profit is reduced by the sunk cost of steering investment.

In exploration for steering in our dataset (Chapter 8), we conclude that steering by Etisalat is effective because, after its uniform retail policy (where roamers are assumed indifferent price-wise), visited networks significantly reduced wholesale prices to gain market share. Additionally, Etisalat roaming alliance networks are found to offer lower wholesale prices to Etisalat only after the policy (Chapter 7). The improvement in their market shares after the policy is interpreted as a result of steering by Etisalat.

All the equilibria in the games of preferential wholesale agreements do not lead to exclusive IOT agreements, because substitutability of visited networks is assumed to be bounded. This is reflected in the dataset, where Etisalat increases its IOT-agreement partners every year during the study period in spite of the existence (and the rise) of preferred visited networks.

Given the role of net payments in all the games of the preferential wholesale agreements, we expect large networks (e.g. in market size) would prefer to be preferential partners to minimize negative net payments. To understand the choice of preferential partner, an extension for future work is to consider asymmetry in networks in terms of market size, marginal cost, and the number of networks in a country.

We ignored network-coverage decisions, relying on assuming such decisions are only relevant for home subscribers, not for hosting temporary roamers. Future work may consider an investment game to improve coverage in order to capture visitors in areas such as airports, learning from the model developed by Ambjørnsen et al (2011).

Additional information on visited networks should improve our empirical estimations. The age of mobile networks can help control for networks in their early phase of expansion, in which case, those networks can rely on unregulated wholesale prices (e.g. IOTs) as interpreted for Etisalat cross-owned networks. Moreover, prices before the year 2007 can help test if there is waterbed effect caused by the EC roaming regulation. In addition, a visited network market share in local subscribers should be informative about its market share in roaming. If the network is dominant in the local market, it should have higher coverage or quality and hence higher share in hosting visitors.

All empirical models in this thesis consider quantities and wholesale prices related to the service of roaming outgoing calls, because among roaming services, the service of outgoing calls is assumed to be exposed to the effects of the shift in Etisalat retail policy. The service of outgoing calls was also the focus of the NRAs' analyses in the EU for the wholesale market of international roaming.

We expect to have similar results if market share estimation is made for the other roaming services separately (i.e. incoming calls, SMS and data roaming). This is so because market shares of those independent services are found highly correlated due to demand-side or supply-side substitution (via home network steering) related to price, or non-price reasons (e.g. the quality of network-coverage).

Future research may employ a model that comprehends all the roaming services. Retail roaming packages (e.g. Etisalat's incoming calls and data roaming) should also be considered in future research. Instrumental variables can be used for each roaming service separately (e.g. Nawras' retail prices for SMS as IV for SMS wholesale prices charged to Etisalat).

Nevertheless, some data problems may arise when expanding estimations to the other roaming services. As seen in our dataset with incoming calls, wholesale prices would include many observations with zero or near zero prices, because visited networks get compensated from international settlement rates. Moreover, with data roaming, the roamer may face difficulty in measuring his usage[150].

The implications of the net payment for the IOT-agreement partners are deemed to be the cause of all the incentives in the games of cross-ownership, steering and roaming alliance formation. However, our dataset is about Etisalat outbound roaming, i.e. Etisalat's IOT out-payments. If data on inbound roaming (i.e. foreign subscribers roaming on Etisalat network inside the UAE) is available, we would have Etisalat's IOT in-payments. Information on the two sides of IOT net payments should enable investigating the determinants of IOTs (e.g. the level of IOTs), learning from the empirical model by Wright (1999). Additionally, information on the retail policy of Etisalat IOT-agreement partners is relevant, especially whether Etisalat is considered a roaming alliance at the side of those partners. Information on the two sides of an IOT net payment should enable testing for steering reciprocity in order to understand the behaviour of roaming alliances, as approached by Rieck et al (2005).

Furthermore, the observed wholesale prices (IOTs) charged by the visited networks to Etisalat may be affected by Etisalat's non-roaming interconnection agreements with those visited networks, such as the agreement of international settlement rates. Despite the independence of the IOT and the international settlement rate agreements, the bargaining positions of the parties involved can affect any wholesale price they choose.

The theoretical models in this thesis assume monopoly retail, which is thought to be plausible if the market does not have mobile number portability, as with our case in the UAE. However, many markets have mobile number portability, where retail competition for subscribers may influence international roaming retail offering. A good example is the market in Saudi Arabia where mobile number portability exists. The new entrant Zain started offering free incoming calls for roamers to gain market share in subscribers. In response to the churn-rate caused by Zain, the other networks (STC and Mobily) matched Zain's offer. The Saudi NRA considered free incoming calls as below-cost pricing (Sutherland, 2011). Future research should consider retail offering in modelling mobile networks that compete at the retail level in international roaming.

150 According to NRA-UAE, most of consumer complaints are about their bill shocks for international roaming, in particular, data roaming.

The thesis, theoretically and empirically, focuses on the demands for visited networks to understand wholesale competition. An interesting future work is the demand for visited markets. There are hot destinations that attract UAE outbound tourists (where Etisalat roamers can serve as a proxy), such as neighbouring GCC countries and the UK. With a random-effect regression estimator, we tried out regressing the log of market quantity on time, the distance between the UAE and the visited market, GDP of the visited market, and the total trades between the UAE and the visited market. All these explanatory variables are highly significant except total trades: time and distance have negative coefficients; and GDP has positive coefficient. However, the coefficients are very small in magnitude.

In the future, we plan to do a separate research on the demand for markets, by including additional information such as the number of flights and the foreign immigrants in the UAE. We plan to shade light on the low visited markets, which seem to host merely postpaid roamers. If those markets are mainly visited by the diplomats for example, one can consider including additional information on the number of staff in the UAE embassies.

An observed business practise in this industry is the emergence of Inbound Roaming Promotion by visited networks (e.g. Viva-Kuwait and Batelco-Bahrain). The promotion is usually a draw to win a prize for roaming on a visited network. Visited networks inform about these prizes through advertisements contained in the welcoming SMSs sent to roamers. A model about the effect of such advertisement on demand for a visited network is awaiting future research.

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Appendix (A). Choice On Retail Policy By A Monopolist

In this appendix, we focus on the problem of a monopolist, ignoring any vertically related issues, in the choice of (linear) retail pricing policy.

Consider a monopolist selling two substitutable goods that have different actual marginal costs. The monopolist's problem is to choose a retail pricing policy. That is, the monopolist either chooses discriminatory prices (i.e. different prices based on marginal costs) or a uniform price (i.e. common price regardless of marginal costs). The demand for good i is given by Shubik and Levitan (1980)

$$q_i = \frac{1}{2}\left(\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_i + \frac{\beta\gamma}{2}p_j\right), \quad (i, j = 1,2)\ (i \neq j).$$

If price is uniform, then the demand for each good is identical

$$q_1 = q_2 = q = \frac{1}{2}(\alpha - \beta p).$$

Next, equilibria are presented for the discriminatory and the uniform policies.

A1. Discriminatory Prices (Policy D)

Under the discriminatory pricing policy (Policy D), the maximization problem is given by

$$\max_{(p_1,p_2)} \Pi = (p_1 - c_1)q_1(p_1,p_2) + (p_2 - c_2)q_2(p_1,p_2).$$

The first order condition (FOC) for the above maximization problem leads to the following retail solution for good i.

$$p_i^* = \frac{\alpha + \beta c_i}{2\beta}.$$

Therefore, the equilibrium profit from selling good i is

$$\pi_i^* = \frac{(\alpha - \beta c_i)\left[2(\alpha - \beta c_i) - \gamma\beta\left(c_i - c_j\right)\right]}{16\beta}, \quad (i = 1,2)\ (i \neq j),$$

and the total profit from selling both goods is

$$\Pi_D^* = \frac{2[(\alpha - \beta c_1)^2 + (\alpha - \beta c_2)^2] + \gamma\,\beta^2(c_1 - c_2)^2}{16\beta}. \tag{A.1}$$

A2. Uniform Price (Policy U)

Under the uniform pricing policy (Policy U), the maximization problem is given by

$$\max_{(p)} \Pi = 2(p - \bar{c})q(p) ,$$

where $\bar{c} = (c_1 + c_2)/2$, which is the average marginal cost. The FOC for the above maximization problem leads to the following uniform retail solution.

$$p^* = \frac{\alpha + \beta\bar{c}}{2\beta}.$$

Therefore, the equilibrium profit from selling good i is

$$\pi_i^* = \frac{(\alpha - \beta\bar{c})^2}{8\beta} , \quad (i = 1,2) ,$$

and the total profit from selling both goods is

$$\Pi_U^* = \frac{(\alpha - \beta\bar{c})^2}{4\beta} = \frac{\left(2\alpha - \beta(c_1 + c_2)\right)^2}{16\beta}. \tag{A.2}$$

A3. Payoffs Comparison

This section compares the payoffs from the discriminatory and uniform pricing policies. The difference between Eq. (A.1) and Eq. (A.2) is given by

$$\Pi_D^* - \Pi_U^* = \frac{\beta(1+\gamma)(c_1 - c_2)^2}{16} \geq 0. \tag{A.3}$$

It is clear from Eq. (A.3) that if marginal costs are symmetric, the monopolist is indifferent between discriminatory and uniform pricing policies. This is true because the prices of the two goods would be symmetric. However, with asymmetric marginal costs, the monopolist is better off choosing the discriminatory policy than choosing the uniform. This conclusion is more appealing as the two goods become more asymmetric in marginal costs or/and more substitutable.

Appendix (B). Derivations Of Base Model Equilibria

This Appendix shows the derivations of the base model equilibria presented in Chapter (3).

B1. Model Background

There are two networks in country A ($A1$ and $A2$); and two networks in country B ($B1$ and $B2$). Each network signs an IOT agreement with each foreign network. Each network is assumed to be a monopolist at the retail level and a duopolist at the wholesale level. Networks are assumed to have symmetric constant marginal costs normalized to zero and no fixed costs. Retail and wholesale prices are assumed to be linear.

The game is played in two stages: in Stage I, networks set their wholesale prices simultaneously; and in Stage II, networks set their retail prices simultaneously. The subgame perfect Nash equilibrium (SPNE) is solved by backward induction.

To simplify notations, we solve for the situation $A1$'s subscriber roaming on $B1$'s network under the $(A1, B1)$ IOT agreement. We show the retail price solution for $A1$ and the wholesale price solution for $B1$. In such two-way access agreements, the solutions apply similarly the other way to all networks. The subscript refers to the network in question and the superscript refers to its IOT-agreement partner.

The utility for $A1$'s subscriber is given by

$$U_{A1} = \frac{\alpha}{\beta}\, Q_{A1} - \frac{Q_{A1}^2}{2\beta} - \frac{(q_{A1}^{B1} - q_{A1}^{B2})^2}{2\beta(1+\gamma)} - p_{A1}^{B1} q_{A1}^{B1} - \ p_{A1}^{B2} q_{A1}^{B2}\,, \tag{B.1}$$

where $Q_{A1} = q_{A1}^{B1} + q_{A1}^{B2}$ is the aggregate quantity demanded by $A1$'s subscriber in country B; p_{A1}^{B1}, p_{A1}^{B2} are the applicable retail prices; α and β are positive demand parameters; and $\gamma \geq 0$ is the substitutability parameter. We will later write $\theta = \gamma/(2+\gamma)$ to index the substitutability level in each country, where $\theta\ \in [0,1)$.

The roamer maximizes his utility for roaming in country B by choosing q_{A1}^{B1} and q_{A1}^{B2}

$$\frac{\partial U_{A1}}{\partial q_{A1}^{B1}} = \frac{\partial U_{A1}}{\partial q_{A1}^{B2}} = 0. \tag{B.2}$$

The direct demand for roaming on networks $B1$ and $B2$ respectively are given by

$$q_{A1}^{B1} = \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_{A1}^{B1} + \frac{\beta\gamma}{2}p_{A1}^{B2}\right],$$

and

$$q_{A1}^{B2} = \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_{A1}^{B2} + \frac{\beta\gamma}{2}p_{A1}^{B1}\right]. \tag{B.3}$$

If the prices are uniform (i.e. $p_{A1}^{B1} = p_{A1}^{B2} = p_{A1}$), the demands will be symmetric

$$q_{A1}^{B1} = q_{A1}^{B2} = q_{A1} = \frac{1}{2}\left[\alpha - \beta p_{A1}\right]. \tag{B.4}$$

The different wholesale pricing strategies explored in the models are considered under two alternative retail-pricing policies: with uniform constraint or without uniform constraint (i.e. discriminatory by visited networks). Such policies produce different retail price mapping functions (RPMFs), which are derived in Stage II. A RPMF is a function of wholesale price(s), which provides the optimal retail price given any previously set wholesale price(s), and is substituted for when solving for wholesale prices in Stage I[151].

B2. The Game

B2.1 Stage II

Discriminatory Retail Policy

Home network $A1$ faces the following profit maximization problem when its subscriber roams in country B

$$\max_{(p_{A1}^{B1}, p_{A1}^{B2})} \Pi_{A1} = \left(p_{A1}^{B1} - w_{B1}^{A1}\right) q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + w_{A1}^{B1}\, q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right)$$
$$+ \left(p_{A1}^{B2} - w_{B2}^{A1}\right) q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2}) + w_{A1}^{B2}\, q_{B2}^{A1}\left(p_{B2}^{A1}, p_{B2}^{A2}\right). \tag{B.5}$$

$A1$'s retail prices are inside its retail profits (the first and the third terms, where the demands are given by Eq. (B.3)). The RPMFs for both networks are derived by solving

$$\frac{\partial \Pi_{A1}}{\partial p_{A1}^{B1}} = \frac{\partial \Pi_{A1}}{\partial p_{A1}^{B2}} = 0,$$

simultaneously, where

$$\frac{\partial \Pi_{A1}}{\partial p_{A1}^{B1}} = q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + \left(p_{A1}^{B1} - w_{B1}^{A1}\right)\frac{\partial\, q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial p_{A1}^{B1}} + \left(p_{A1}^{B2} - w_{B2}^{A1}\right)\frac{\partial\, q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial p_{A1}^{B1}} = 0,$$

151 The second order condition is negative in all retail (discriminatory or uniform) and wholesale maximization problems.

$$\rightarrow \frac{1}{2}\left[\alpha-\beta\left(1+\frac{\gamma}{2}\right)p_{A1}^{B1}+\frac{\beta\gamma}{2}p_{A1}^{B2}\right]-\frac{\beta}{2}\left(1+\frac{\gamma}{2}\right)\left(p_{A1}^{B1}-w_{B1}^{A1}\right)+\frac{\beta\gamma}{4}\left(p_{A1}^{B2}-w_{B2}^{A1}\right)=0,$$

and similarly for $\partial \Pi_{A1}/\partial p_{A1}^{B2}$; yielding the following retail price functions

$$p_{A1}^{B1}=\frac{2\alpha+\beta(2+\gamma)w_{B1}^{A1}+\beta\gamma\left(2p_{A1}^{B2}-w_{B2}^{A1}\right)}{2\beta(2+\gamma)},$$

and

$$p_{A1}^{B2}=\frac{2\alpha+\beta(2+\gamma)w_{B2}^{A1}+\beta\gamma\left(2p_{A1}^{B1}-w_{B1}^{A1}\right)}{2\beta(2+\gamma)}.$$

By solving for p_{A1}^{B1}, we have

$$p_{A1}^{B1}=\frac{2\alpha+\beta(2+\gamma)w_{B1}^{A1}-\beta\gamma\, w_{B2}^{A1}+\theta[2\alpha+\beta(2+\gamma)w_{B2}^{A1}-\beta\gamma\, w_{B1}^{A1}+2\beta\gamma\, p_{A1}^{B1}]}{2\beta(2+\gamma)},$$

$$\rightarrow p_{A1}^{B1}=\frac{2\alpha(1+\theta)+\beta(2+\gamma-\theta\gamma)w_{B1}^{A1}+\beta[(2+\gamma)\theta-\gamma]\, w_{B2}^{A1}}{2\beta(2+\gamma)(1-\theta^{2})},$$

where $\theta=\gamma/(2+\gamma)$. After substituting for θ in the above two equations, the last term in the numerator becomes zero. Then by multiplying the numerator and the denominator by $(2+\gamma)$, the RPMF is given by

$$p_{A1}^{B1}=\frac{\alpha+\beta\, w_{B1}^{A1}}{2\beta},$$

and similarly for p_{A1}^{B2}

$$p_{A1}^{B2}=\frac{\alpha+\beta\, w_{B2}^{A1}}{2\beta}.$$

(B.6)

Uniform Retail Policy

In the absence of steering and with uniform retail, home network $A1$ sets identical retail prices in country B, resulting in identical demands. The average wholesale price $A1$ faces is $\overline{w}_{B}^{A1}=(w_{B1}^{A1}+w_{B2}^{A1})/2$. The following profit maximization problem is for $A1$ when its subscriber roams in country B

$$\max_{(p_{A1})}\Pi_{A1}=2\left(p_{A1}-\overline{w}_{B}^{A1}\right)q_{A1}(p_{A1})+w_{A1}^{B1}q_{B1}(p_{B1})+w_{A1}^{B2}q_{B2}(p_{B2}).$$

(B.7)

$A1$'s retail price is inside its retail profit (the first term, where the demands are given by Eq. (B.4)). The first order condition (FOC) must satisfy

$$\frac{\partial \Pi_{A1}}{\partial p_{A1}}=2\, q_{A1}(p_{A1})+2\left(p_{A1}-\overline{w}_{B}^{A1}\right)\left[\frac{\partial q_{A1}(p_{A1})}{\partial p_{A1}}\right]=0,$$

$$\rightarrow \frac{1}{2}\,[\alpha-\beta p_{A1}]-\frac{\beta}{2}\left(p_{A1}-\overline{w}_{B}^{A1}\right)=0.$$

By solving for p_{A1}, the RPMF is given by

$$p_{A1} = \frac{\alpha + \beta\overline{w}_B^{A1}}{2\beta}.$$

(B.8)

Note importantly that, as compared to Eq. (B.6), p_{A1} depends on both w_{B1}^{A1} and w_{B2}^{A1}.

Next, four wholesale pricing strategies are presented. In each wholesale strategy, networks are assumed to set their (monopoly) retail prices independently according to the relevant RPMF. Any price cooperation between networks is only assumed upstream. The following first order conditions (FOCs) are with respect to w_{B1}^{A1} (i.e. $B1$'s wholesale price to $A1$), where $A1$'s retail price is given by the RPMFs of Eq. (B.6) for the discriminatory retail policy, or by the RPMF of Eq. (B.8) for the uniform retail policy.

B2.2 Stage I

B2.2i International Cartel Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the following international market profit

$$\max_{(w_{B1}^{A1},w_{B1}^{A2},w_{B2}^{A1},w_{B2}^{A2},w_{A1}^{B1},w_{A1}^{B2},w_{A2}^{B1},w_{A2}^{B2})} \Pi_{(A,B)} = \begin{aligned}[t] & p_{A1}^{B1}\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + p_{A1}^{B2}\ q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2}) \\ & + p_{A2}^{B1}\ q_{A2}^{B1}(p_{A2}^{B1}, p_{A2}^{B2}) + p_{A2}^{B2}\ q_{A2}^{B2}(p_{A2}^{B1}, p_{A2}^{B2}) \\ & + p_{B1}^{A1}\ q_{B1}^{A1}(p_{B1}^{A1}, p_{B1}^{A2}) + p_{B1}^{A2}\ q_{B1}^{A2}(p_{B1}^{A1}, p_{B1}^{A2}) \\ & + p_{B2}^{A1}\ q_{B2}^{A1}(p_{B2}^{A1}, p_{B2}^{A2}) + p_{B2}^{A2}\ q_{B2}^{A2}(p_{B2}^{A1}, p_{B2}^{A2}). \end{aligned}$$

(B.9)

Under Discriminatory Retail Policy

Using the demands as in Eq. (B.3), and substituting Eq. (B.6) in Eq. (B.9), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A,B)}}{\partial w_{B1}^{A1}} = \frac{\partial p_{A1}^{B1}}{\partial w_{B1}^{A1}}\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + p_{A1}^{B1}\left[\frac{\partial\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] + p_{A1}^{B2}\left[\frac{\partial\ q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\to \frac{1}{4}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)p_{A1}^{B1} + \frac{\beta\gamma}{2}p_{A1}^{B2}\right] - \frac{\beta}{4}\left(1 + \frac{\gamma}{2}\right)p_{A1}^{B1} + \frac{\beta\gamma}{8}p_{A1}^{B2} = 0,$$

$$\to p_{A1}^{B1} = \theta\, p_{A1}^{B2} + \frac{\alpha}{\beta(2+\gamma)},$$

where $\theta = \gamma/(2+\gamma)$. Substituting further the relevant RPMFs (from Eq. B.6) in the above equation, we have

$$\frac{\alpha + \beta\, w_{B1}^{A1}}{2\beta} = \theta\left(\frac{\alpha + \beta\, w_{B2}^{A1}}{2\beta}\right) + \frac{\alpha}{\beta(2+\gamma)}.$$

By solving for w_{B1}^{A1}, we have

$$w_{B1}^{A1} = \theta\, w_{B2}^{A1} + \frac{\alpha}{\beta}\left[\theta - \frac{\gamma}{2+\gamma}\right].$$

The second term cancels in the above equation after substituting for θ. The international cartel's best wholesale price is given by

$$w_{B1}^{A1} = \theta\, w_{B2}^{A1}.$$

(B.10)

Because $\theta \in [0,1)$, the only symmetric wholesale equilibrium is when $\theta = 0$, otherwise $w_{B1}^{A1} \neq\ w_{B2}^{A1}$. Thus the equilibrium wholesale and retail solutions are

$$w^* = 0,$$

then from Eq. (B.6)

$$p^* = \frac{\alpha}{2\beta}.$$

(B.11)

Under Uniform Retail Policy

Using the demands as in Eq. (B.4), and substituting Eq. (B.8) in Eq. (B.9), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A,B)}}{\partial w_{B1}^{A1}} = 2\ \frac{\partial p_{A1}}{\partial w_{B1}^{A1}} q_{A1}(p_{A1}) + 2\ p_{A1}\left[\frac{\partial q_{A1}(p_{A1})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{8}\ [\alpha - \beta p_{A1}] - \frac{\beta}{8} p_{A1} = 0,$$

$$\rightarrow\ p_{A1} = \frac{\alpha}{2\beta}.$$

By substituting further for the RPMF (from Eq. B.8) in the above equation, we have

$$\frac{\alpha +\ \beta\left(\frac{w_{B1}^{A1} + w_{B2}^{A1}}{2}\right)}{2\beta} = \frac{\alpha}{2\beta}.$$

By solving for w_{B1}^{A1}, the international cartel's best wholesale price is given by

$$w_{B1}^{A1} =\ - w_{B2}^{A1}.$$

(B.12)

The only symmetric wholesale price solution is zero. Thus the equilibrium wholesale and retail solutions are

$$w^* = 0,$$

then from Eq. (B.8)

$$p^* =\ \frac{\alpha}{2\beta}.$$

(B.13)

B2.2ii National Cartel Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the national market profit. The maximization problem for networks in country B is

$$\max_{(w_{B1}^{A1}, w_{B1}^{A2}, w_{B2}^{A1}, w_{B2}^{A2})} \Pi_B =$$

$$\begin{aligned} &\left(p_{B1}^{A1} - w_{A1}^{B1}\right) q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A1}\ \ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) \\ &+\left(p_{B1}^{A2} - w_{A2}^{B1}\right) q_{B1}^{A2}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A2}\ \ q_{A2}^{B1}(p_{A2}^{B1}, p_{A2}^{B2}) \\ &+\left(p_{B2}^{A1} - w_{A1}^{B2}\right) q_{B2}^{A1}\left(p_{B2}^{A1}, p_{B2}^{A2}\right) + w_{B2}^{A1}\ \ q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2}) \\ &+\left(p_{B2}^{A2} - w_{A2}^{B2}\right) q_{B2}^{A2}\left(p_{B2}^{A1}, p_{B2}^{A2}\right) + w_{B2}^{A2}\ \ q_{A2}^{B2}(p_{A2}^{B1}, p_{A2}^{B2}). \end{aligned} \tag{B.14}$$

Under Discriminatory Retail Policy

Using the demands as in Eq. (B.3), and substituting Eq. (B.6) in Eq. (B.14), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_B}{\partial w_{B1}^{A1}} = \ \ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + w_{B1}^{A1}\ \ \left[\frac{\partial\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] + w_{B2}^{A1}\ \left[\frac{\partial\ q_{A1}^{B2}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right) p_{A1}^{B1} + \frac{\beta\gamma}{2} p_{A1}^{B2}\right] - \frac{\beta}{4}\left(1 + \frac{\gamma}{2}\right) w_{B1}^{A1} + \frac{\beta\gamma}{8} w_{B2}^{A1} = 0.$$

By substituting further for the relevant RPMFs (from Eq. B.6) in the above equation, we have

$$\frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)\left(\frac{\alpha + \beta\ w_{B1}^{A1}}{2\beta}\right) + \frac{\beta\gamma}{2}\left(\frac{\alpha + \beta\ w_{B1}^{A1}}{2\beta}\right)\right] - \frac{\beta}{4}\left(1 + \frac{\gamma}{2}\right) w_{B1}^{A1} + \frac{\beta\gamma}{8} w_{B2}^{A1} = 0.$$

By solving for w_{B1}^{A1}, the national cartel's best wholesale price is given by

$$w_{B1}^{A1} = \ \theta\ w_{B2}^{A1} + \frac{\alpha}{\beta(2 + \gamma)}. \tag{B.15}$$

where $\theta = \gamma/(2 + \gamma)$. By substituting symmetrically for w_{B2}^{A1} in the above equation, then substituting for θ, we get

$$w^* = \frac{\alpha}{\beta(2 + \gamma)(1 - \theta)} = \frac{\alpha}{2\beta},$$

then from Eq. (B.6),

$$p^* = \frac{\alpha + \beta\left(\frac{\alpha}{2\beta}\right)}{2\beta} = \frac{3\alpha}{4\beta}. \tag{B.16}$$

Under Uniform Retail Policy

Using the demands as in Eq. (B.4), and substituting Eq. (B.8) in Eq. (B.14), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_B}{\partial w_{B1}^{A1}} = q_{A1}(p_{A1}) + w_{B1}^{A1} \left[\frac{\partial q_{A1}(p_{A1})}{\partial w_{B1}^{A1}}\right] + w_{B2}^{A1} \left[\frac{\partial q_{A1}(p_{A1})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{2}\left[\alpha - \beta p_{A1}\right] - \frac{\beta}{8} w_{B1}^{A1} - \frac{\beta}{8} w_{B2}^{A1} = 0.$$

By substituting further for the RPMF (from Eq. B.8) in the above equation, we have

$$\frac{1}{2}\left[\alpha - \beta\left(\frac{\alpha + \beta\left(\frac{w_{B1}^{A1} + w_{B2}^{A1}}{2}\right)}{2\beta}\right)\right] - \frac{\beta}{8} w_{B1}^{A1} - \frac{\beta}{8} w_{B2}^{A1} = 0.$$

By solving for w_{B1}^{A1}, the national cartel's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\alpha}{\beta} - w_{B2}^{A1}. \tag{B.17}$$

The symmetric wholesale price requires $w_{B1}^{A1} = w_{B2}^{A1} = w^*$; thus Eq. (B.17) gives us

$$w^* = \frac{\alpha}{\beta} - w^*,$$

$$\rightarrow w^* = \frac{\alpha}{2\beta}.$$

Therefore, the equilibrium wholesale price solution that maximizes the national market profit, and its resulting retail price solution are

$$w^* = \frac{\alpha}{2\beta},$$

then from Eq. (B.8),

$$p^* = \frac{\alpha + \beta\left(\frac{\alpha}{2\beta}\right)}{2\beta} = \frac{3\alpha}{4\beta}. \tag{B.18}$$

B2.2iii Narrow Vertical Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the vertical retail revenues of the two IOT partners within each separate IOT agreement (i.e. ignoring implications for other revenues received by the networks). The maximization problem for the networks in the $(A1, B1)$ IOT agreement is

$$\max_{(w_{B1}^{A1}, w_{A1}^{B1})} \Pi_{(A1,B1)} = p_{A1}^{B1}\ q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + p_{B1}^{A1}\ q_{B1}^{A1}(p_{B1}^{A1}, p_{B1}^{A2}). \tag{B.19}$$

The above equation will result in symmetric wholesale prices for all networks, in line with the rest of the strategies of this chapter.

Under Discriminatory Retail Policy

Using the demands as in Eq. (B.3), and substituting Eq. (B.6) in Eq. (B.19), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A1,B1)}}{\partial w_{B1}^{A1}} = \frac{\partial p_{A1}^{B1}}{\partial w_{B1}^{A1}}\, q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2}) + \; p_{A1}^{B1} \left[\frac{\partial\, q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{4}\left[\alpha - \beta\left(1+\frac{\gamma}{2}\right)p_{A1}^{B1} + \frac{\beta\gamma}{2}p_{A1}^{B2}\right] - \frac{\beta}{4}\left(1+\frac{\gamma}{2}\right)p_{A1}^{B1} = 0,$$

$$\rightarrow p_{A1}^{B1} = \frac{\theta}{2}\, p_{A1}^{B2} + \frac{\alpha}{\beta(2+\gamma)},$$

where $\theta = \gamma/(2+\gamma)$. By substituting further for the relevant RPMFs (from Eq. B.6) in the above equation, we have

$$\frac{\alpha + \beta\, w_{B1}^{A1}}{2\beta} = \frac{\theta}{2}\left(\frac{\alpha + \beta\, w_{B2}^{A1}}{2\beta}\right) + \frac{\alpha}{\beta(2+\gamma)}.$$

By solving for w_{B1}^{A1}, the vertical strategy's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\theta}{2} w_{B2}^{A1} - \frac{\theta\alpha}{2\beta}. \tag{B.20}$$

By substituting symmetrically for w_{B2}^{A1} in the above equation, we get

$$w^* = \frac{\alpha\,\theta}{\beta\,(\theta-2)},$$

then from Eq. (B.6),

$$p^* = \frac{\alpha + \beta\left(\frac{\alpha\,\theta}{\beta\,(\theta-2)}\right)}{2\beta} = \frac{\alpha}{2\beta}\left(1+\frac{\theta}{\theta-2}\right) = \frac{\alpha}{\beta}\left(\frac{\theta-1}{\theta-2}\right) = \frac{2\alpha}{\beta(4+\gamma)}. \tag{B.21}$$

Since $\theta \in [0,1)$, $w^* < 0$ if $\theta > 0$. The negative wholesale price reduces the retail price and effectively enhances the demand for the IOT partner. Intuitively, the mutual wholesale price subsidy is necessary to bring down the retail price.

Under Uniform Retail Policy

Using the demands as in Eq. (B.4), and substituting Eq. (B.8) in Eq. (B.19), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{(A1,B1)}}{\partial w_{B1}^{A1}} = \frac{\partial p_{A1}}{\partial w_{B1}^{A1}} q_{A1}(p_{A1}) + p_{A1} \left[\frac{\partial q_{A1}(p_{A1})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{8}\,[\alpha - \beta p_{A1}] - \frac{\beta}{8} p_{A1} = 0,$$

$$\rightarrow p_{A1} = \frac{\alpha}{2\beta}.$$

By substituting further for the RPMF (from Eq. B.8) in the above equation, we have

$$\frac{\alpha + \beta\left(\frac{w_{B1}^{A1} + w_{B2}^{A1}}{2}\right)}{2\beta} = \frac{\alpha}{2\beta}.$$

By solving for w_{B1}^{A1}, the vertical strategy's best wholesale price is given by

$$w_{B1}^{A1} = -w_{B2}^{A1}. \tag{B.22}$$

The only symmetric wholesale price solution is zero. Thus the equilibrium wholesale and retail solutions are

$$w^* = 0,$$

then from Eq. (B.8),

$$p^* = \frac{\alpha}{2\beta}. \tag{B.23}$$

B2.2iv Unilateral Wholesale Pricing Strategy

This strategy sets wholesale prices to maximize the own wholesale profit for each network. The maximization problem for $B1$ is

$$\max_{(w_{B1}^{A1}, w_{B1}^{A2})} \Pi_{B1} = \left(p_{B1}^{A1} - w_{A1}^{B1}\right) q_{B1}^{A1}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A1}\; q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})$$
$$+\left(p_{B1}^{A2} - w_{A2}^{B1}\right) q_{B1}^{A2}\left(p_{B1}^{A1}, p_{B1}^{A2}\right) + w_{B1}^{A2}\; q_{A2}^{B1}(p_{A2}^{B1}, p_{A2}^{B2}). \tag{B.24}$$

Under Discriminatory Retail Policy

Using the demands as in Eq. (B.3), and substituting Eq. (B.6) in Eq. (B.24), we find p_{A1}^{B1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{B1}}{\partial w_{B1}^{A1}} = q_{A1}^{B1}(\,p_{A1}^{B1},\, p_{A1}^{B2}) + w_{B1}^{A1} \left[\frac{\partial\, q_{A1}^{B1}(p_{A1}^{B1}, p_{A1}^{B2})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right) p_{A1}^{B1} + \frac{\beta\gamma}{2} p_{A1}^{B2}\right] - \frac{\beta}{4}\left(1 + \frac{\gamma}{2}\right) w_{B1}^{A1} = 0.$$

By substituting further for the relevant RPMFs (from Eq. B.6) in the above equation, we have

$$\frac{1}{2}\left[\alpha - \beta\left(1 + \frac{\gamma}{2}\right)\left(\frac{\alpha + \beta\, w_{B1}^{A1}}{2\beta}\right) + \frac{\beta\gamma}{2}\left(\frac{\alpha + \beta\, w_{B2}^{A1}}{2\beta}\right)\right] - \frac{\beta}{4}\left(1 + \frac{\gamma}{2}\right) w_{B1}^{A1} = 0.$$

By solving for w_{B1}^{A1}, the unilateral strategy's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\theta}{2} w_{B2}^{A1} + \frac{\alpha}{\beta(2+\gamma)},$$

(B.25)

where $\theta = \gamma/(2+\gamma)$. By substituting symmetrically for w_{B2}^{A1} in the above equation, then substituting for θ, we get

$$w^{*} = \frac{2\alpha}{\beta(2+\gamma)(2-\theta)} = \frac{2\alpha}{\beta(4+\gamma)},$$

then from Eq. (B.6),

$$p^{*} = \frac{\alpha + \beta\left(\frac{2\alpha}{\beta(4+\gamma)}\right)}{2\beta} = \frac{\alpha(6+\gamma)}{2\beta(4+\gamma)}.$$

(B.26)

Under Uniform Retail Policy

Using the demands as in Eq. (B.4), and substituting Eq. (B.8) in Eq. (B.24), we find p_{A1} a direct function of w_{B1}^{A1}, and the FOC is

$$\frac{\partial \Pi_{B1}}{\partial w_{B1}^{A1}} = q_{A1}(p_{A1}) + w_{B1}^{A1} \left[\frac{\partial q_{A1}(p_{A1})}{\partial w_{B1}^{A1}}\right] = 0,$$

$$\rightarrow \frac{1}{2}\left[\alpha - \beta p_{A1}\right] - \frac{\beta}{8} w_{B1}^{A1} = 0.$$

By substituting further for the RPMF (from Eq. B.8) in the above equation, we have

$$\frac{1}{2}\left[\alpha - \beta\left(\frac{\alpha + \beta\left(\frac{w_{B1}^{A1} + w_{B2}^{A1}}{2}\right)}{2\beta}\right)\right] - \frac{\beta}{8} w_{B1}^{A1} = 0.$$

By solving for w_{B1}^{A1}, the unilateral strategy's best wholesale price is given by

$$w_{B1}^{A1} = \frac{\alpha}{\beta} - \frac{w_{B2}^{A1}}{2}.$$

(B.27)

By substituting symmetrically for w_{B2}^{A1} in the above equation, we get

$$w^{*} = \frac{2\,\alpha}{3\,\beta},$$

then from Eq. (B.8),

$$p^{*} = \frac{\alpha + \beta\left(\frac{2\,\alpha}{3\,\beta}\right)}{2\beta} = \frac{5\,\alpha}{6\,\beta}.$$

(B.28)

Appendix (C). Networks Choice On Retail Policy

In this Appendix, we show a game whereby mobile networks choose wholesale prices simultaneously, then decide on a retail policy (either discriminatory or uniform at-the-monopoly-level).

C1. Model Background

Assume there are two countries; each has two networks. Each network signs an IOT agreement with each foreign network. Each network is a monopolist downstream and a duopolist upstream. Networks have symmetric constant marginal costs normalized to zero, no fixed costs, and no steering technology. Retail and wholesale prices are linear.

The one-shot pricing game is played in two stages. In Stage I, networks simultaneously choose wholesale prices. In Stage II, networks simultaneously either choose retail prices discriminated by visited networks (hereafter discriminatory policy) or choose a uniform retail price that equals the monopoly price (hereafter uniform policy). The subgame perfect Nash equilibrium (SPNE) is solved by backward induction.

The demand for visited network i is given by Shubik and Levitan (1980)

$$q_i = \frac{1}{2}\left[\alpha - \beta\left(1+\frac{\gamma}{2}\right)p_i + \frac{\beta\gamma}{2}p_j\right], \qquad (i,j=1,2), \qquad (i \neq j).$$

Networks have symmetric demand parameters (α, β, γ), with $\alpha, \beta > 0$ and $\gamma \geq 0$ (the substitutability parameter). If the prices are identical (i.e. $p_i = p_j = p$), the demands will be symmetric,

$$q_1 = q_1 = q = \frac{1}{2}\ [\alpha - \beta p].$$

Consider the unilateral equilibria of the discriminatory retail pricing policy of the base model in Section (3.2.8iv). When wholesalers set wholesale prices non-cooperatively, the equilibrium wholesale and retail prices are, respectively, $w^N = 2\alpha/[\beta(4+\gamma)]$ and $p^N = \alpha(6+\gamma)/[2\beta(4+\gamma)]$. Therefore, the demand for a visited network is $q^N = \alpha(2+\gamma)/[4(4+\gamma)]$.

Consider the case the home network chooses the monopoly price, which equals $p^M = \alpha/(2\beta)$. The demand for a visited network, therefore, is $q^M = \alpha/4$. Given uniform retail price and absence of steering, wholesalers do not have an incentive to undercut because undercutting does not raise market shares. In this case, the wholesale price will equal the monopoly price, i.e. $w^M = \alpha/(2\beta)$.

In the following game, we will be comparing profits, where the profit to each network from each IOT agreement consists of a retail revenue and a net payment. The net payment is the difference between a network's wholesale profit and wholesale cost with its IOT-agreement partner. Each term in the net payment (either wholesale profit or wholesale cost) consists of a wholesale price times a demand.

In our case, the wholesale profit/cost to any network is either $w^M q^M$ or $w^N q^N$. Notice that $w^M = \alpha/(2\beta) > w^N = 2\alpha/[\beta(4+\gamma)]$ as long as $\gamma > 0$; otherwise $w^M = w^N$. Notice also that $q^M = \alpha/4 > q^N = \alpha(2+\gamma)/[4(4+\gamma)]$ except in the limit of γ, where $q^M = q^N$, (because the respective retail prices would be equal).

Assume network i, where i is any network, chooses the discriminatory policy while its IOT-agreement partner chooses the uniform policy. Then, the net payment to network i is

$$net_i = \overbrace{\frac{\alpha}{2\beta}}^{w^M} \overbrace{\frac{\alpha}{4}}^{q^M} - \overbrace{\frac{2\alpha}{\beta(4+\gamma)}}^{w^N} \overbrace{\frac{\alpha(2+\gamma)}{4(4+\gamma)}}^{q^N} = \frac{\alpha^2(8+4\gamma+\gamma^2)}{8\beta(4+\gamma)^2} > 0. \tag{C.1}$$

Network i receives the net payment from its IOT partner because i charges a higher wholesale price (i.e. $w^M > w^N$) and has a lower (retail) demand (i.e. $q^N < q^M$).

C2. The Game

The total profits, Π, to any network from its both IOT agreements if all networks apply the same policy will equal its total revenues, R. This is because net payments are zero in this case.

When all networks apply the uniform policy, the total profits/revenues to each network are

$$\Pi^M = R^M = \frac{\alpha^2}{4\beta}. \tag{C.2}$$

When all networks apply the discriminatory policy, the total profits/revenues to each network are

$$\Pi^N = R^N = \frac{(2+\gamma)(6+\gamma)\alpha^2}{4\beta(4+\gamma)^2}. \tag{C.3}$$

The difference between Eq. (C.2) and (C.3) is positive,

$$\Pi^M - \Pi^N = R^M - R^N = \frac{\alpha^2}{4\beta} - \frac{(2+\gamma)(6+\gamma)\alpha^2}{4\beta(4+\gamma)^2} = \frac{\alpha^2}{\beta(4+\gamma)^2} > 0. \tag{C.4}$$

Therefore, all networks are better off if they all choose the uniform policy (with retail price at-the-monopoly-level). However, there is an incentive to deviate from such cooperation, as explained next.

If network i plays the discriminatory policy, and only one of its IOT-agreement partners plays the uniform policy, i's total payoffs are

$$R^N + net_i = \frac{\alpha^2(8+3\gamma)}{8\beta(4+\gamma)}, \tag{C.5}$$

where net_i is given by Eq. (C.1).

The difference between Eq. (C.5) and (C.2) is

$$R^N + net_i - R^M = \frac{\gamma\,\alpha^2}{8\beta(4+\gamma)} \geq 0, \tag{C.6}$$

which is positive only if $\gamma > 0$. If, instead, both IOT partners of network i play uniform policy, network i will have two net payments; hence Eq. (C.5) will increase to $R^N + 2net_i$.

Therefore, each network has an incentive to deviate from cooperation in choosing uniform policy by playing the discriminatory policy. As a result, discriminatory policy is a dominant strategy to each network, which is the equilibrium in this one-shot game as long as visited networks are substitutes (i.e. $\gamma > 0$).

C3. Discussion

In this one-shot game, the equilibrium payoffs to each network is Π^N, which is inefficient because it is less than Π^M when all networks choose the uniform policy (i.e. retail price at-the-monopoly-level). In a repeated game with infinite time horizon, networks can sustain setting the retail price at the monopoly level. Because steering is assumed absent, the uniform retail price provides the wholesaler with no incentive to undercut, as undercutting does not increase market share. Thus, wholesale price at the monopoly level is consequently self-sustained.

Intuitively, cooperation to play the uniform retail policy eliminates net payments, which are the source of deviation incentives. A similar cooperation in the context of balancing net payments is found in Shy (2001) model on international settlement rates.

The game can be depicted in the following extensive form. The bold inner segments represent the one-shot and repeated game equilibria. In the one-shot game, the retailer non-cooperatively plays discriminatory retail policy, p^N, and the wholesaler plays unilateral price w^N. If the game is repeated infinitely, uniform retail policy, p^M, with wholesale monopoly price fixing, w^M, are the equilibria.

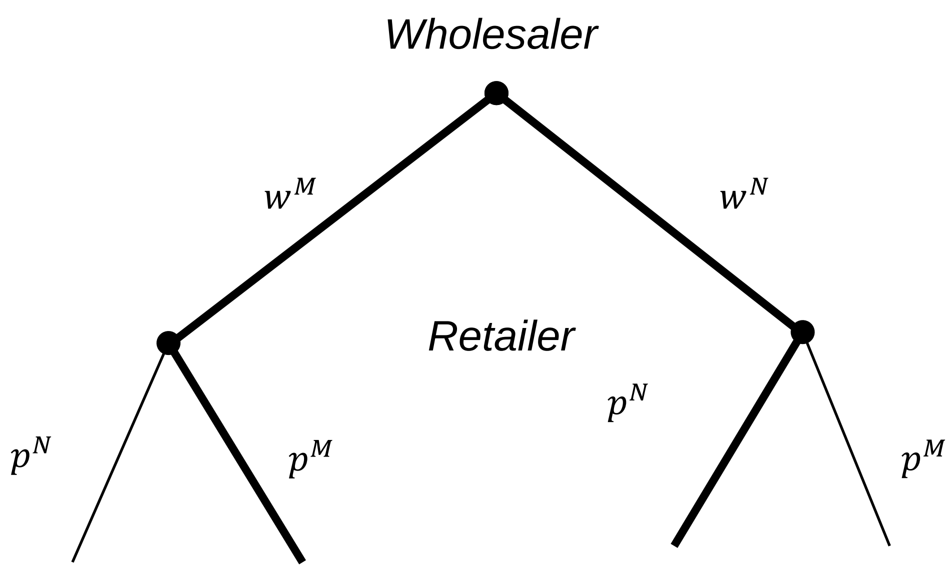

Figure (C) Networks choice on retail policy in extensive form.

Appendix (D). Instrumental Variables

In this appendix, we evaluate the use of the Omani networks (Nawras and Oman-Mobile), separately and jointly, as instrumental variables (IVs) in the Two-Stage Least Square (2SLS) estimation of Chapter (6), for the following model.

$$\begin{gathered} ln(s_j) - ln(s_o) = \beta_0 + \beta_1 YEAR + \beta_2 POLICY + \beta_3 PRICE_j \\ +\beta_4 CROSSOWNED_j + \beta_5 ALLIANCE_j + \beta_6 CAMEL_j \\ +\beta_7 POLICY \times CROSSOWNED_j + \beta_8 POLICY \times ALLIANCE_j + \beta_9 POLICY \times CAMEL_j + \xi_j, \\ (j = 0, 1, \dots, 552). \end{gathered} \tag{D}$$

The variables are defined in Table (6.1). The observations are limited to highly visited markets as explained in Chapter (6).

In Table (D.1) below, model (D5) is the same 1SLS used in Chapter (7); and model (D6) is the same 2SLS used in Chapter (6). In the first-stage regression, the coefficients of the Omani networks IVs, separately and jointly, are positive and significant at 1% level. As shown in Table (D.2), the associated coefficient has F-statistics above 10.

However, their implications on the endogenous regressor (i.e. wholesale prices charged to Etisalat) in the 2SLS differ considerably. Only with Nawras IV we find a negative and significant price coefficient. In contrast, the price coefficient is negative and insignificant with Oman-Mobile IV, and incorrect (i.e. with positive sign) and insignificant when both IVs are used.

We checked for the validity of using both Omani networks as IVs, using the over identification restrictions test, where the null hypothesis states that all instruments are uncorrelated with the error term, ξ_j, of Eq. (D). As shown in Table (D.2), at 5% significance level, we fail to reject the null that both IVs are valid.

We think the validity of both IVs comes from the ability of each IV to reflect cost differentials across markets, as will be elaborated next.

Furthermore, we run Durbin and Wu-Hausman tests for the null hypothesis that the OLS estimator is equivalent to the 2SLS estimator using the Omani networks IVs, separately and jointly. If OLS and 2SLS are similar, then there is no need for the instrument because OLS is efficient; in other words, the endogenous regressor, $PRICE_{jt}$, should be treated as exogenous.

However, we know in our case that the OLS estimator is biased due to the endogeneity problem. With these tests, we try to know which IV(s) should recommend using 2SLS. Only with Nawras IV we find significance: we reject the null hypothesis at 1% significance level, and conclude the OLS and the 2SLS estimators are different. Therefore, the use of 2SLS is only recommended when Nawras IV is used.

Therefore, in Chapter (6), we proceeded in the 2SLS estimation with the price of Nawras as an IV. Next, we provide an interpretation why Nawras can be a better IV compared to Oman-Mobile.

A variable of a home network's retail prices (other than Etisalat) is chosen as an IV based on the assumption that the retail prices reflect actual costs of visited networks. If the IV has discriminatory retail prices, as with Oman-Mobile, it should reflect actual costs within a market and across markets. However, because a discriminatory retail price reflects the embedded wholesale price, this IV does not overcome any bias at the wholesale level stemming from preferential agreements (e.g. alliance discounts). This bias can be in the IV itself (e.g. Oman-Mobile retail prices), in the endogenous regressor (e.g. wholesale prices charged to Etisalat), or in both variables if preferential agreements differ between home networks.

On the other hand, an IV using uniform retail pricing, as with Nawras, is assumed to reflect the common costs of visited networks in a given market, providing cost differentials across markets. Although it does not tell about costs asymmetry within a market, an IV using uniform retail pricing is neutral to preferential agreements and hence it overcomes the bias caused by preferential wholesale prices.

Table (D.1) Instrumental variables for simple logit demand models with Oman-Mobile.

Market	High Visited Markets					
Instrumental Variable(s)	**Oman-Mobile & Nawras**		**Oman-Mobile**		**Nawras**	
Estimator	**1SLS**	**2SLS**	**1SLS**	**2SLS**	**1SLS**	**2SLS**
Dependent variable	$PRICE_{jt}$	$ln(s_j) - ln(s_o)$	$PRICE_{jt}$	$ln(s_j) - ln(s_o)$	$PRICE_{jt}$	$ln(s_j) - ln(s_o)$
Model	**(D1)**	**(D2)**	**(D3)**	**(D4)**	**(D5)**	**(D6)**
CONSTANT	2.107*** (0.306)	-4.860*** (0.253)	3.255*** (0.283)	-4.764*** (0.253)	2.733*** (0.314)	-3.865*** (0.330)
YEAR	-0.310** (0.141)	-0.031 (0.103)	-0.262* (0.139)	-0.071 (0.100)	-0.251* (0.148)	-0.060 (0.128)
POLICY (Dummy=1 for 2010-2011)	0.773** (0.355)	-0.797*** (0.258)	0.518 (0.348)	-0.533** (0.250)	0.655* (0.369)	-0.639** (0.318)
$PRICE_{jt}$ (network's own price)	- -	0.021 (0.027)	- -	-0.015 (0.027)	- -	-0.203*** (0.037)
$OMAN\_MOBILE_j$ (Oman-Mobile retail price in AED in 2013 for roaming on *j*)	0.150*** (0.018)	- -	0.298*** (0.011)	- -	- -	- -
$NAWRAS_j$ (Nawras retail price in AED in 2013 for roaming on *j*)	0.207*** (0.018)	- -	- -	- -	0.262*** (0.011)	- -
Network characteristics:						
$CROSSOWNED_{jt}$ (Dummy=1 if network is cross-owned by Etisalat)	-0.795 (0.605)	-0.024 (0.440)	-0.798 (0.596)	0.052 (0.429)	-1.050* (0.635)	-0.342 (0.549)
$ALLIANCE_j$ (Dummy=1 if network is alliance to Etisalat)	0.459 (0.289)	0.135 (0.211)	0.476* (0.288)	0.319 (0.207)	0.671** (0.315)	0.439 (0.273)
$CAMEL_j$ (Dummy=1 if network allows Etisalat prepaid)	0.331 (0.216)	0.649*** (0.156)	-0.050 (0.208)	0.766*** (0.149)	0.575** (0.225)	1.042*** (0.193)
Interaction with *POLICY*:						
$CROSSOWNED_{jt}$	1.341* (0.723)	-1.688*** (0.526)	0.814 (0.721)	-1.621*** (0.518)	1.513** (0.760)	-1.103* (0.655)
$ALLIANCE_j$	-1.133*** (0.411)	0.434 (0.300)	-1.081*** (0.409)	0.392 (0.295)	-1.124** (0.448)	0.133 (0.388)
$CAMEL_j$	-0.454 (0.292)	0.717*** (0.212)	-0.083 (0.286)	0.539*** (0.205)	-0.489 (0.307)	0.563** (0.264)
Observations	765	765	907	907	831	831
R^2	0.509	-	0.442	-	0.413	-
R^2 *Adjusted*	0.502	-	0.436	-	0.406	-

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table (D.2) Tests for the instrumental variables used in Table (D.1).

Instrumental Variable(s)	**Oman-Mobile & Nawras**		**Oman-Mobile**		**Nawras**	
Test/Result	Score or F-statistics	P-value	Score or F-statistics	P-value	Score or F-statistics	P-value
1SLS coefficient's significance (H_0: IV's coefficient is insignificant)	374.195	0.000***	689.083	0.000***	550.561	0.000***
Over identification restrictions (H_0: Both IVs are valid)						
Sargan	5.105	0.024**	-	-	-	-
Basmann	5.066	0.024**	-	-	-	-
Price endogeneity: (H_0: OLS and 2SLS are the same)						
Durbin	1.703	0.192	0.748	0.388	37.980	0.000***
Wu-Hausman	1.682	0.195	0.739	0.390	39.272	0.000***

* p<0.10, ** p<0.05, *** p<0.01

Furthermore, we try Oman-Mobile IV, but after taking its average retail price in the relevant market. By doing so, we try to eliminate what we call the wholesale bias, as explained previously, by turning the discriminatory nature of the IV to something like uniform IV.

In Table (D.3) below, the number of observations for Oman-Mobile prices rises from 907 to 987, because the missing visited networks in Oman-Mobile IV take the market average. The average price has a positive and significant coefficient at 1% level in the 1SLS models (D7) and (D9). Notice the significance of the endogenous regressor, $PRICE_{jt}$, in Table (D.3), compared to the previous models (D2) and (D4). The sign of the coefficient is negative with 1% significance level. The size of the coefficients in models (D6), (D8) and (D10) is similar. Moreover, model (D10) has very similar results to model (D6) regarding the rest of regressors; and the same is true with model (D8) except for $POLICY$ and $ALLIANCE_j$.

Table (D.4) below presents test results related to the market average of Oman-Mobile. Interestingly, the null hypothesis related to price endogeneity is rejected with 1% significance level, compared to Table (D.2) when we failed to reject it. The lesson learned here is that the discriminatory IV can be a good instrument if we take its market average, intuitively, because of removing preferential wholesale bias.

Table (D.3) Instrumental variables for simple logit demand models with average Oman-Mobile.

Market	High Visited Markets			
Instrumental Variable(s)	**Average Oman-Mobile**		**Average Oman-Mobile & Nawras**	
Estimator	**1SLS**	**2SLS**	**1SLS**	**2SLS**
Dependent variable	$PRICE_{jt}$	$ln(s_j) - ln(s_o)$	$PRICE_{jt}$	$ln(s_j) - ln(s_o)$
Model	**(D7)**	**(D8)**	**(D9)**	**(D10)**
CONSTANT	2.754*** (0.288)	-3.954*** (0.312)	2.498*** (0.313)	-3.976*** (0.325)
YEAR	-0.212 (0.136)	-0.045 (0.120)	-0.252* (0.146)	-0.055 (0.127)
POLICY (Dummy=1 for 2010-2011)	0.455 (0.340)	-0.481 (0.299)	0.604* (0.363)	-0.647** (0.316)
$PRICE_{jt}$ (network's own price)	- -	-0.216*** (0.035)	- -	-0.186*** (0.036)
$AVERAGE\_OMAN\_MOBILE_r$ (Oman-Mobile average retail price in AED in 2013 for roaming in market *r*)	0.315*** (0.012)	- -	0.135*** (0.026)	- -
$NAWRAS_j$ (Nawras retail price in AED in 2013 for roaming on *j*)	- -	- -	0.172*** (0.021)	- -
Network characteristics:				
$CROSSOWNED_{jt}$ (Dummy=1 if network is cross-owned by Etisalat)	-1.143* (0.590)	-0.272 (0.521)	-1.063* (0.625)	-0.315 (0.545)
$ALLIANCE_j$ (Dummy=1 if network is alliance to Etisalat)	0.843*** (0.294)	0.568** (0.260)	0.754** (0.310)	0.423 (0.271)
$CAMEL_j$ (Dummy=1 if network allows Etisalat prepaid)	0.259 (0.205)	1.086*** (0.180)	0.437* (0.223)	1.038*** (0.192)
Interaction with *POLICY*:				
$CROSSOWNED_{jt}$	1.246* (0.714)	-1.101* (0.629)	1.494** (0.748)	-1.124* (0.651)
$ALLIANCE_j$	-1.121*** (0.418)	0.119 (0.369)	-1.127** (0.441)	0.152 (0.385)
$CAMEL_j$	-0.152 (0.281)	0.417* (0.247)	-0.426 (0.303)	0.567** (0.262)
Observations	987	987	831	831
R^2	0.407	-	0.431	-
R^2 *Adjusted*	0.401	-	0.424	-

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table (D.4) Tests for the instrumental variables used in Table (D.3).

Instrumental Variable(s)	**Average Oman-Mobile**		**Average Oman-Mobile & Nawras**	
Test/Result	Score or F-statistics	P-value	Score or F-statistics	P-value
1SLS coefficient's significance (H$_0$: IV's coefficient is insignificant)	646.622	0.000***	296.585	0.000***
Over identification restrictions (H$_0$: Both IVs are valid)				
Sargan	-	-	5.400	0.020**
Basmann	-	-	5.364	0.021**
Price endogeneity: (H$_0$: OLS and 2SLS are the same)				
Durbin	39.9823	0.000***	32.8469	0.000***
Wu-Hausman	41.2059	0.000***	33.7459	0.000***

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Appendix (E). Additional Estimations For Demand And Steering Models

This appendix provides additional estimations that are referred to in the demand models (Chapter 6) and the effectiveness of steering models (Chapter 8). Those two chapters share similarities in the fact that they have visited networks' market shares as the dependent variable.

The main purpose of this appendix is to support the argument that we should have a demand model that is separate from a steering model such that the demand model reflects demand-side substitution made by Etisalat roamers, while the steering model reflects supply-side substitution made by the home network, Etisalat. In addition, the wholesale price set by a visited network as given in the dataset (hereafter given price) suits the demand model; and the wholesale price set by a visited network relative to its market arithmetic mean (hereafter relative price) suits the steering model.

For the sake of the above argument, we will use the simple logit demand model similar to Eq. (6.1) of Chapter (6) under different specifications using either the given price or the relative price, with and without the interaction term of price and policy. Moreover, we will compare estimations between highly visited markets, low visited markets and all markets. Since we shall be testing for steering also and for the sake of the above argument, we found the results are very similar if, instead, we used the functional form as in Chapter (8) for steering models.

The model for the simple logit demand is provided by Eq. (E.1) with the given price, which is estimated by Ordinary Least Squares (OLS). Subscript for year is dropped as data is pooled, and market subscript is dropped for convenience.

$$
\begin{aligned}
ln(s_j) - ln(s_o) = {} & \beta_0 + \beta_1 YEAR + \beta_2 POLICY + \beta_3 PRICE_j \\
& + \beta_4 CROSSOWNED_j + \beta_5 ALLIANCE_j + \beta_6 CAMEL_j \\
& + \beta_7 POLICY \times CROSSOWNED_j + \beta_8 POLICY \times ALLIANCE_j + \beta_9 POLICY \times CAMEL_j \\
& + \beta_{10} POLICY \times PRICE_j + \xi_j, \\
& \qquad (j = 0, 1, \dots, 552).
\end{aligned}
\tag{E.1}
$$

$ln(s_j)$ is the natural log of the market share of visited network j; $ln(s_0)$ is the natural log of the outside good share; and ξ_j is the error term. The product $j = 0$ refers to the outside good (see Table 6.2). All the variables that will be used in this appendix are listed in Table (E.1) below.

In addition, we will also re-estimate the demand using the relative price in the following model.

$$
\begin{aligned}
ln(s_j) - ln(s_o) = {} & \beta_0 + \beta_1 YEAR + \beta_2 POLICY + \beta_3 RPRICE_j \\
& + \beta_4 CROSSOWNED_j + \beta_5 ALLIANCE_j + \beta_6 CAMEL_j \\
& + \beta_7 POLICY \times CROSSOWNED_j + \beta_8 POLICY \times ALLIANCE_j + \beta_9 POLICY \times CAMEL_j \\
& + \beta_{10} POLICY \times RPRICE_j + \xi_j, \\
& \quad (j = 0, 1, \ldots, 552).
\end{aligned} \tag{E.2}
$$

The key variable that can support the aforementioned argument lies in the interaction term of the price and the policy dummy variable (1 if uniform; 0 if discriminatory), which tells us about the effect of wholesale price on a visited network's market share before and after Etisalat retail pricing policy. The reason behind this is the consumer's discretion regarding price as assumed throughout the thesis. That is, before the policy, roamers care about price (since the retail price reflects the wholesale price) and thus should choose manually between visited networks; while after the policy, roamers leave handsets on automatic mode since retail price is common to use any network in a given market (assuming roamers' decisions on network selection are mainly based on price). Automatic network selection allows Etisalat to choose between visited networks via its steering technologies. In other words, before the policy, demand-side substitution is assumed; and after the policy, supply-side substitution is assumed. Accordingly, the testable hypotheses are listed and explained as follows.

- H1: $\widehat{\beta_3} = 0$.
  - That is, before the policy (i.e. during the years when Etisalat retail price was discriminatory by visited networks), the price coefficient is insignificant.
  - If the coefficient is insignificant, we fail to reject H1 and conclude that roamers do not care about price before the policy such that they leave their handsets on default-automatic mode. This conclusion can also mean that roamers are price insensitive. In addition, it means steering by Etisalat can be enabled, but is ineffective because market share does not respond to changes in wholesale price.

- If the coefficient is negative and significant, we reject H1 and conclude that roamers care about price before the policy such that they use their handsets to manually select the visited network with the cheapest price. This also means that steering by Etisalat is disabled because steering requires handsets to be on automatic mode.

- H2: $\widehat{\beta_3} + \widehat{\beta_{10}} = 0$.
  - That is, after the policy (i.e. during the years when Etisalat retail price became uniform), the joint coefficients of price and the interaction term are insignificant.
  - If the joint coefficients are insignificant, we fail to reject H2 and conclude that roamers do not care about price after the policy such that they leave their handsets on default-automatic mode. This conclusion also means steering by Etisalat can be enabled, but is ineffective because market share does not respond to changes in wholesale price.
  - If the joint coefficients are negative and significant, we reject H2 and conclude that market share is responsive to wholesale price after the policy. Given automatic network selection that enables steering, this conclusion is interpreted in terms of buyer power as steering by Etisalat is effective because market share responds to changes in wholesale price.

The results of testing the above hypotheses together will be interpreted to judge which model should be considered a demand model, a steering model, and a demand or steering model, or none of these (see Table E.0 below). Then based on such judgement, we justify why we should use the given price and why we should use the relative price.

Table (E.0) Possible scenarios for the hypotheses test results and our intuitions.

Possible hypotheses test results	Explanation	Suggested use of the model
Reject both H1 and H2	Price is significant before and after the policy	Demand or steering
Reject H1 but fail to reject H2	Price is significant only before the policy	Demand only
Fail to reject H1 but reject H2	Price is significant only after the policy	Steering only
Fail to reject both H1 and H2	Price is insignificant before and after the policy	None

Demand estimations are presented for highly visited markets in Table (E.2), for low visited markets in Table (E.3), and for all markets (i.e. all observations) in Table (E.4). The marginal effects of price and policy are reported in Table (E.5).

Table (E.1) Notations and variables related to estimations.

Notation	**Description**
j	Subscript for visited networks, where (*j=1,…,552*).
t	Subscript for year, where (*t=2008,2009,2010,2011*).
r	Subscript for geographic market, where (*r=1,…,204*).
Time variables	**Description**
YEAR	Discrete variable for the study years, where *(1=2008, 2=2009, 3=2010, 4=2011)*.
POLICY	Dummy variable equals 1 for the years 2010-2011 (when Etisalat implemented its uniform retail policy); 0 for the years 2008-2009 (when Etisalat implemented discriminatory retail policy).
Price variables	**Description**
$PRICE_{jt}$	j's average wholesale price per minute of outgoing call in year t (in constant AED with 2007 as base year).
$RPRICE_{jrt}$	j's average wholesale price per minute of outgoing call relative to the arithmetic mean of its market r in year t (in constant AED with 2007 as base year).
Visited network's characteristic variables	**Description**
$CROSSOWNED_{jt}$	Dummy variable equals 1 if j is cross-owned by Etisalat in year t; 0 otherwise.
$ALLIANCE_j$	Dummy variable equals 1 if j is a roaming alliance to Etisalat; 0 otherwise.
$CAMEL_j$	Dummy variable equals 1 if j allows Etisalat prepaid roaming; 0 otherwise.
Market shares variables	**Description**
s_{jrt}	j's market share in minutes of outgoing calls in market r and year t.
s_{ot}	Outside good market share in year t.

Table (E.2) Simple logit demand models for observations in Highly Visited Markets.

Dependent variable: $ln(s_j) - ln(s_o)$	**(E1)**	**(E2)**	**(E3)**	**(E4)**	**(E5)**	**(E6)**	**(E7)**	**(E8)**
CONSTANT	-4.305***	-5.112***	-5.006***	-4.749***	-4.352***	-5.320***	-5.283***	-5.743***
	(0.253)	(0.245)	(0.252)	(0.307)	(0.289)	(0.279)	(0.284)	(0.466)
YEAR	-0.028	-0.006	-0.007	-0.006	-0.013	0.008	0.006	0.004
	(0.125)	(0.116)	(0.116)	(0.116)	(0.126)	(0.117)	(0.116)	(0.116)
POLICY	-0.379	-0.328	-0.526*	-0.916**	-0.392	-0.342	-0.539*	0.052
(Dummy=1 for 2010-2011)	(0.282)	(0.262)	(0.290)	(0.393)	(0.283)	(0.262)	(0.290)	(0.556)
$PRICE_{jt}$	-0.056**	-0.055***	-0.052**	-0.095***	-	-	-	-
(network own price)	(0.023)	(0.021)	(0.021)	(0.036)	-	-	-	-
$RPRICE_{jrt}$	-	-	-	-	-0.313	-0.147	-0.060	0.411
(network own price relative to arithmetic mean)	-	-	-	-	(0.203)	(0.189)	(0.192)	(0.424)
Network characteristics:								
$CROSSOWNED_{jt}$	-	-0.912***	-0.003	-0.070	-	-0.847***	0.069	0.140
(Dummy=1 if network is cross-owned by Etisalat)	-	(0.285)	(0.504)	(0.506)	-	(0.286)	(0.506)	(0.509)
$ALLIANCE_j$	-	0.621***	0.465*	0.488**	-	0.610***	0.440*	0.425*
(Dummy=1 if network is alliance to Etisalat)	-	(0.177)	(0.248)	(0.249)	-	(0.178)	(0.249)	(0.249)
$CAMEL_j$	-	1.328***	1.092***	1.088***	-	1.330***	1.098***	1.086***
(Dummy=1 if network allows Etisalat prepaid)	-	(0.119)	(0.174)	(0.174)	-	(0.120)	(0.175)	(0.175)
Interaction with *POLICY*:								
$CROSSOWNED_{jt}$	-	-	-1.286**	-1.208**	-	-	-1.318**	-1.357**
	-	-	(0.610)	(0.612)	-	-	(0.617)	(0.617)
$ALLIANCE_j$	-	-	0.293	0.281	-	-	0.335	0.330
	-	-	(0.353)	(0.353)	-	-	(0.356)	(0.355)
$CAMEL_j$	-	-	0.407*	0.412*	-	-	0.400*	0.408*
	-	-	(0.240)	(0.239)	-	-	(0.241)	(0.241)
$PRICE_{jt}$	-	-	-	0.065	-	-	-	-
	-	-	-	(0.044)	-	-	-	-
$RPRICE_{jrt}$	-	-	-	-	-	-	-	-0.592
	-	-	-	-	-	-	-	(0.475)
Observations	995	995	995	995	995	995	995	995
R^2	0.017	0.158	0.164	0.166	0.013	0.152	0.159	0.161
R^2 *Adjusted*	0.0141	0.153	0.157	0.158	0.0105	0.147	0.152	0.152

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table (E.3) Simple logit demand models for observations in Low Visited Markets.

Dependent variable: $ln(s_j) - ln(s_o)$	**(E9)**	**(E10)**	**(E11)**	**(E12)**	**(E13)**	**(E14)**	**(E15)**	**(E16)**
CONSTANT	-3.856***	-3.760***	-3.754***	-3.715***	-2.621***	-2.512***	-2.583***	-3.613***
	(0.201)	(0.199)	(0.199)	(0.233)	(0.241)	(0.240)	(0.240)	(0.404)
YEAR	-0.102	-0.101	-0.100	-0.100	-0.115	-0.108	-0.107	-0.107
	(0.095)	(0.094)	(0.093)	(0.093)	(0.094)	(0.092)	(0.091)	(0.091)
POLICY	-0.310	-0.285	-0.319	-0.386	-0.303	-0.281	-0.306	1.037**
(Dummy=1 for 2010-2011)	(0.212)	(0.209)	(0.212)	(0.299)	(0.210)	(0.205)	(0.208)	(0.473)
PRICE$_{jt}$	0.038**	0.024	0.026	0.020	-	-	-	-
(network own price)	(0.016)	(0.016)	(0.016)	(0.024)	-	-	-	-
RPRICE$_{jrt}$	-	-	-	-	-0.955***	-1.055***	-0.972***	0.047
(network own price relative to arithmetic mean)	-	-	-	-	(0.180)	(0.178)	(0.178)	(0.368)
Network characteristics:								
CROSSOWNED$_{jt}$	-	-1.314***	0.133	0.120	-	-1.501***	-0.207	0.086
(Dummy=1 if network is cross-owned by Etisalat)	-	(0.236)	(0.400)	(0.402)	-	(0.231)	(0.396)	(0.405)
ALLIANCE$_j$	-	-0.230	-0.439	-0.440	-	-0.295	-0.373	-0.448
(Dummy=1 if network is alliance to Etisalat)	-	(0.226)	(0.326)	(0.326)	-	(0.222)	(0.322)	(0.321)
CAMEL$_j$	-	0.281**	-0.031	-0.028	-	0.236*	-0.046	-0.015
(Dummy=1 if network allows Etisalat prepaid)	-	(0.129)	(0.182)	(0.183)	-	(0.127)	(0.179)	(0.179)
Interaction with *POLICY*:								
CROSSOWNED$_{jt}$	-	-	-2.160***	-2.139***	-	-	-1.921***	-2.231***
	-	-	(0.489)	(0.494)	-	-	(0.484)	(0.492)
ALLIANCE$_j$	-	-	0.387	0.393	-	-	0.147	0.175
	-	-	(0.446)	(0.447)	-	-	(0.442)	(0.440)
CAMEL$_j$	-	-	0.575**	0.569**	-	-	0.533**	0.479*
	-	-	(0.255)	(0.256)	-	-	(0.252)	(0.251)
PRICE$_{jt}$	-	-	-	0.010	-	-	-	-
	-	-	-	(0.032)	-	-	-	-
RPRICE$_{jrt}$	-	-	-	-	-	-	-	-1.326***
	-	-	-	-	-	-	-	(0.420)
Observations	932	932	932	932	932	932	932	932
R^2	0.039	0.074	0.099	0.099	0.062	0.106	0.125	0.134
R^2 *Adjusted*	0.0360	0.0681	0.0904	0.0895	0.0587	0.100	0.116	0.125

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table (E.4) Simple logit demand models for all observations.

Dependent variable: $ln(s_j) - ln(s_o)$	(E17)	(E18)	(E19)	(E20)	(E21)	(E22)	(E23)	(E24)
CONSTANT	-4.266***	-4.452***	-4.397***	-4.339***	-3.618***	-3.876***	-3.905***	-4.710***
	(0.168)	(0.170)	(0.172)	(0.205)	(0.197)	(0.198)	(0.200)	(0.334)
YEAR	-0.043	-0.035	-0.037	-0.037	-0.045	-0.036	-0.039	-0.041
	(0.082)	(0.081)	(0.080)	(0.080)	(0.082)	(0.080)	(0.080)	(0.080)
POLICY	-0.349*	-0.310*	-0.410**	-0.505*	-0.348*	-0.310*	-0.401**	0.635
(Dummy=1 for 2010-2011)	(0.184)	(0.181)	(0.190)	(0.263)	(0.183)	(0.180)	(0.189)	(0.394)
$PRICE_{jt}$	0.012	0.010	0.012	0.003	-	-	-	-
(network own price)	(0.014)	(0.014)	(0.014)	(0.022)	-	-	-	-
$RPRICE_{jrt}$	-	-	-	-	-0.566***	-0.505***	-0.411***	0.398
(network own price relative to arithmetic mean)	-	-	-	-	(0.142)	(0.140)	(0.141)	(0.304)
Network characteristics:								
$CROSSOWNED_{jt}$	-	-1.011***	0.344	0.328	-	-1.018***	0.235	0.408
(Dummy=1 if network is cross-owned by Etisalat)	-	(0.200)	(0.346)	(0.348)	-	(0.198)	(0.346)	(0.350)
$ALLIANCE_j$	-	0.291**	0.101	0.103	-	0.261*	0.122	0.086
(Dummy=1 if network is alliance to Etisalat)	-	(0.145)	(0.205)	(0.205)	-	(0.145)	(0.204)	(0.204)
$CAMEL_j$	-	0.521***	0.278**	0.277**	-	0.508***	0.278**	0.275**
(Dummy=1 if network allows Etisalat prepaid)	-	(0.088)	(0.126)	(0.126)	-	(0.087)	(0.126)	(0.126)
Interaction with *POLICY*:								
$CROSSOWNED_{jt}$	-	-	-1.984***	-1.961***	-	-	-1.840***	-1.987***
	-	-	(0.422)	(0.424)	-	-	(0.423)	(0.425)
$ALLIANCE_j$	-	-	0.359	0.361	-	-	0.269	0.271
	-	-	(0.288)	(0.288)	-	-	(0.289)	(0.288)
$CAMEL_j$	-	-	0.422**	0.424**	-	-	0.407**	0.402**
	-	-	(0.175)	(0.175)	-	-	(0.174)	(0.174)
$PRICE_{jt}$	-	-	-	0.015	-	-	-	-
	-	-	-	(0.028)	-	-	-	-
$RPRICE_{jrt}$	-	-	-	-	-	-	-	-1.029***
	-	-	-	-	-	-	-	(0.343)
Observations	1,927	1,927	1,927	1,927	1,927	1,927	1,927	1,927
R^2	0.015	0.050	0.064	0.064	0.023	0.056	0.068	0.072
R^2 *Adjusted*	0.0137	0.0468	0.0598	0.0595	0.0213	0.0529	0.0636	0.0675

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table (E.5) Marginal effects on visited networks' prices post Etisalat uniform retail policy.

Observations	Null Hypothesis	Relevant model	F-statistics	P-value
Observations in High Visited Markets (Table E.2)	$\widehat{\beta_3} + \widehat{\beta_{10}} = 0$	Given price (E4)	1.35	0.245
		Relative price (E8)	0.71	0.400
Observations in Low Visited Markets (Table E.3)	$\widehat{\beta_3} + \widehat{\beta_{10}} = 0$	Given price (E12)	2.04	0.154
		Relative price (E16)	40.08	0.000***
All observations (Table E.4)	$\widehat{\beta_3} + \widehat{\beta_{10}} = 0$	Given price (E20)	0.98	0.321
		Relative price (E24)	15.79	0.000***

* p<0.10, ** p<0.05, *** p<0.01

We discuss models (E4) and (E8) for the highly visited markets (Table E.2), models (E12) and (E16) for the low visited markets (Table E.3), and models (E20) and (E24) for all observations (Table E.4). The marginal effects post-the-policy are discussed based on Table (E.5). Conclusions regarding which model and price suits to model demand or steering are drawn in light of Table (E.0).

For visited networks in the highly visited markets, the given price is found negative and significant only before the policy (model E4); while the relative price is found insignificant before or after the policy (model E8). Therefore, we can reject H1 but fail to reject H2 with the given price; however with the relative price, we fail to reject both H1 and H2.

We conclude that the model for highly visited markets with the given price, model (E4), should be used to model demand, as roamers care about the wholesale price only during the time when it was reflected in the retail price (i.e. before the policy when retail prices were discriminatory). However, no model for highly visited markets suits to model steering, as the market share does not respond to changes in wholesale price after the policy. Moreover, the relative price does not suit the demand model as it is insignificant before or after the policy, which can be due to the fact that relative price does not reflect the level of prices to which roamers are sensitive.

For visited networks in the low visited markets, the given price is found insignificant before or after the policy (model E12); while the relative price is found negative and significant only after the policy (E16). Therefore, we fail to reject H1 and H2 with the given price; however with the relative price, we fail to reject H1 but we can reject H2.

We conclude that the model for low visited markets with the relative price, model (E16), should be used to model steering. This is so because market share is responsive to changes in wholesale price, suggesting that Etisalat has effective steering after its uniform retail policy that makes undercutting by a visited network attractive to raise own market share. However, no model for low visited markets suits to model demand, as the market share does not respond to changes in wholesale price before the policy. Moreover, the given price does not suit the steering model as it is insignificant before or after the policy, because probably roamers are insensitive to price in the low visited markets. In addition, the same intuitions for the low visited markets are true for all observations (models E20 and E24).

In sum, we think the given price suits the demand model as it represents roamers' response to price (i.e. demand-side substitution), while relative price suits the steering model as it represents Etisalat's response to price (i.e. supply-side substitution).

A part from the hypotheses, the coefficient of the given price in the low visited markets is found positive and significant (model E9). This is caused by not controlling for visited network's characteristics. In fact, CAMEL dummy variable's coefficient is only significant after the policy. However, the significance and size of the CAMEL dummy variable's coefficient indicate that low visited markets do not significantly host prepaid roamers as compared to the highly visited markets.

Appendix (F). Mean Elasticities In EEA Countries

Table (F) Estimated mean own price elasticity of demand for EEA visited networks by market.

Market	Mean elasticity (2008-2011)
AUSTRIA	-1.428
BELGIUM	-1.659
CYPRUS	-0.511
CZECH REPUBLIC	-2.018
DENMARK	-1.174
FINLAND	-0.931
FRANCE	-1.640
GERMANY	-1.244
GREECE	-1.127
IRELAND	-1.140
ITALY	-1.490
NETHERLANDS	-1.176
NORWAY	-0.718
PORTUGAL	-1.548
ROMANIA	-1.689
SPAIN	-1.458
SWEDEN	-1.020
UK	-1.178
All EEA	-1.295

Source: Estimated elasticity based on Eq. (6.2) using the price coefficient of model (6f).

Appendix (G). List Of Visited Networks

Table (G) List of all foreign networks visited by Etisalat roamers during the years 2008-2011.

SERIAL	TAP	OPERATOR	MARKET	SERIAL	TAP	OPERATOR	MARKET
1	AFGAW	AFGHAN WIRELESS	AFGHANISTAN	51	BIHER	HT ERONET	BOSNIA HERZEGOVINA
2	AFGEA	ETISALAT-AFGHN	AFGHANISTAN	52	BIHMS	MOBILNA - BIH	BOSNIA HERZEGOVINA
3	AFGAR	MTN	AFGHANISTAN	53	BWAGA	MASCOM-BOTSWANA	BOTSWANA
4	AFGTD	TDC(ROSHAN) AFG	AFGHANISTAN	54	BWAVC	VISTA CELLULAR	BOTSWANA
5	ALBAM	AMC, ALBANIA	ALBANIA	55	BRABT	14 BRASIL TELCO	BRAZIL
6	ALBEM	EAGLE MOBILE	ALBANIA	56	BRACS	TIM - BRACS	BRAZIL
7	ALBVF	VODAFONE ALBANI	ALBANIA	57	BRARN	TIM - BRARN	BRAZIL
8	DZAA1	ATM MOBILIS ALG	ALGERIA	58	BRASP	TIM - BRASP	BRAZIL
9	DZAOT	DJEZZY	ALGERIA	59	BRATM	TNL PCS BRAZIL	BRAZIL
10	DZAWT	WATANIYA - DZA	ALGERIA	60	BRATC	VIVO-MG	BRAZIL
11	ANDMA	MOBILAND GSM	ANDORRA	61	BRNBR	B.MOBILE COMM.	BRUNEI
12	AGOUT	UNITEL	ANGOLA	62	BRNDS	DST COMMUNICATI	BRUNEI
13	AIACW	C&W ANGUILLA	ANGUILLA	63	BGRVA	BTC	BULGARIA
14	ATGCW	C&W ANTIGUA	ANTIGUA & BARBUDA	64	BGRCM	GLOBUL	BULGARIA
15	ARGTP	TELE. ARGENTINA	ARGENTINA	65	BGR01	MOBILTEL,BULGRI	BULGARIA
16	ARM01	ARMENTEL GSM900	ARMENIA	66	BFACT	CELTEL - B.FASO	BURKINA FASO
17	ARM05	K-TEL VIVACELL	ARMENIA	67	BFATL	TELECEL - BFASO	BURKINA FASO
18	ARMOR	ORANGE ARMENIA	ARMENIA	68	BFAON	TELMOB	BURKINA FASO
19	AUSHU	HUTCHISON 3G AU	AUSTRALIA	69	BDIET	ECONET WIRELESS	BURUNDI
20	AUSOP	OPTUS,AUSTRALIA	AUSTRALIA	70	KHMCC	CADCOMMS	CAMBODIA
21	AUSTA	TELSTRA, AUS	AUSTRALIA	71	KHMGM	CAMGSM	CAMBODIA
22	AUSVF	VODAFONE-AUS	AUSTRALIA	72	KHMSM	CASACOM	CAMBODIA
23	AUTHU	H3G	AUSTRIA	73	KHML1	LATEZ CO, LTD	CAMBODIA
24	AUTPT	MOBILKOM, AUT	AUSTRIA	74	KHMSH	SHINAWTRA CO.	CAMBODIA
25	AUTCA	ORANGE AUSTRIA	AUSTRIA	75	CMRMT	MTN - CAMEROON	CAMEROON
26	AUTMM	T-MOBIL AUSTRIA	AUSTRIA	76	CMR02	ORANGE CAMEROUN	CAMEROON
27	AZEAC	AZERCEL - AZB	AZERBAIJAN	77	CANBM	BELL MOBILITY	CANADA
28	AZEAF	AZERFON LLC	AZERBAIJAN	78	CANRW	ROGERS - CANADA	CANADA
29	AZEBC	BAKCELL LTD	AZERBAIJAN	79	CANTS	TELUS	CANADA
30	BHRBT	BATELCO,BAHRAIN	BAHRAIN	80	CYMCW	C&W CAYMAN	CAYMAN
31	BHRST	STC BAHRAIN	BAHRAIN	81	CAFAT	MOOV-RCA	CENTRAL AFRICA REPUBLIC
32	BHRMV	ZAIN-BAHRAIN	BAHRAIN	82	TCDCT	CELTEL - TCHAD	CHAD
33	BGDGP	GRAMEEN PHONE	BANGLADESH	83	TCDML	MILICOM (TIGO)	CHAD
34	BGDBL	SHEBA TELECOM	BANGLADESH	84	CHLMV	ENTEL PCS TELEC	CHILE
35	BGDTT	TELETALK BNGDSH	BANGLADESH	85	CHNCT	CHINA TELECOM	CHINA
36	BGDAK	TM INTERNATIONL	BANGLADESH	86	CHNCU	CHINA UNICOM	CHINA
37	BGDWT	WARID(BANGLADSH	BANGLADESH	87	COLCM	COM.COMCEL S.A	COLOMBIA
38	BRBCW	C&W BARBADOS	BARBADOS	88	COMHR	COMORES TELECOM	COMOROS ISLANDS
39	BLRMD	FE 'VELCOM'	BELARUS	89	CODCT	CELTEL-DRC CONG	CONGO (DEMOCRATIC REPUBLIC)
40	BLR02	MTS - BELARUS	BELARUS	90	CODSA	OASIS SPRL	CONGO (DEMOCRATIC REPUBLIC)
41	BELTB	BELGACOM - BEL	BELGIUM	91	CODVC	VODACOM - CONGO	CONGO (DEMOCRATIC REPUBLIC)
42	BELKO	KPN(BASE)	BELGIUM	92	COGCT	CELTEL - CONGO	CONGO (PEOPLES REPUBLIC)
43	BELMO	MOBISTAR GSM	BELGIUM	93	COGLB	LIBERTIS - COG	CONGO (PEOPLES REPUBLIC)
44	BENSP	AREEBA - BENIN	BENIN	94	COGWC	WARID CONGO S.A	CONGO (PEOPLES REPUBLIC)
45	BEN02	MOOV-BENIN	BENIN	95	HRVCN	T-MOBILE CROTIA	CROATIA
46	BMUNI	M3 WITELESS LTD	BERMUDA	96	HRVVI	VIP NET GSM	CROATIA
47	BTNBM	B-MOBILE(BTNBM)	BHUTAN	97	CUB01	C_COM (CUBACEL)	CUBA
48	BOLME	MOVIL DE ENTEL	BOLIVIA	98	CYPCT	CYTA, CYPRUS	CYPRUS
49	BOLNT	NUEVATEL	BOLIVIA	99	CYPSC	MTN CYPRUS	CYPRUS
50	BIHPT	GSMBIH - BOSNIA	BOSNIA HERZEGOVINA	100	CZECM	OSKAR	CZECH REPUBLIC

Table (G) List of all foreign networks visited by Etisalat roamers during the years 2008-2011.

SERIAL	TAP	OPERATOR	MARKET	SERIAL	TAP	OPERATOR	MARKET
101	CZERM	T-MOBILE CZECH	CZECH REPUBLIC	151	GRCSH	TIM - GREECE	GREECE
102	CZEET	TELEFONICA O2	CZECH REPUBLIC	152	GRCPF	VODAFONE PANAFO	GREECE
103	DNKHU	HI3G ACCESS-DNK	DENMARK	153	GRDCW	C&W GRENADA	GRENADA
104	DNKDM	SONOFON,DENMARK	DENMARK	154	GUMHT	GUAM WIELESS	GUAM
105	DNKTD	TDC MOBIL A/S	DENMARK	155	GTMSC	SERCOM (CLARO)	GUATEMALA
106	DNKIA	TELIA-DENMARK	DENMARK	156	GBRGT	GUERNSEY, UK	GUERNSEY
107	DJIDJ	DJIBOUTI-TELECO	DJIBOUTI	157	GIN07	CELLCOM GUINEA	GUINEA
108	DMACW	C&W DOMINICA	DOMINICA	158	GIN03	INTERCEL GUINEE	GUINEA
109	DOM01	ORANGE DOMINICA	DOMINICAN REPUBLIC	159	GINGS	ORANGE GUINEE	GUINEA
110	EGYEM	ETISALAT MISR	EGYPT	160	GUYUM	CEL*STAR GUYANA	GUYANA
111	EGYAR	MOBINIL, EGYPT	EGYPT	161	HKGPP	CHINA MBLE PTCL	HONGKONG
112	EGYMS	VODAFONE EGYPT	EGYPT	162	HKGNW	CSL LTD	HONGKONG
113	SLVTP	STE TELECOM SLV	EL SALVADOR	163	HKGTC	CSL, HONG KONG	HONGKONG
114	SLVTM	TELEMOVIL EL SL	EL SALVADOR	164	HKGMC	HKT(PCCW MBL)	HONGKONG
115	GNQ01	ORANGE GQ	EQUATORIAL GUINEA	165	HKGM3	HKT(PCCW MBLE)	HONGKONG
116	ESTEM	AS EMT(EMT GSM)	ESTONIA	166	HKGH3	HUTCHISON - HKG	HONGKONG
117	ESTRE	ELISA MOBIILSID	ESTONIA	167	HKGHT	HUTCHISON, HKG	HONGKONG
118	ESTRB	TELE2 - ESTONIA	ESTONIA	168	HKGSM	SMARTONE-VODAFN	HONGKONG
119	ETH01	ETHIOPIAN TELE	ETHIOPIA	169	HUNH2	MAGYAR TELEKOM	HUNGARY
120	FROFT	FAROESE TELE	FAROE ISLANDS	170	HUNH1	PANNON GSM	HUNGARY
121	FJIDP	DIGICEL(FIJI)	FIJI	171	HUNVR	VODAFONE-HUN	HUNGARY
122	FJIVF	VF FIJI LIMITED	FIJI	172	ISLPS	SIMINN -ICELAND	ICELAND
123	FIN2G	DNA FINLAND	FINLAND	173	ISLTL	VODAFONE	ICELAND
124	FINRL	ELISA CORPORTN.	FINLAND	174	INDJH	BHARTI, ANDHRA	INDIA, Andhra Pradesh
125	FINTF	SONERA FINLAND	FINLAND	175	IND23	DISHNET-AIRCELL	INDIA, Andhra Pradesh
126	FINAM	ALANDS MOBITEL	FINLAND, ALANDS	176	INDAH	ETISALAT DB	INDIA, Andhra Pradesh
127	FRAF3	BOUYGUES GSM	FRANCE	177	IND07	IDEA CELLULAR	INDIA, Andhra Pradesh
128	FRAF1	FRANCE TELECOM	FRANCE	178	INDT0	TATA TELESERVCE	INDIA, Andhra Pradesh
129	FRAF2	SFR - CEGETEL	FRANCE	179	IND04	DISHNET-AIRCELL	INDIA, Bihar
130	FRAF4	BOUYGUES TELECM	FRENCH WEST INDIES	180	INDBR	ETISALAT DB	INDIA, Bihar
131	GUF01	OUTREMER TELECO	FRENCH WEST INDIES	181	INDIB	IDEAR CELLULAR	INDIA, Bihar
132	GABCT	CELTEL - GABON	GABON	182	INDTB	TATA TELESERVIC	INDIA, Bihar
133	GAB01	LIBERTIS-GABON	GABON	183	INDRC	AIRCEL CELLULAR	INDIA, Chennai
134	GABTL	MOOV-GABON	GABON	184	INDSC	SKYCELL COMM	INDIA, Chennai
135	GMBAC	AFRICELL-GAMBIA	GAMBIA	185	IND19	AIRCELL LTD	INDIA, Delhi
136	GMBCM	COMIUM GAMBIA	GAMBIA	186	INDAT	AIRTEL, INDIA	INDIA, Delhi
137	GMB01	GAMCEL - GAMBIA	GAMBIA	187	INDE1	ESSAR MOBILE	INDIA, Delhi
138	GEOGC	GEOCEL,GEORGIA	GEORGIA	188	INDND	ETISALAT DB	INDIA, Delhi
139	GEOMA	MAGTICOM,GEO	GEORGIA	189	INDID	IDEA CELLULAR	INDIA, Delhi
140	GEOMT	MOBITEL GEORGIA	GEORGIA	190	INDDL	MTNL - DELHI	INDIA, Delhi
141	DEUE1	E-PLUS, GERMANY	GERMANY	191	INDA3	B.A.GUJARAT	INDIA, Gujarat
142	DEUE2	O2 (GERMANY) GM	GERMANY	192	INDGU	EISALAT DB	INDIA, Gujarat
143	DEUD1	T-MOBILE,GERMAN	GERMANY	193	INDF1	ESSAR GUJARAT	INDIA, Gujarat
144	DEUD2	VODAFONE GERMAN	GERMANY	194	INDBI	IDEA CELLULAR	INDIA, Gujarat
145	GHAMT	MILLICOM	GHANA	195	INDTG	TATA TELESERVIC	INDIA, Gujarat
146	GHASC	MTN (SCANCOM)	GHANA	196	INDA5	B.A.HARYANA	INDIA, Haryana
147	GHAGT	ONETOUCH - GHA	GHANA	197	INDHY	ETISALAT DB	INDIA, Haryana
148	GHAZN	ZAIN COM.GHANA	GHANA	198	INDEH	IDEA CELLULAR	INDIA, Haryana
149	GIBGT	GIBTEL, GIB	GIBRALTAR	199	INDTH	TATA TELESERVIC	INDIA, Haryana
150	GRCCO	COSMOTE GSM	GREECE	200	INDBL	AIRTEL,HIMACHAL	INDIA, Himachal Pradesh

Table (G) List of all foreign networks visited by Etisalat roamers during the years 2008-2011.

SERIAL	TAP	OPERATOR	MARKET	SERIAL	TAP	OPERATOR	MARKET
201	IND02	DISHNET AIRCELL	INDIA, Himachal Pradesh	251	INDTC	ETISALAT DB	INDIA, Tamilnadu
202	INDIH	IDEA CELLULAR	INDIA, Himachal Pradesh	252	INDIT	IDEA CELLULAR	INDIA, Tamilnadu
203	IND22	AIRCELL LIMITED	INDIA, Karnataka	253	INDT2	TATA TELESERVIC	INDIA, Tamilnadu
204	INDJB	BHARTI,KARNATAK	INDIA, Karnataka	254	IND17	DISHNET AIRCELL	INDIA, Uttar Pradesh East
205	INDKA	ETISALAT DB	INDIA, Karnataka	255	INDPE	ETISALAT DB	INDIA, Uttar Pradesh East
206	INDSK	SPICE TELECOM-K	INDIA, Karnataka	256	INDIU	IDEA CELLULAR	INDIA, Uttar Pradesh East
207	INDT1	TATA TELESERVIC	INDIA, Karnataka	257	INDT7	TATA TELESRVICE	INDIA, Uttar Pradesh East
208	INDA7	BHARTI KERALA	INDIA, Kerala	258	INDA6	B.A.UP	INDIA, Uttar Pradesh West
209	IND20	DISHNET AIRCELL	INDIA, Kerala	259	IND18	DISHNET AIRCELL	INDIA, Uttar Pradesh West
210	INDBK	ESSAR CELLULAR	INDIA, Kerala	260	INDPW	ETISALAT DB	INDIA, Uttar Pradesh West
211	INDKE	ETISALAT DB	INDIA, Kerala	261	INDEU	IDEA CELLULAR	INDIA, Uttar Pradesh West
212	INDEK	IDEA CELLULAR	INDIA, Kerala	262	INDT8	TATA TELESERVCE	INDIA, Uttar Pradesh West
213	INDT3	TATA TELESERVIC	INDIA, Kerala	263	INDWB	BSNL - INDIA	INDIA, West Bengal
214	INDMT	BHARTI MOBITEL	INDIA, Kolkata	264	IND03	DISHNET AIRCELL	INDIA, West Bengal
215	INDCC	EAST LIMITED	INDIA, Kolkata	265	INDIW	IDEA CELLULAR	INDIA, West Bengal
216	INDIK	IDEA CELLULAR	INDIA, Kolkata	266	INDT9	TATA TELESERVIC	INDIA, West Bengal
217	INDTK	TATA TELESERVIC	INDIA, Kolkata	267	IDNLT	AXIS(LIPPOTEL)	INDONESIA
218	INDA8	B.A.MP	INDIA, Madhya Pradesh	268	IDNEX	EXCELCOMINDO	INDONESIA
219	INDMD	ETISALAT DB	INDIA, Madhya Pradesh	269	IDN89	HUTCHISON CP	INDONESIA
220	INDMP	IDEA CELLULAR	INDIA, Madhya Pradesh	270	IDNSL	SATELINDO	INDONESIA
221	INDRM	RELIANCE INDIA	INDIA, Madhya Pradesh	271	IDNTS	TELKOMS, IDA	INDONESIA
222	INDT5	TATA TELESERVIC	INDIA, Madhya Pradesh	272	IRNMI	MTN IRANCELL	IRAN
223	IND24	AIRCELL LTD	INDIA, Maharashtra	273	IRNRI	TALIYA IRAN	IRAN
224	INDA2	B.A.MAHARASHTA	INDIA, Maharashtra	274	IRN11	TCI-GSM 900	IRAN
225	INDBM	ESSAR CELLULAR	INDIA, Maharashtra	275	IRNKI	TKC-KIFZO, IRAN	IRAN, KISH ISLAND
226	INDMA	ETISALAT DB	INDIA, Maharashtra	276	IRQAC	ASIA CELL-IRAQ	IRAQ
227	INDBO	IDEA CELLULAR	INDIA, Maharashtra	277	IRQOR	IRAQNA (ZAIN)	IRAQ
228	INDT6	TATA TELESERVIC	INDIA, Maharashtra	278	IRQKK	KOREK TELECOM	IRAQ
229	IND21	AIRCELL LTD	INDIA, Mumbai	279	IRQAT	ZAIN-IRAQ	IRAQ
230	INDA1	B.A.MUMBAI	INDIA, Mumbai	280	IRLH3	HUTCHISON 3G	IRELAND
231	INDB1	BPL MOBILE-MUM	INDIA, Mumbai	281	IRLME	METEOR, IRELAND	IRELAND
232	INDHM	ESSAR LIMITED	INDIA, Mumbai	282	IRLDF	O2 - IRELAND	IRELAND
233	INDMU	ETISALAT DB	INDIA, Mumbai	283	IRLEC	VODAFONE-IRELND	IRELAND
234	INDIM	IDEA CELLULAR	INDIA, Mumbai	284	GBRMT	MANX TELECOM,UK	ISLE OF MAN
235	INDMB	MTNL - MUMBAI	INDIA, Mumbai	285	ITAH3	H3G S.P.A ITALY	ITALY
236	INDTM	TATA TELESERVIC	INDIA, Mumbai	286	ITASI	TIM - ITALIA	ITALY
237	IND05	DISHNET AIRCELL	INDIA, Orissa	287	ITAOM	VODAFON-OMNITEL	ITALY
238	INDIO	IDEA CELLULAR	INDIA, Orissa	288	ITAWI	WIND - ITALY	ITALY
239	INDTO	TATA TELESERVIC	INDIA, Orissa	289	CIVTL	LOTENY TELECOM	IVORY COST
240	INDPN	ETISALAT DB	INDIA, Punjab	290	CIV02	MOOV(A-CELL)	IVORY COST
241	INDA9	PUNJAB - BHARTI	INDIA, Punjab	291	CIV03	ORANGE-IVORY C	IVORY COST
242	INDSP	SPICE TELECOM-P	INDIA, Punjab	292	JAMCW	CABLE&WIRELESS	JAMAICA
243	INDTP	TATA TELESERVIC	INDIA, Punjab	293	JAMDC	DIGICEL-JAMAICA	JAMAICA
244	INDRS	ETISALAT DB	INDIA, Rajasthan	294	JPNDO	NTT DOCOMO-JPN	JAPAN
245	INDH1	HEXACOM INDIA	INDIA, Rajasthan	295	JPNJP	SOFTBANK MOBLE	JAPAN
246	INDIR	IDEA CELLULAR	INDIA, Rajasthan	296	GBRAJ	AIRTEL	JERSEY
247	INDTR	TATA TELESERVIC	INDIA, Rajasthan	297	GBRJT	JERSY TELECOM	JERSEY
248	INDAC	AIRCELL LTD.	INDIA, Tamilnadu	298	JORMC	ORANGE	JORDAN
249	INDA4	B.A.TAMIL NADU	INDIA, Tamilnadu	299	JORUM	UMNIAH JORDAN	JORDAN
250	INDBT	ESSAR CELLULAR	INDIA, Tamilnadu	300	JORXT	XPRESS - JORDAN	JORDAN

Table (G) List of all foreign networks visited by Etisalat roamers during the years 2008-2011.

SERIAL	TAP	OPERATOR	MARKET	SERIAL	TAP	OPERATOR	MARKET
301	JORFL	ZAIN,JORDAN	JORDAN	351	MLTGO	GO MOBILE	MALTA
302	ARMKT	KARABAKH - ARM	KARABAKH (DISPUTED REGION)	352	MLTMM	MELITA MOBILE	MALTA
303	KAZKZ	K.CELL	KAZAKHSTAN	353	MLTTL	VDF MALTA LTD	MALTA
304	KAZKT	KAR-TEL LLP(KM)	KAZAKHSTAN	354	MRTMT	MATTEL	MAURITANIA
305	KAZ77	MOBILE TELECOM	KAZAKHSTAN	355	MRTMM	MAURITEL MOBILE	MAURITANIA
306	KENEC	ESSAR TELECOM	KENYA	356	MUSCP	CELLPLUS,MTS	MAURITIUS
307	KENSA	SAFARICOM	KENYA	357	MUSEM	EMTEL LIMITED	MAURITIUS
308	KENTK	TELKOM KENYA	KENYA	358	MEXTL	RADIOMOVL(TELCL	MEXICO
309	KENKC	ZAIN-KENYA	KENYA	359	MEXMS	TELEFONICA MVLS	MEXICO
310	KWTKT	KUWAIT_KTC	KUWAIT	360	MDAMC	MOLDCELL	MOLDOVA
311	KWTNM	WATANIYA TELE	KUWAIT	361	MDAVX	VOXTEL	MOLDOVA
312	KWTMT	ZAIN,KUWAIT	KUWAIT	362	MCOM1	MONACO TELECOM	MONACO
313	KGZ01	BITEL,KYRGYZSTN	KYRGYZSTAN	363	MNGMC	MOBICOM-MONGOLI	MONGOLIA
314	KGZNT	NURTELECOM LLC	KYRGYZSTAN	364	MNEMT	MTEL	MONTENEGRO
315	LAOTL	TANGO	LAO	365	YUGPM	PRO MONTE GSM	MONTENEGRO
316	LVABT	BITE LATVIA	LATVIA	366	YUGTM	T-MOBILE	MONTENEGRO
317	LVALM	LATVIA MOBILE	LATVIA	367	MSRCW	MONTSERRAT	MONTSERRAT
318	LVABC	TELE2 - LATVIA	LATVIA	368	MARMT	MEDI TELECOM SA	MOROCCO
319	LBNFL	MIC 1 (ALFA)	LEBANON	369	MARM1	MOROCO TELECOM	MOROCCO
320	LBNLC	MTC - LEBANON	LEBANON	370	MARM3	WANA CORPORATE	MOROCCO
321	LBR07	CELLCOM TELCO.	LIBERIA	371	MOZ01	MCEL (TDM)	MOZAMBIQUE
322	LBRCM	COMIUM LIBERIA	LIBERIA	372	MOZVC	VODACOM - MOZ	MOZAMBIQUE
323	LBY01	ELMADAR ALJADID	LIBYA	373	NAM03	CELL ONE	NAMIBIA
324	LBYLM	LIBYANA MOBPHON	LIBYA	374	NAM01	NAMIBIA TELECOM	NAMIBIA
325	LIEMK	MOBILKOM GSM	LIECHTENSTEIN	375	NPLM2	SPICE NEPAL	NEPAL
326	LIEVE	ORANGE-LIEVE	LIECHTENSTEIN	376	NLDPT	KPN TELECOM	NETHERLANDS
327	LIETG	TELE 2 AKTIENGE	LIECHTENSTEIN	377	NLDDT	T-MBLE(ORANGE)	NETHERLANDS
328	LTUOM	OMNITEL, LIT	LITHUANIA	378	NLDPN	T-MOBILE - NLD	NETHERLANDS
329	LTU03	TELE2-LITHUANIA	LITHUANIA	379	NLDLT	VODAFONE-NLD	NETHERLANDS
330	LTUMT	UAB BITE	LITHUANIA	380	NZLNH	NZ-COMMUNICATN	NEW ZEALAND
331	LUXPT	P&T, LUXEMBOURG	LUXEMBOURG	381	NZLTM	TELECOM MOBILE	NEW ZEALAND
332	LUXTG	TANGO-LUXEMBURG	LUXEMBOURG	382	NZLBS	VODAFON N.ZELND	NEW ZEALAND
333	LUXVM	VOX.MOBILE- LUX	LUXEMBOURG	383	NICEN	ENITEL-GSM1900	NICARAGUA
334	MACCT	CTM, MACAU	MACAU	384	NERCT	CELTEL - NIGER	NIGER
335	MACHT	HUTCHISON-MACAU	MACAU	385	NERTL	MOOV-NIGER	NIGER
336	MKDCC	COSMOFON - MKD	MACEDONIA	386	NGAEM	ETISALT NIGERIA	NIGERIA
337	MKDMM	T-MBLE MACEDNIA	MACEDONIA	387	NGAGM	GLO MOBILE -NGA	NIGERIA
338	MKDNO	VIP OPERATOR	MACEDONIA	388	NGAMN	MTN NIGERIA	NIGERIA
339	MDGCO	CELTEL-MADACOM	MADAGASCAR	389	NGAET	ZAIN-NIGERIA	NIGERIA
340	MDGAN	ORANGE - MDGAN	MADAGASCAR	390	NORNC	NETCOM, NORWAY	NORWAY
341	MDGTM	TELMA MOBILE	MADAGASCAR	391	NORNN	NETWORK NORWAY	NORWAY
342	MWICT	CELTEL - MALAWI	MALAWI	392	NORTM	TELENOR, NORWAY	NORWAY
343	MWICP	TELEKOM MALAWI	MALAWI	393	OMNNT	NAWRAS - OMAN	OMAN
344	MYSCC	CELCOM, MYA	MALAYSIA	394	OMNGT	OMAN MOBILE	OMAN
345	MYSMT	DIGI TELECOM	MALAYSIA	395	PAKMK	MOBILINK, PAK	PAKISTAN
346	MYSBC	MAXIS, MALAYSIA	MALAYSIA	396	PAKTP	TELENOR - PAK	PAKISTAN
347	MDV01	DHIRAAGU	MALDIVES	397	PAKUF	UFONE - PAK	PAKISTAN
348	MDVWM	WATANIYA-MDVWM	MALDIVES	398	PAKWA	WARIDTEL - PAK	PAKISTAN
349	MLI01	MALITEL GSM-900	MALI	399	PAKPL	ZONG(PAKTEL)	PAKISTAN
350	MLI02	ORANGE MALI SA	MALI	400	PSEJE	JAWWAL(PALCELL)	PALESTINE

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SERIAL	TAP	OPERATOR	MARKET	SERIAL	TAP	OPERATOR	MARKET
401	PSEWM	WATANIYA MOBILE	PALESTINE	451	SLEAC	AFRICELL-LINTEL	SIERRA LEONE
402	PANCW	CW PANAMA	PANAMA	452	SLECT	CELTEL - S.L	SIERRA LEONE
403	PANDC	DIGICEL PANAMA	PANAMA	453	SLECM	COMIUM(SL)LMTD.	SIERRA LEONE
404	PRYVX	HOLA-PARAGUAY	PARAGUAY	454	SGPM1	MOBILEONE, SPE	SINGAPORE
405	PRYTC	TELECEL PARAGUY	PARAGUAY	455	SGPST	SINGTEL (900)	SINGAPORE
406	PERTM	CLARO PERU	PERU	456	SGPSH	STARHUB PTE LT	SINGAPORE
407	PHLDG	DIGITAL - PHLDG	PHILIPPINES	457	SVKGT	ORANGE SLOVAK	SLOVAKIA
408	PHLGT	GLOBE TELECOM	PHILIPPINES	458	SVKET	T-MOBILE SVK	SLOVAKIA
409	PHLSR	SMART COMM INC	PHILIPPINES	459	SVKO2	TELEFONICA O2	SLOVAKIA
410	POL02	ERA GSM, POLAND	POLAND	460	SVNMT	MOBITEL,SLOVEN	SLOVENIA
411	POLKM	POLKOMTEL, POL	POLAND	461	SVNSM	SI.MOBIL	SLOVENIA
412	POL03	PTK-CENTERTEL	POLAND	462	SVNVG	TUSMOBIL	SLOVENIA
413	PRTOP	OPTIMUS	PORTUGAL	463	SOMNL	NATIONLINK TEL.	SOMALIA
414	PRTTM	TMN, PORTUGAL	PORTUGAL	464	ZAFCC	CELL C (PTY)LTD	SOUTH AFRICA
415	PRTTL	VODAFONE - PRT	PORTUGAL	465	ZAFMN	MTN - S.AFRICA	SOUTH AFRICA
416	PRICL	CLARO P RICO	PUERTO RICO	466	ZAFVC	VODACOM - S.A	SOUTH AFRICA
417	QATQT	QTEL, QATAR	QATAR	467	KORKT	KT FREETEL	SOUTH KOREA
418	QATB1	VODAFONE QATAR	QATAR	468	KORKF	KT FREETEL CO.	SOUTH KOREA
419	REU02	ORANGE REUNION	REUNION	469	KORSK	SK TELE-S.KOREA	SOUTH KOREA
420	REUOT	OUTREMER TELCOM	REUNION	470	ESPRT	ORANGE ES	SPAIN
421	FRARE	SFR REUNIONAISE	REUNION	471	ESPTE	TELEFONICA, SPN	SPAIN
422	ROMMR	ORANGE-ROMANIA	ROMANIA	472	ESPAT	VODAFONE ESPANA	SPAIN
423	ROMCS	S.C. COSMOTE	ROMANIA	473	LKAAT	AIRTEL LANKA	SRI LANKA
424	ROMMF	VODAFNE ROMANIA	ROMANIA	474	LKADG	DIALOG TEL PLC	SRI LANKA
425	RUSKH	BAYKALWESTCOM	RUSSIA	475	LKAHT	HUTCHISON	SRI LANKA
426	RUS17	ERMAK RMS	RUSSIA	476	LKA71	MOBITEL-SRILANK	SRI LANKA
427	RUSEC	LLC EKATERNBURG	RUSSIA	477	LKACT	TIGO	SRI LANKA
428	RUSNW	MEGAFON-RUSSIA	RUSSIA	478	KNACW	ST. KITTS	ST. KITTS & NEVIS
429	RUS01	MTS, RUSSIA	RUSSIA	479	VCTCW	ST.VINCENT	ST. VINCENT
430	RUS03	NCC - RUSSIA	RUSSIA	480	LCACW	S. LUCIA	ST.LUCIA
431	RUSNO	NOVGOROD TELCOM	RUSSIA	481	SDNBT	AREEBA SUDAN	SUDAN
432	RUS16	NTC - RUSSIA	RUSSIA	482	SDNVC	VIVACELL	SUDAN
433	RUSSC	SCS	RUSSIA	483	SUDMO	ZAIN SD - SUDAN	SUDAN
434	RUS14	TELESET LTD.	RUSSIA	484	SWZMN	MTN - SWAZILAND	SWAZILAND
435	RUSUT	URALTEL	RUSSIA	485	SWEHU	HI3G ACCESS-SWE	SWEDEN
436	RUSBD	VIMPELCOM	RUSSIA	486	SWEIQ	TELE2, SWEDEN	SWEDEN
437	RUS07	ZAO SMARTS	RUSSIA	487	SWEEP	TELENOR SVERIGE	SWEDEN
438	RWAMN	MTN RWANDACELL	RWANDA	488	SWETR	TELIASONERA-SWE	SWEDEN
439	RWATG	TIGO RWANDA	RWANDA	489	CHEOR	ORANGE COMM SA	SWITZERLAND
440	SMOSM	SAN MARINO TELE	SAN MARINO	490	CHEDX	SUNRISE COMM.AG	SWITZERLAND
441	SAUET	ETIHAD ETISALAT	SAUDI ARABIA	491	CHEC1	SWISSCOM, SWZ	SWITZERLAND
442	SAUAJ	SAUDI TELECOM	SAUDI ARABIA	492	SYRSP	AREEBA SYRIA	SYRIA
443	SAUZN	ZAIN KSA	SAUDI ARABIA	493	SYR01	SYRIATEL- SYRIA	SYRIA
444	SENSG	SENTEL GSM	SENEGAL	494	TWNLD	CHANGHWA-TAIWAN	TAIWAN
445	SENAZ	SONATEL	SENEGAL	495	TWNFE	FAR EAST,TAIWAN	TAIWAN
446	YUGTS	TELEKOM-SERBIA	SERBIA	496	TWNKG	KG TELECOM LTD	TAIWAN
447	YUGMT	TELENOR D.O.O	SERBIA	497	TWNPC	TAIWAN MBLE CO.	TAIWAN
448	SRBNO	VIP MOBLE D.O.O	SERBIA	498	TWNTG	VIBO TELCOM INC	TAIWAN
449	SYCAT	AIRTEL TELECOM	SEYCHELLES	499	TJKBM	BABILON-MOBIL	TAJIKISTAN
450	SYCCW	CABLE WIRELESS	SEYCHELLES	500	TJK01	INDIGO NORTH-TJ	TAJIKISTAN

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SERIAL	TAP	OPERATOR	MARKET
501	TJKIT	INDIGO SOUTH-TJ	TAJIKISTAN
502	TJK91	TACOM	TAJIKISTAN
503	TZACT	CELTEL - TZA	TANZANIA
504	TZAMB	MOBITEL-TZA	TANZANIA
505	TZAVC	VODACOM LTD	TANZANIA
506	TZAZN	ZANTEL	TANZANIA
507	THAAS	AIS ,THAILAND	THAILAND
508	THAWP	TOTAL ACCESS	THAILAND
509	THACO	TRUE MOVE CO.	THAILAND
510	TGOTL	TELECEL - TOGO	TOGO
511	TTO12	TSTT-TRINIDAD	TRINIDAD & TOBAGO
512	TUNOR	ORANGE TUNISIA	TUNISIA
513	TUNTA	TUNISIANA	TUNISIA
514	TUNTT	TUNISIE TELECOM	TUNISIA
515	TURIS	AVEA ILETISIM H	TURKEY
516	TURTC	TURKCELL-TURKEY	TURKEY
517	TURTS	VODAFONE TELEKO	TURKEY
518	TKMBC	BCTI TURKMENIST	TURKMENISTAN
519	TCACW	TURKS & CAICOS	TURKS & CAICOS
520	UGACE	CELTEL - UGANDA	UGANDA
521	UGAMN	MTN-UGANDA	UGANDA
522	UGAOR	ORANGE UGANDA	UGANDA
523	UGATL	UTL - UGANDA	UGANDA
524	UGAWT	WARID TELECOM	UGANDA
525	GBRHU	HUTCHISON 3G-UK	UK
526	GBRCN	O2 (CELLNET),UK	UK
527	GBROR	ORANGE, UK	UK
528	GBRME	T-MOBILE - U.K	UK
529	GBRVF	VODAFONE, U.K.	UK
530	UKRAS	ASTELIT	UKRAINE
531	UKRGT	GOLDEN TELECOM	UKRAINE
532	UKRKS	KYIVSTAR - GSM	UKRAINE
533	UKRUM	MOBILECOMM, UKR	UKRAINE
534	UKRUT	UKRTELECOM	UKRAINE
535	UKRRS	URS	UKRAINE
536	URYAN	ANTEL	URUGUAY
537	USACG	CINGULAR GENES	USA
538	USANC	NEXTEL COMM	USA
539	USAW6	T-MOBILE USA	USA
540	UZBDU	BELEENE UZ	UZBEKISTAN
541	UZB05	UCELL-COSCOM JV	UZBEKISTAN
542	UZB07	UZDUNROBITA-UZB	UZBEKISTAN
543	VEND2	DIGITEL	VENEZUELA
544	VNMVI	VIETNAM TELECOM	VIETNAM
545	VNMVT	VIETTEL TELECM	VIETNAM
546	YEMYY	HITS-UNITEL	YEMEN
547	YEMSA	SABAFON YEMEN	YEMEN
548	YEMSP	SPACETEL (MTN)	YEMEN
549	ZMBCE	CELTEL - ZAMBIA	ZAMBIA
550	ZMB02	MTN (TELECEL)	ZAMBIA
551	ZWEET	ECONET-ZIMBABWE	ZIMBABWE
552	ZWEN1	NET ONE - ZIMB	ZIMBABWE