AN INVESTIGATION OF THE EFFECT OF MOBILE NUMBER PORTABILITY ON MARKET COMPETITION

by

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Abstract

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This thesis examines possible affects of implementation of technology known as mobile number portability (MNP) on market competition. Previously it was strongly believed that MNP leads to improvement of market competition, but recently several papers argued that.

This work developed theoretical model aplicable for investigation of the effect of MNP under different market parameters such as growth rate and interconnection costs.

Arellano-Bond GMM model was used to estimate empirically the effects described in theoreical literature on switching costs and also the ways that MNP changes these effects. Original cross-country firm-level panel data was used for the estimation. Empirical results provide theoretical evidence, besides, estimated model is transformed into a rule that could be applied for testing possible effect of MNP on market competition.

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GLOSSARY

Balanced calling pattern - the percentage of calls originating on a network and completed on the same network equals to the percentage of consumers subscribed to this network.

Interconnection costs – arise when mobile carriers charge lower usage fees for calls within the same networks than or calls between the networks.

Key Performance Indicators (KPI) – indicators of operational performance of a mobile carrier, disclosed on regularly (quarterly, semiannually, or annually). Among them usually are ARPU (average revenue per user), MOU (minutes of usage per user), Churn (percentage of customers that switched), Number of subscribers.

Mobile Number Portability (MNP) – regulatory policy that allows consumers to retain the same phone numbers when they switch service providers.

One-way access – refers to a setting with one firm monopolizing input(s) needed by all firms in more competitive sector (e.g. gas and electricity supply).

Two-way access – denotes competing networks, each with its own subscribers, and firms need to purchase vital inputs (services) from each other.

National regulatory authority (NRA) – used as general term denoting a governmental structure responsible for regulation of telecommunications industry in a country.

Number prefix – the first three digits of a mobile number. In absence of MNP number prefix indicates the network of the person being called. Under MNP number prefix has no indicative meaning.

On-network – an adjective denoting calls made by a customer of some network to a customers belonging to the same network.

Off-network – an adjective denoting calls made by a customer of some network to customers belonging to another (competing) network.

Reciprocal access pricing – a network pays as much for termination of a call on the rival network as it receives for completing a call originated on the rival network.

Switching costs – costs that consumers have to bear when they switch from one provider (or product/service) to an alternative.

Chapter 1

INTRODUCTION

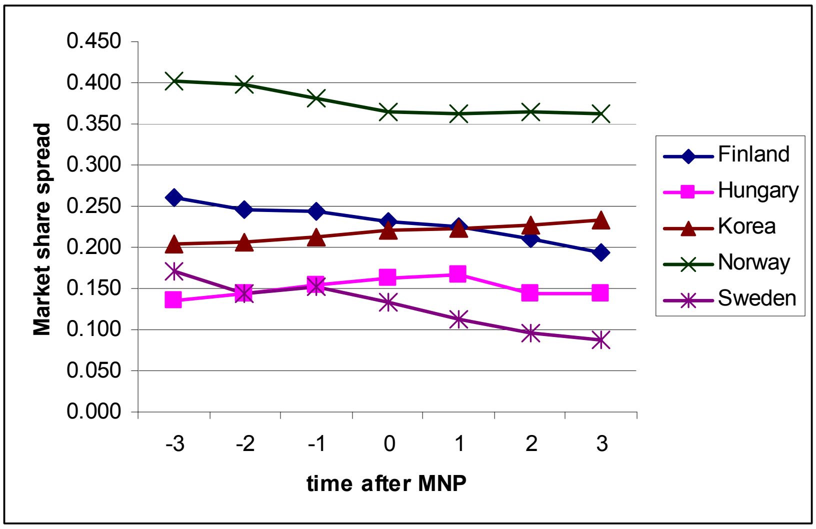
After switching costs were discovered and described in academic literature regulators in many industries became preoccupied with finding the ways to either decrease or eliminate switching costs that was considered a great impediment to competition.

In particular, national regulatory authorities (NRAs) in telecommunications industry began to actively discuss and even implement the regulation known as mobile number portability (MNP). The goal of MNP implementation is decrease in the consumer switching costs. In this way, it is believed, that after reduction in switching costs, competition among the mobile carriers would increase.

Concern about impact of MNP on evolution of market shares of competing mobile carriers was firstly expressed by Shi, 2002. He noticed that after MNP implementation in Hong-Kong market shares of the competing firms did not converge, but even started to diverge. Mergers and takeovers became more likely among mobile operators and competition is more likely to deteriorate.

Figure 1.1. below shows the evolution of differences between market shares of the largest firm and its closest competitors during 3 quarters before and 3 quarters after MNP implementation. Hardly is there any evidence that MNP leads to improved competition – in Sweden and Finland difference between market shares of the two largest competitors indeed started to decrease, but in Korea it started to increase, whereas in Norway and Hungary the behavior is unclear.

Figure 1.1. Evolution of Market Share Spreads With Implementation of MNP.



In this work theoretical model is developed and used to verify some effets that MNP has on market competition. Series of simulations were undertaken to observe how decrease of switcing costs (an outcome of MNP implementation) affects the market shares and prices of main competiors.

Besides, dynamic Arellano-Bond GMM method is used to estimate dynamic model of explaining evolution of market share spread. The results of estimation are applicable for predicting whether MNP would lead towards improvement of market competition or its deterioration, based on such market parameters as market growth rate, penetration rate, spread between prices charged by competitors.

This might be of interest for policy-makers as it suggests a simple method to predict whether MNP will lead to improved competition or to deterioration of it. Data, needed for the predictions, is openly available and is easier to collect if compared to alternative methods based on numerous surveys (such as NEAR/Smith, 1998). Also it might be of interest to mobile carriers, which must be also very interested in the question how market competition is affected by MNP.

The empirical investigation conducted in this paper supports theoretical predictions of previous studies. Namely, such theoretical suggestions were empirically supported as, first, that firms with initially larger market shares have advantage in maintaining larger size of their network in the future, second, that larger price differences between larger and smaller competitors leads towards faster convergence of market shares, third, that higher market growth rates and low penetration rates characterizing the market lead towards slower convergence, and even divergence of the market shares is possible.

I found out that MNP is more likely to lead towards improvement of competition when market is saturated, growing slowly, or when smaller competitor sells at large discount as compared to the large one. And on quickly growing markets with low penetration rates MNP may lead to adverse effect on competition.

The reminder of the paper is organized in the following way. Chapter 2 introduces to empirical and theoretical studies considering MNP and such related issues as competition in network industries and competition on markets with switching costs. In Chapter 3 theoretical model setup is provided. Chapter 4 provides data description. Chapter 5 describes the empirical investigation conducted with the main goal of developing a method to predict whether MNP will have positive or negative effect on market competition. Chapter 6 concludes.

C h a p t e r 2

LITERATURE REVIEW

So far no single theory emerged to explain competition in mobile telecommunications and to analyze possible outcomes of implementation of Mobile Number Portability. But there are advances of theory in some tightly related areas which provide the necessary framework to analyze the problem through.

The structure of this review is as follows. Recent papers that investigate the issue of MNP directly are reviewed first. Then the research that created foundation for the analysis of MNP and telecommunication is described. Also, relevant empirical methodology and interesting findings of empirical investigations are discussed.

2.1. Theoretical Developments

So far only few theoretical papers concerned the problem of MNP implementation directly. All these papers develop from the framework of network competition, as provided by Armstrong, 1998, and Laffont et al., 1998, which are describe below, mostly by adding switching costs to the model.

Aoki and Small (2005) is the most frequently cited paper that directly investigates the effect of MNP implementation. This work gave the interpretation to MNP as a reduction in switching costs accompanied by increase in fixed and marginal costs of the firms. Their analytical investigation is focused on the MNP-caused welfare change of consumers and producers. The model is not convenient for analysis of competition, because authors focus on entry of a second firm to a market previously monopolized by incumbent. Authors assume positive and significant switching costs of consumers and two-part tariff pricing by both firms. They found that on a mature market MNP leads to completely different welfare outcomes, depending on relative sizes of switching costs, "transportation cost" and consumer valuations.

They also analyzed introduction of MNP on a growing market by extending the originally two-period game with additional period. The findings for the growing market were more precise: MNP has no affect on incumbent and improves welfare of consumers and the entrant.

Buehler and Haucap (2004) also investigated the effect on MNP implementation on consumers' welfare. Novelty of this research was consideration of the effect of MNP on level of information available to consumers. They argue that under MNP number prefix has no indicative power. Callers are not able to distinguish between on-network and off-network phone numbers and may end up paying higher average bills. They also argue that MNP implementation will benefit entrant firm and will hurt incumbent. Buehler and Haucap (2004) concentrate on the analysis of fixed-to-mobile calls ignoring more difficult mobile-to-mobile case, which involves changes of market shares.

Shi, Chiang and Rhee (2002) found that when networks incur interconnection costs, MNP may lead to higher market concentration. Their paper was motivated by increased concentration on the Hong Kong mobile telecommunications market. They argue that if there are large on-network discounts on a market, reduced switching costs, after MNP implementation, could make on-network discounts of the larger firm more attractive for consumers of the small firm and result in higher switching of the later. Shi, Chiang and Rhee (2002) do not solve the problem with new consumers on the market, but make logical conclusion that the less competitive outcome is also possible, though with new consumers equilibrium market prices are expected to decrease. The paper also assumes two-part tariff pricing scheme resulting in per-minute prices being equal to marginal cost of providing one minute of the service.

Here it is important to underline that most of previous researches of MNP assumed two-part tariff pricing, which lead to conclusion that variable charges equal to marginal costs. I am going to argue that usually, in mobile telecommunications variable charges are not equal to marginal costs. So, using linear pricing assumption would be more appropriate, at least for empiric analyses of mobile telecommunications industry.

From my prospective, recently emerged theoretical literature on Economics of MNP has developed from two separate streams of research in Industrial Organizations: competition in network industries and competition on markets with switching costs. So, next goes description of the literature on network competition, followed by the literature on switching costs. The former was established by two seminal works. The later has richer history and naturally receives more representation in my overview.

Armstrong (1998) was among the first to develop model of network competition with the two-way access pricing between the firms. In his model consumers did not consider choosing number of minutes to consume, but only decided on number of calls. The finding of the paper was that if, in a case of symmetric firms, interconnection costs remains unregulated the firms jointly choose it in order to maximize their profits. Besides, this is the only paper that assumes uniform pricing by the players.

Laffont, Rey and Tirole (1998a) and Laffont, Rey and Tirole (1998b) make generalization and refinement of the existing literature on network competition.

The models in these two papers now are basic for most researchers of Economics of MNP.

Laffont, Rey and Tirole (1998a) developed their two-way access pricing model at the same time as Armstrong (1998). This paper refines the notion of 'balanced calling pattern' and 'reciprocal access pricing'. The model developed is one of competition in linear pricing between two networks on saturated market, where consumers are Hotelling-differentiated. The distinguishing feature is the way the authors modeled demand – they incorporated 'balanced calling pattern' and 'reciprocal access pricing' in it. Modeling consumers' demand in such way lately was applied in works by Shi, 2002 and Haucap, 2004.

Another stream of literature, equally important for understanding possible MNP effects, is in analysis of switching costs.

Wide introduction to switching costs was started from research by Klemperer (1987a, b), Klemperer (1988), Klemperer (1989), Farrell and Shapiro (1988). The authors worked with two firms – two periods setup with Hotelling-diferentiated consumer demand. Such important issues were studied as entry to the market with switching costs, price dynamics on the market with switching costs, pricing on growing market with switching costs.

Lately, Beggs and Klemperer (1992) and Padilla (1995) set up infinitely many period models and provided analytical solutions and interpretation. These papers mostly supported previous 'two-period' findings. Most popular two-period model of oligopoly with switching costs and generalization to infinite-horizon were developed by Klemperer (1995). The generalized to infinite horizon model shows that, on average, firms have higher incentives to exploit existing customers rather than attract new ones. The key assumption to this finding was that market growth rate cannot exceed 100% per period. The paper also provides general classification of types of switching costs. This paper argues that policymakers are to reduce switching costs, as the latter result in welfare losses: switching costs reduce product variety offered to consumer and prevent switching between products (services) by making it costly. This was the paper to stimulate talks on implementation of MNP among policy-makers.

We proceed with two papers that analyzed impact of switching costs on entry decision and on price wars – Klemperer (1987) and Klemperer (1989). Model developed in the former allowed to conclude that most effective entry deterrents are very low and very high customer bases. Thus, low customer base signals that incumbent may behave aggressively when entrance takes place. High base is signal that entrant will not gain any more or less significant market share. Other conclusion is that very high switching costs can encourage entry because very high switching costs signal about incumbent unwillingness to fight aggressively for new customers. The latter paper develops a four-period model of market with switching costs with an entry. The model provides intuition for why prices decrease strongly in the first after the entry period and then increase to a high level.

Farrell and Klemperer (2001) provided broad review and classification of all available literature and findings related to switching costs. The paper provides analysis of practically all situations where switching costs arise and do have an effect. They approached the conventionally controversial issue of whether switching costs attract or distract entry. The authors suggested that resolution would depend upon the size of the switching, costs, the scale of entry, market dynamics, and existence of economies of scale. They also analyzed the competition strategy called penetration pricing, when firm gives up present periods profits to build-up market share and receive higher profits in the future.

The important equation is: $$0 = \frac{\partial V_t}{\partial p_t} = \frac{\overset{+}{\partial \pi_t}}{\partial p_t} + \delta \frac{\overset{+}{\partial V_{t+1}}}{\partial \sigma_t} \frac{\overset{-}{\partial \sigma_t}}{\partial p_t} ,$$

Where present profits are assumed to be increasing in prices, market share is decreasing in prices, and future discounted profits are increasing in market share. Therefore, the important trade-off is the one between present-period and future-periods gains.

Several later papers tried to adjust the 'basic' switching costs models for the complications of real life. Issues studied include heterogeneity of consumers (low/high willingness to pay), non-linear pricing (two-part tariff), quality of services (coverage), self competition (complementarity between different services profiles of the same company) etc.

Among papers that concentrate on heterogeneity of consumers by their willingness to pay and on non-linear pricing are Gabrielsen and Vagstad (2002) and Corrocher and Zirulia (2005). Each paper develops theoretical model based on previous studies and comes to useful conclusion. The former paper found that when firms use two-part tariff, oligopoly produces no dead-weight losses, and the only item affected is distribution of surplus between producers and consumers. The later paper introduces two-part tariff into model developed by Klemperer 1987 and finds convergence in market shares – there is inverse relation between growth in share of market leader in the market of consumers with high willingness to pay and the share in the market of consumers with low willingness to pay.

Capuano (2002) develops a model of substitution effect between old and new customers for an operator that charges lower prices for new customers while keeping prices for old customers unchanged. This paper drops assumption that firm can't charge different prices for "old" and "new" customers and thus reflects the reality of the industry better. It warns that when market matures losses from old customers shifting to a new cheaper charge profiles can destroy profits from new customers demand.

Valetti (1999) and Campo-Rembado and Sundararajan (2002) draw attention to quality issues in competition between mobile operators. The former paper used coverage as proxy for quality and the latter recognized that loss-rates is much better reflection of quality but coverage is just one of the many determinants of quality. Two-stage model of the latter paper shows that because of constraints on spectrum availability and infrastructure operators with higher market share usually provide higher quality of services.

Theory often provided contradictory results, as for example, whether firms operating on a market with switching costs will chose to rip their customer base or engage in penetration pricing. Considering MNP no work was dedicated to Mobile-to-Mobile interconnection, and also though much preparatory work was done, no model to predict impact of MNP on market competition was developed.

2.2. Empirical Contributions

Naturally that number of empirical papers on the issue of the effect of MNP is smaller than that of the theoretical ones. Actually, empirical work aiming at investigation outcome of MNP on market competition and welfare was coducted by either NRAs or by consulting firms for NRAs (NERA/Smith, 1998). Other empirical papers, conducted by academicians aim at detecting switching costs and also at quantifying how switching costs decrease when MNP is introduced (Kim, 2005).

Already mentioned empirical paper by NERA/Smith (1998) was the result of extensive data – collection process and market research and analysis.

Representative sample of personal mobile customers as well as of business mobile customers were interviewed which allowed to estimate possible benefits of MNP implementation for different welfare groups of the consumers on the market. The authors classified the benefits from MNP into 3 types. Type 1 benefits are the benefits which accrue to subscribers who maintain their mobile numbers when changing operator. Type 2 benefits – the benefits from increased competitive pressure, such as efficiency improvement and price reduction. Type 3 benefits are – those from avoiding of high misdialing rates, making changes to information stored in customer equipment.

Other papers estimated switching costs, with either direct or indirect method, as classified by Padilla et al., 2003.

Solid and comprehensive methodology-producing paper is Padilla et al. (2003) that classifies different approaches to measure switching costs into two groups – direct and indirect methods. Direct approach measures switching costs based on consumer-level data and indirect approach, based on enterprise-level or aggregated data. Direct method is based on random utility framework and indirect method is based on either elasticities or on prices/profit margins framework.

Among papers that employ direct method to estimate switching costs is Kim (2005), that measured the effect of MNP on consumer switching costs. The econometric method used is mixed logit. He found that number portability reduced switching costs on average by 35%.

Grzybowski (2005) uses consumer-level data for 1999-2001 and is able to measure switching costs in random utility framework via mixed logit econometric model specification, based on methodology developed Padilla et al (2003). The empirical investigation resulted in finding no significant switching costs for UK leading to conclusion that now switching costs ceased to be an issue for regulators in the UK mobile industry.

Another methodology-producing paper concerning approaches to measure switching costs is Shy (2002). Striving to meet the need for estimating switching costs under data availability constraint the method was developed that allows estimating switching costs given data on process and market shares only. But several strong assumptions are to be fulfilled – first, there are only two firms in the market and, second, duopolists do not under price each other.

Though number of empirical papers grows quickly still there is enormous space for investigation. Up to my knowledge no research was done on measuring the effect that MNP has on future evolution of market shares. And no empirical research was conducted so far on how MNP changes the effect of other factors that affect evolution of market shares of competitors. So, there is some space for novelty and this thesis is aiming at this.

Chapter 3

METHODOLOGY

In this part of the thesis I develop theoretical model that allows to investigate effect of different parameters of the market on success of MNP implementation in terms of improving market competition. This model follows Shi, 2002, but unlike him, linear pricing is assumed, which is more appropriate as discussed above, and is more difficult to solve. It is a one-period game, but it accounts for dynamic decisions of agents.

Unlike previous researches, e.g. Shi et al.(2002), Buehler and Haucap (2004), Aoki and Small (2005), I assume linear pricing schedule, not the two-part tariff as by those economists. Applying two-part tariff, as shown by Laffont, Rey and Tirole (1998b) leads to outcome, where variable part equals to constant marginal costs and fixed part remains the only strategic price variable, hence, analytical solution can be easily obtained.

Though sound in theory, for the reasons stated below, such an approach is not quite applicable for theoretical and especially empirical the analysis of mobile telecommunications market.

Mobile telecommunications charge both connection fee and per-minute price. But from own experience and from studying pricing behavior, described in annual reports of those companies, in becomes clear that per-minute price is the one that varies most of all, whereas fixed part is stable, very small compared to per-minute ones, and plays regulatory role. Its regulatory role is to prevent consumers from making extra-short calls and overloading in such a way the network. So, for these reasons analysis of mobile telecommunications behavior requires linear pricing, because in reality per-minute charges differ from marginal costs of operators and applying two-part tariff would lead to serious bias in empirical research.

In order to make the model more solvable and capable of being estimated, I developed quadratic functional from for the individual utility function. Laffont et al. applied CES utility function, but they had to assumed elasticity higher than 1. it is not necessary under my setup.

So, the first section of this chapter explains main assumptions of the model. Next section develops on individual utility and choice. Following section explains derivation of market demand. The pre-last section of this chapter presents pricing problem for the two firms. The last section concludes with analysis of the simulation results.

3.1. Assumptions of the Model

A1: There are two firms on the market: firm A with constant marginal costs C_A and firm B with constant marginal costs C_B.

A2: There are many identical consumers with same switching costs, S, with same number of friends, n. They value minutes of talking to their friends positively, but at decreasing rate.

A3: Initially, there were K consumers on the market, θ_A of which consumed from operator A, and θ_B - from operator B. Besides, N new consumers arrive to the market and start consuming from either of operator.

A4: Consumers of each of the three consumer groups (those consuming from A, those consuming from B and the new ones) are differentiated by their tastes (or propensity to advertisement, or ethical tastes etc.) and are conventionally 'placed' on three intervals from 0 to 1 – one for each group.

A5: Firms know demand functions and simultaneously set their prices. Then, after per-minute prices are observed, consumers decide on network (A or B) and on amount of minutes to talk to their friends.

A6: There is interconnection cost on the market that is for mobile carriers marginal costs of delivering a call to the rival network costs *m* times higher than for same call inside the own network. Firms are allowed to price on-network and off-network calls differently.

A7: Balanced calling pattern is assumed, that is out of n friends of every identical consumer, θ_A initially are subscribers of network A, and θ_B - of network B. A consumer every period talks with each of his/her friends, but he may choose duration of a call..

3.2. Consumers Utility and Individual Demand

There is difference between Mobile telecommunications within and between networks. Those calls that are terminated within the same network are called "on-net" calls and those terminated between networks are called "off-net" calls. Usually, "off-net" calls are more expensive than "on-net" calls because former are costlier for operators to deliver and besides they are free to set-up higher price for those calls.

I assume that utility function is concave and increasing in number of minutes talked with a friend until some level q^* is achieved.

$$u(q_{AA}) = -aq_{AA}^2 + bq_{AA} \qquad (3.2.1)$$

From this function an indirect utility function can be derived:

$$v_{AA} = \max_q \{u(q_{AA}) - p_{AA} q_{AA}\} \tag{3.2.2}$$

Which after substituting $A = \frac{b}{2a}$, and $B = \frac{1}{2a}$, becomes:

$$v_{AA} = v(p_{AA}) = \frac{1}{2} B p_{AA}^2 - AB^2 p_{AA} + \frac{1}{4}(AB)^2 \tag{3.2.3}$$

It is important to do the following restrictions:

$B \geq \frac{1}{2}$ (necessary condition for the indirect utility function to have intersection points with horizontal axis);

$p \leq p^* = a(B - \sqrt{B^2 - \frac{1}{2}B}), \forall B \geq \frac{1}{2}$. This is one of the zeros of the function. The one at which $\frac{\partial v_{AA}}{\partial p_{AA}} < 0$. This is needed, because, unlike the direct utility function, this function is convex, and its range has to be restricted from above.

From this equation, by Roy's Identity demand function of consumer of network A for minutes to talk with a friend from network A can be easily obtained:

$$q_{AA} = -\frac{\partial v_{AA}}{\partial p_{AA}} = A - Bp_{AA} \tag{3.2.4}$$

The three other possible individual demand functions are obtained in the similar way.

3.3. Market Demand

So, as was discussed above, there are 3 groups of consumers on the market that consume from the two firms at time period *t*, – $K\theta_A$, and $K\theta_B$ are 'old' consumers consuming from firms A and B, correspondingly, and N new consumers.

As consumers in each of the three groups are uniformly distributed on a unit interval, with transportation costs τ, which are assumed to be the same for consumers from each group, it is important to find the 'indifferent' (between consuming from A or B) consumer from each group.

For this purpose, we introduce consumer gains,(w^A and w^B) and equate them for an indifferent consumer from every group.

$$w(p_A) = n\sigma_A v(p_{AA}) + n\sigma_B v(p_{AB}) \tag{3.3.1.a}$$

$$w(p_B) = n\sigma_B v(p_{BB}) + n\sigma_A v(p_{BA}) \tag{3.3.1.b}$$

These gains are obtained be a consumer per period, depending whether he joins network A, with market share at time *t* of σ_A, or network B with market share at time *t* of σ_B. Derivation of market shares is provided later.

So, for the indifferent consumer from the group of consumers that previously consumed from network A:

$$w_A - \tau X_A = w_B - \tau(1 - X_A) - S \tag{3.3.2}$$

Where X_A is the location of the indifferent consumer on the unit interval. S are the switching costs that he will have to bear were he/she to switch to the network B. Because consumers are distributed on the unit interval of uniform distribution, X_A is also fraction of the consumers of that group who will purchase from network A at time *t*.

Similarly, for the two other groups we have:

$$w_A - \tau X_B - S = w_B - \tau(1 - X_B) \qquad (3.3.3)$$

$$w_A - \tau X = w_B - \tau(1 - X) \qquad (3.3.4)$$

Note that consumers of the second group have to pay switching costs when switching to network A, and new consumers do not have to pay any switching costs.

In order to solve for X, XA, and XB, we need to substitute the expressions for consumer gains from joining networks A and B (w_A and w_B) and also the expressions for market shares of each firm at time t which are provided below:

$$\sigma_A = \frac{\theta_A K X_A + \theta_B K X_B + NX}{N + K} \qquad (3.5.5.a)$$

$$\sigma_B = \frac{\theta_A K(1 - X_A) + \theta_B K(1 - X_B) + N(1 - X)}{N + K} \qquad (3.3.5.b)$$

Proposition 1[1]. The fraction of consumers of each of the three groups that will consume at time t from network *A* can be found by the following expression:

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[1] Proof of Proposition 1 is provided in ANNEX 1.

$$X_A = \frac{\tau + S - n(v_{BB} - v_{AB}) - \frac{nS}{2\tau} \cdot \frac{N + 2K\theta_B}{N + K}}{2\tau - n(v_{AA} + v_{BB} - v_{AB} - v_{BA})} \qquad (3.3.6.a)$$

$$X_B = \frac{\tau - S - n(v_{BB} - v_{AB}) + \frac{nS}{2\tau} \cdot \frac{N + 2K\theta_A}{N + K}}{2\tau - n(v_{AA} + v_{BB} - v_{AB} - v_{BA})} \qquad (3.3.6.b)$$

$$X = \frac{\tau - n(v_{BB} - v_{AB}) + \frac{nS}{2\tau} \cdot \frac{K\theta_A - K\theta_B}{N + K}}{2\tau - n(v_{AA} + v_{BB} - v_{AB} - v_{BA})} \qquad (3.3.6.c)$$

Now, that it is known how consumers of each of the three groups behave, it is time to switch towards analysis of the behavior of mobile operators and their pricing behavior.

3.4. The Pricing Problem

The competing networks know the 'group' demand as in expressions (3.3.6.a), (3.3.6.b), and (3.3.6.c). Thus they simultaneously charge prices – on-network and off-network ones. Noticeably, that the prices affect their profits by two directions, first, they affect per user revenue (if he/she did not change amount of communications), and second, prices affect market shares of the operators. This is represented by expressions (3.4.1.a) and (3.4.1.b) below:

$$\pi_A = (K + N)[n\sigma_A q_{AA}(p_{AA} - c_A) + n(1 - \sigma_A) q_{AB}(p_{AB} - mc_A)]$$

$$\pi_B = (K + N)[n\sigma_A q_{BA}(p_{BA} - mc_B) + n(1 - \sigma_A) q_{BB}(p_{BB} - c_B)]$$

It can be derived that prices charged by the operators for minute of an on-network call and of an off-network call are related by the following expressions:

$$p_{AB} = p_{AA}k_1^A + k_0^A \text{ and } p_{BA} = p_{BB}k_1^B + k_0^B \qquad (3.4.2)$$

Where $k_1^A = \dfrac{A - B \cdot c_A \cdot m}{A - B \cdot c_A}$, $\quad k_0^A = \dfrac{c_A A(m-1)}{A - B \cdot c_A}$, and

$$k_1^B = \frac{A - B \cdot c_B \cdot m}{A - B \cdot c_B}, \qquad k_0^B = \frac{c_B A(m-1)}{A - B \cdot c_B}$$

He problem of finding solution to the system (3.4.3.) is non-trivial and it is highly possible that there is no closed-form solution to it. Thus, we found the solution numerically, and performed a number of simulations to study the behavior of the model when MNP is implemented. The results are described in the following section.

3.5. Interpretation of Simulation Results

The algorithm of obtaining Nash equilibrium in prices, which was applied to the model, is provided in ANNEX 3.

Simulations were conducted with the purpose to investigate how decrease in switching costs affects equilibrium market shares of the two competitors.

Decrease of switching costs was implemented under several conditions. First, we decreased switching costs from 3 units to 2 with step 0.25 and observed the resulting market equilibria. This experiment was conducted several times for different market parameters. As provided in ANNEXES D – G, several different levels of market growth and also of interconnection costs were tested to check for differences in the effect of MNP on market competition.

Chapter 4

DATA DESCRIPTION

Obtaining data for an empirical analysis has always been an issue for a researcher, especially data on mobile telecommunications. One of novelties of this thesis is that the empirical investigation is based on firm-level cross-country panel, which was never utilized before for the purpose of analyzing mobile telecommunications, in particular for analysis of MNP[2].

Earlier either consumer-level data, available from surveys, or market-level data on mobile telecommunications was utilized. This data-set has its advantages over the previous two, which I am going to take use of. Cross-country panel data brings in more variability than survey data does, as the later usually provides observations only within one country; besides, time span is usually longer in cross-country panel data. If compared to macro-level data-bases, this data set provides more opportunities to measure and analyze competition – information on market shares and prices are available, while macro-level data-sets hardly provide it. So, it seems that the advantages of the data-set make it a good tool for the investigation in this thesis.

The empirical investigation presented in this part of the thesis relies on the analysis of the firm-level cross-country data-set constructed from the information on quarterly Key Performance Indicators (KPIs) of mobile carriers. KPIs are regularly disclosed by some carriers in their financial reports[3] on quarterly basis.

[2] There are papers analysing "macro-level" telecommunications data. Among such is Chakravarty (2005), he uses cross-country market-level data-base to study determinants of the diffusion of cellular services in Asia.

[3] Practically, all the data is available on the web-sites of all firms from my data-set, in section "Investor Relations."

Mobile carriers usually are subsidiaries of holding companies, and quarterly financial results are disclosed by the holding companies, not by the carriers themselves.

Of course, the film-level source of data I utilize has some drawbacks but it has a great potential to become one of the main sources of the information on mobile telecommunications in the nearest future, as history of the industry gets longer and as more and more firms start reporting their KPIs.

Unlike financial information, nowadays no agency requires a detailed disclosure of the operational information (of KPIs), and reporting or not reporting KPIs is left to decide to carriers themselves.

Basically, I collected the data necessary to calculate average prices charged by mobile carriers, their market shares, GDP per capita as a proxy for income, market growth index, market penetration rate, and also whether and when the country has implemented MNP.

There were several data-sources used. For operational information on firms I used quarterly and annual reports by each individual operator. I took exchange rates from the Federal Reserve System[4] . Information on GDP and total population of a country was available either from national statistic agencies of those countries or from the Eurostat databases. Inflation rates were available from the US Department of Commerce.

The data is available for 11 countries (22 firms - 2 largest firms from each country in the sample) and for time span varying from 6 (Netherlands) to 24 periods (Sweden), resulting into 158 market-level observations or 316 firm-level observations. As could be observed from the table below, the sample consists of

[4] www.federalreserve.gov/releases/G5.

5 countries with observations before and after MNP implementation, 4 countries with observations only after MNP implementation, and 2 countries with observations only before MNP implementation.

Table 4.1. Geography of the data in the sample

Country	Name of Companies	Available period	MNP Date
Finland	TeliaSonera, Elisa	1q2001 - 4q2005	3q2003
Hungary	Magyar-T, Pannon	1q2002 – 4q2005	2q2004
Korea	SKT, KTF	1q2001 – 4q2005	1q2003
Norway	Telenor, NetCom	3q2000 – 4q2005	4q2001
Sweden	TeliaSonera Tele2	1q2000 – 4q2005	4q2001
Denmark	TDC, Sonofon	1q2004 – 4q2005	3q2001
Japan	DoCoMo, KDDI	1q2002 – 4q2005	No MNP
Netherlands	KPN, Vodafone	2q2004 – 3q2005	2q1999
Spain	Telefonica, Vodafone	2q2004 – 4q2005	4q2000
Ukraine	UMC, Kyivstar	1q2003 – 4q2005	No MNP
Portugal	TMN, Vodafone	2q2004 – 4q2005	1q2002

I had to construct several variables ('secondary' data) needed for my research based on the available data ('primary' data).

Table 4.2. Primary Data Description

Variable	Description
ARPU, $ per customer per month	Average revenue per user, computed as ratio of total revenues, excluding handset revenues, to weighted average number of customers (weighted by sum of the beginning and ending number of consumers in given period).
MoU, minutes per customer per month	Volume of minutes per customer per month handled by operator, includes incoming, outgoing and visitor calls.

Variable	Description
Market penetration, % of population	Shows the relation of number of subscriptions to country population, can be > 1 as some people have 2 or more subscriptions.
Market Share, % of overall customers	The relation of number of operator's subscribers to overall number of subscribers on the market.
Number of customers, thousands of people	Number of subscriptions to a network. Measured in thousands of people.
GDP p.c., $ per person per month	Quarterly GDP, in USD, divided by total population of the country.

Based on the available 'primary' data I calculated several 'secondary' variables, directly used in empirical investigation[5].

The table 4.3. provides summary statistics for the main variables used in the empirical part of the thesis.

Table 4.3. Summary Statistics of Secondary Variables

Variable	Mean	Std. error	Min	Max	Obs.
P, $ per min	0.227	0.068	0.066	0.427	316 (firm-level)
Mkt share	0.414	0.119	0.177	0.680	316 (firm-level)
Mkt penetration	0.781	0.208	0.080	1.120	158 (mkt-level)
Mkt growth rate	0.034	0.063	-0.043	0.440	147 (mkt-level)
MNP	0.576		0	1	158 (mkt-level)
GDP/cap, $	6394.23	3581.62	195.50	14545.80	151 (mkt-level)

[5] For detailed explanation of how the variables were constructed, please refer to ANNEX A.

For empirical estimation I use differences of prices and market shares of two main competitors on the market (that of larger firm minus that of smaller). Summary statistics for these differences is presented in table 4.4. below.

Table 4.4. Summary Statistics of Differences of Prices and Market Shares

Variable	Mean	Std. error	Min	Max	Obs.
$p_{i,t} - p_{j,t}$	-0.011	0.042	-0.148	0.123	151
$\sigma_{i,t} - \sigma_{j,t}$	0.203	0.109	-0.088	0.422	151

There are several drawbacks of the dataset used. First, it was impossible to include each firm from every market, so the dataset has somewhat small size, and data only on 2 largest firms in every market is included. Almost every mobile telecommunications market is settled by 3 to 5 mobile carriers. Naturally, considering only two firms out of 3 or 5 will lead to certain bias, as for example was shown by Shy (1996) for the Cournot set-up of N identical firms. But on mobile telecommunications markets firms are very different in terms of size, mostly because they entered sequentially. Market shares of the remaining players, besides the two largest, rarely exceeds 25-30% of the market, as presented in table below.

Table 4.5. Summary Statistics of Joint Shares of not Included Small Players*.

Country	Joint Share of 'small' players		
	Min	*Max*	*Avg*
Finland	8.1%	25.2%	16.9%
Hungary	12.6%	23.6%	18.9%
South Korea	13.9%	26.8%	17.6%
Sweden	11.4%	17.4%	14.9%
Denmark	21.3%	28.6%	24.4%
Japan	20.2%	23.5%	22.5%
Netherlands	34.2%	36.8%	35.1%
Portugal	19.7%	20.4%	19.9%
Spain	17.5%	23.3%	21.0%
Ukraine	0.0%	9.0%	3.1%

* Summarized across time-period available in the data-set for each country.

Among the other countries the 'outlier' is Netherlands where 35.1% of market are not included in the sample. In Netherlands though operate 6 mobile carriers, that is the unobserved 4 carrier have average share of 8.75% versus 32.4% of average market of two largest firms in Netherlands. So, it is comparatively small firms that are not included and I suppose that, under non-cooperative setup[6], the main players concentrate more on competition between each other rather than with much smaller players. Because of the small size of the unconsidered firms I expect to have relatively small bias and hope that my results will track closely real-life situation.

Second, because information on overall number of consumers on the market is known only approximately - recent entrants with low consumer base and low revenue almost never disclose their KPIs, – thus data on market penetration and, more important, on market shares has some measurement problems. In the case of this data-base measurement error is cushioned by the fact that in some countries national regulatory authorities provide information on market shares, and also companies themselves occasionally undertake surveys that allow them to learn their market shares and disclose more precise estimates.

This data-set is the first firm-level panel to be employed the analysis the effect of MNP on market competition. So, it provides new opportunities for research and has the potential to disclose more information on the issue.

6 Padilla (2005) showed that for market with switching costs collusive outcome is hard to achieve and that it is very unstable.

Chapter 5

EMPIRICAL INVESTIGATION

Buehler and Haucap (2004) claimed that empirical estimation of different effects caused by implementation of MNP is difficult because, firstly, MNP was introduced only recently and time span observable is very short for empirical analysis, secondly, very little data on consumer's switching behavior is publicly available, thirdly, mobile telecommunications sector develops so dynamically that it is difficult to isolate effect of MNP empirically.

In my empirical investigation I try to either overcome or avoid these difficulties. Cross-country firm-level panel data-set provides me with the sufficient variability, hence mitigating the first difficulty. In my empirical investigation of the effect of MNP I do not aim to model consumers' switching explicitly, thus I do not have to deal with the second difficulty. And finally, in my regression I include market-specific and time-specific fixed effects which help me to rule out the effect of technological advancement across different markets and time periods.

This chapter is structured in the following way. Subsection 5.1 provides the rationale for the model to be estimated. Subsection 5.2 follows with description of the empirical methodology applied here. Subsection 5.3 proceeds with description of the results obtained from the empirical investigation and their possible value for policy applications.

5.1. Rationale for Model Specification

The empirical model that is estimated on the data-set described above has its root in the results obtained in the mainstream theoretical investigations, described in literature review part of this thesis.

Now I describe the model, which is estimated in next subsections, in general terms explaining its connection to the theory. Following the economists which used the difference between the market shares of the 'large' and the 'small' firms as an index of competitiveness (e.g. Shi, 2002; Farrel and Klemperer, 2004). I also choose difference between market shares of 'large' and 'small' firms[7] ($\sigma_{ij,t} = \sigma_{i,t} - \sigma_{j,t}$) as dependent variable for my model. Naturally, we would like the difference between market shares to decrease, because this means that market shares of both firms converge. If, after implementation of MNP, market shares of the firms do not converge, but at the same time average price on the market decreases, this may lead towards bankruptcy of a smaller firm and hence towards subsequent deterioration of competition.

Ideally, the general form of the model would be as represented by (5.1.1).

$$\sigma_{ij,t} = F(\sigma_{ij,t-1}, p_{ij,t}, g_t, \eta_t, \psi_t, \nu_t) \qquad (5.1.1)$$

$\sigma_{ij,t}$ - the difference between market shares of 'large' and 'small' firms at ***t***.

$\sigma_{ij,t-1}$ - the difference between market shares of 'large' and 'small' firms at ***t-1***.

$p_{ij,t}$ - the difference between prices charged by 'large' and 'small' firms at ***t***.

g_t - growth rate of the market at ***t***.

η_t - market penetration rate – a proxy for future market growth.

ψ_t - switching costs for an 'average customer' on the market at ***t***.

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[7] Further on the largest firm is denote as 'Large' and the second largest as 'Small'.

v_t - the interconnection cost between the two networks at ***t***.

Unfortunately, the last two variables are not available for this empirical research.

All the explanatory variables are also picked to utilize the suggestions of the mainstream literature on MNP, analyzed in the literature review section.

Klemperer (1989) and Beggs and Klemperer (1992) analyzed how difference between prices charged by 'large' and 'small' firms ($p_{ij,t}$) changes under different market parameters (growth, size of switching costs) and also explained its importance for subsequent equilibrium market shares. For example, under high enough switching costs and slow growth of the market, the 'large' firm would normally charge higher price to 'rip-off' its consumers base while 'small' would charge lower price to build-up its customer base. Thus as the result, ceteris parabis, market shares of the two firms would slowly converge. When market is growing (or is expected to grow) quickly (large g_t, and small η_t), 'large' firm might also try to build-up its customer base, and $p_{ij,t}$ will be lower compared to previous case. Price difference, besides determining equilibrium market shares, itself is an endogenous variable. Because, the aim of this investigation is analysis of the changes to market competition which is better reflected by evolution of market shares, prices are placed among explanatory variables. Next section includes description of the method I applied to solve this endogeneity problem.

Importance of previous difference between market share, $\sigma_{ij,t-1}$, for predicting next period outcome is discussed by Shi (2002), who argued that $\sigma_{ij,t-1}$ affects opportunities of customers to receive on-network discounts. As argued by Shi (2002), Laffont, Rey, and Tirole (1998a,b), ceteris parabis, the firm with larger market share has advantage in acquiring new customers, as they would like to benefit more from "on-network" discounts of the 'large' firm. These papers also showed importance of interconnection cost, v_t, as degree of market competition decreases in size of interconnection cost.

Switching costs, ψ_t, are the discussion issue for many authors. Usually, it is shown that as switching costs decrease, consumers become more willing to switch. But there were no predictions made considering changes in different factors' effects on dynamics of market shares after implementation of MNP. So, I try to make my own Ex-ante predictions, mostly based on intuition.

It seems that MNP leads to more fierce competition, so possibly than the effects of the factors determining dynamics of market shares as described above ($p_{ij,t}$ and of $\sigma_{ij,t}$) will increase in magnitude while sign should remain the same. That is, the lower is the price of 'Small' player relatively to that of 'Large' one, the quicker will market shares converge. The larger is present market share of 'Large' firm relatively to that of 'Small' the slower (quicker) will marker shares converge (diverge). These effects if not increase, than change anyway, after MNP is introduced, so it is necessary to know relative importance of each of them for every particular market, and this investigation aims at doing this.

As main outcome of MNP is a decrease in switching costs (Aoki and Small (2005)), the natural question is, which factor – $p_{ij,t}$ or $\sigma_{ij,t}$ – will be decisive for further evolution of market shares and market competition. Theoretical investigations lead to different conclusions, dependent on assumptions about model parameters. So, an empirical investigation is needed. The following investigation estimates effect of the MNP on an 'average' market and determines the condition which is necessary to be satisfied for MNP to lead towards improvement of competition.

5.2. Estimation Methodology

In this section detailed description of my empirical model is provided along with analysis of the methods used in its estimation.

Based on the general form of my empirical model (5.1.1) below is provided the model to be estimated on the available cross-country firm-level data-set[8]:

$$\sigma_{ij,t} = \alpha_0 + \gamma_0 M + \alpha_1 \sigma_{ij,t-1} + \gamma_1 M \sigma_{ij,t-1} + \alpha_2 p_{ij,t} + \gamma_2 M p_{ij,t} + \\ + \alpha_3 g_t + \gamma_3 M g_t + \alpha_4 \eta_t + \gamma_4 M \eta_t + \sum_{n=2}^{N} \beta_n \tau_n + c + u_t \quad (5.2.1)$$

Where $\sigma_{ij,t}$, $\sigma_{ij,t-1}$, $p_{ij,t}$, g_t, η_t, are, correspondingly, difference between market shares of 'Large' and 'Small' firms at time ***t***, difference between market shares of 'Large' and 'Small' firms at time ***t-1***, difference between prices charged by 'Large' and 'Small' firm at time ***t***, growth rate of the market at time ***t***, and market penetration rate at time ***t***.. The model, stated above, as most linear panel data model, according to Wooldridge, 2002, is most likely a type of unobserved effects model. So, finally, c_k is the unobserved effect, that is unobserved time-constant variable; and $u_{k,t}$ is white noise (or idiosyncratic error).

Switching costs and interconnection costs are not represented in this model for the reason that they were not available – switching costs is not observable and hence cannot be reported; interconnection costs are observable and are known to mobile carriers, but they are not reported regularly and besides are not disclosed by sufficient number of firms. Possible effects of these two variables on the explanatory variable will be considered by application of an appropriate estimation technique. Inclusion of time-specific dummies is necessary for consideration of technological development that occurs over time.

It is important to mention that price, which is included as an explanatory variable in the model, is itself a function of market shares of previous period – firms use price as their actions to maximize their expected flows of profits given

[8] Each variable in this regression should also be indexed by country specific index 'k'. I do it 'implicitly' not to overload the expression.

the observed market parameters. Thus, for model 5.2.1. endogeneity problem arises. Precisely, the difference between prices is 'predetermined': $corr(p_{ij,t}, e_s) \neq 0 \Leftrightarrow t > s.$

Also among the right hand-side variables included is lag of the explained variable – this also is a source of the endogeneity issue.

Endogeneity necessarily leads to biased estimates, and unreliable predictions. To deal with the endogeneity problem, I estimate Arellano-Bond linear dynamic panel-data model. Briefly, benefits of the method is that it corrects for unobserved effects by taking differences, applies instrumental variable procedure to correct for endogeneity problem, and also makes it possible to apply robust estimate of variance-covariance matrix and also to deal with endogeneity at the same time.

Arellano-Bond Generalized Method of Moments Estimator

The Arellano-Bond GMM estimation procedure goes as follows[9]. First, general form of a dynamic panel-data model (similar to that in equation 5.2.1) to be estimated is represented by expression 5.2.2.

$$y_{it} = \sum_{j=1}^{p} a_j y_{i,t-j} + x_{it}\beta_1 + w_{it}\beta_2 + v_i + \varepsilon_{it}, \qquad i = 1,...N \qquad t = 1,...,T_i \tag{5.2.2}$$

Where a_j are p parameters to be estimated, β_1 and β_2 are vectors of the parameters to be estimated.

x_{it} and w_{it} are $1 \times k_1$ and $1 \times k_2$ vectors of, correspondingly, strictly exogenous and predetermined (or endogenous) covariates.

[9] For detailed references see Arellano and Bond, 1991.

In order to obtain estimates of the parameters a_j, β_1 and β_2,

After assuming ρ =2 (2 lags of dependent variable are included in the RHS) lag differencing the equation 5.2.2. becomes equation 5.2.3, with no random effects (c_k) left.:

$$\Delta y_{it} = \Delta y_{i,t-1}a_1 + \Delta y_{i,t-2}a_2 + \Delta x_{it}\overline{\beta} + \Delta u_{it}, \qquad i = 1,...N \qquad t = 1,...,T_i \tag{5.2.3}$$

Then Arellano and Bond provide a procedure to instrument the lags of explained variable together with the predetermined variables in the model. As instrumental variables lagged levels of the explained variable are used. Under assumption of no autocorrelation in idiosyncratic error terms (u_{it}) for every ***i*** at t=4 $y_{i,1}$ and $y_{i,2}$ are valid instruments for the lags of the explained variable. For t=4 $y_{i,3}$ and $y_{i,4}$ cannot be used as instruments as they already are in the model – in the lagged variables on the RHS. Then for every ***i*** at t=5 $y_{i,1}$, $y_{i,2}$, and $y_{i,3}$ are the valid instruments, and so on. In such a way matrix of instruments, Z_i, is constructed for every ***i***. :

$$Z_i = \begin{pmatrix} y_{i2} & y_{i3} & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & \Delta x_{i5} \\ 0 & 0 & y_{i2} & y_{i3} & y_{i4} & \cdots & 0 & 0 & 0 & \Delta x_{i6} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & y_{i2} & \cdots & y_{i,T-2} & \Delta x_{iT} \end{pmatrix} \tag{5.2.4.}$$

All Δx_i s are strictly exogenous and instrument themselves. Endogenous (predetermined) variables, Δw_i s, are treated like the lagged dependent variables – their levels lagged 2 (lagged 1 for predetermined ones) are valid instruments.

Matrix Z_i, in case of balanced panel data-set, has $T-\rho-1$ rows and $\sum_{m=\rho}^{T-2} m + k_1$ columns, where k_1 is number of variables in *x*.

The robust estimator of the variance-covariance matrix, which allows to correct for heteroscedasticity, is given by :

$$\hat{V}_{1r} = Q_1^{-1}\left(\sum_{i=1}^{N} X_i^{*'} Z_i\right) A_1 A_2^{-1} A_1 \left(\sum_{i=1}^{N} Z_i^{'} X_i^{*}\right) Q_1^{-1} \qquad (5.2.5)$$

Where $Q_1 = \left(\sum_{i=1}^{N} X_i^{*'} Z_i\right) A_1 \left(\sum_{i=1}^{N} Z_i^{'} X_i^{*}\right)$, $A_1 = \sum_{i=1}^{N} Z_i^{'} H_i Z_i$, and

$H_i = E[u_i^{*} u_i^{*'}]$, the covariance matrix of differenced idiosyncratic errors.

X_i^{*} - vector of all RHS explanatory variables.

The estimation by the Arellano-Bond GMM procedure is based on the assumption of no serial correlation in the idiosyncratic error, i.e. matrix H_i is assumed to have zeros outside the main diagonal. In Stata estimation algorithm automatically provides 2 Arellano-Bond tests – for autocovariance in residuals of order 1 and for autocovariance in residuals of order 2. According to Arellano and Bond, 1991, if residuals are autocorrelated of order 1 this leads to inefficiency of the estimates. But is autocovariance of order 2 (or higher) is present, the estimate will be biased.

The next subsection provides description and verification of the estimation results.

5.3. Interpretation of Estimation Results

Along way of estimating the Arellano-Bond GMM model, I also estimated pooled OLS model (Model [1]), fixed-effect model (Model [2]), random-effect model with AR(1) residuals (Model [3]), and 2 Stages Least-Squares model (Model [4]). This allows me to better learn properties of the data-set at hand and compare the estimation results to the estimation results of the ultimate Arellano-Bond GMM model (Model [5]). All the estimates are placed in table 5.3.2 below.

Before estimating the model, the theoretical predictions about the signs of coefficients near the factors predicting market share evolution is placed in table 5.3.1. My own ex-ante expectations about signs of the change of the coefficients near the factors are also placed in table.

Table 5.3.1. Expectations of Signs of Explanatory Variables

Regressor	$\sigma_{ij,t-1}$	$M_t\sigma_{ij,t-1}$*	$p_{ij,t}$	$Mp_{ij,t}$*
Expected Sign	+	+	-	-
Regressor	g_t	Mg_t*	η_t	$M\eta_t$*
Expected Sign	+	+	+	+

* - my own expectations.

To estimate Model [2] I choosed fixed-effect model, based on Hausman test. Also, for estimation Model [3] random-effect model was chosen based on Hausman test. Also after estimation of Model [3] Breusch-Pagan tests for random effects and founds no evidence of those.

Table 5.3.2. Estimation Results for Main Specifications of the Model

Variables	Model [1]	Model [2]	Model [3]	Model [4]	Model [5]
$\sigma_{ij,t-1}$	0.983***	0.844***	0.982***	0.766***	0.793***
$M_t\sigma_{ij,t-1}$	-0.023	-0.048	-0.052	0.123	-0.041**
$p_{ij,t}$	-0.004	-0.098	0.029	-0.340	-0.098

Variables	Model [1]	Model [2]	Model [3]	Model [4]	Model [5]
$Mp_{ij,t}$	-0.006	0.205	-0.081	0.636***	0.135
g_t	0.154	0.311***	0.270***	0.333***	0.035+
Mg_t	-0.108	-0.226	-0.240	-0.272*	-0.065
η_t	0.033	-0.122***	0.059**	-0.110**	0.021**
$M\eta_t$	-0.018	0.039	-0.048	0.134**	-0.023**
M_t	0.015	-0.015	0.049	-0.106**	0.018**
Time_ dummies (2-24)	+	+	+	+	+/-
cons	-0.036	0.096	-0.057	0.121	-0.016**
R^2[10]	0.9653	Not Reported	Not Reported	Not Reported	Not Reported
No obs.	147	147	147	136	131
DF	115	105	105	105	100

Significance levels: *** - 1%, ** - 5%, * -10%, + - 20%

For Mode [4] lagged explanatory variables $l.p_{ij}$, $l.Mp_{ij}$, $l.g$, and $l.\eta$ as instruments for predetermined p_{ij} and Mp_{ij}. But endogeneity stemming from having lags of explained variable among explanatory ones is not resolved.

So, none of the models [1] through [4] is able to eliminate all problems – endogeneity in RHS lagged explained variable and RHS predetermined variables, heteroscedasticity, and autocorrelation.

For the purpose of drawing away endogeneity Model [5] – Arellano-Bond linear dynamic GMM was estimated. It also allows correcting for heteroscedasticity and testing for AR(1) and AR(2) processes in estimation errors. Further model was specified as in 5.2.1 and after differencing it became:

[10] Coefficient of determination (R^2) is not reported for Models [2]-[4], because time-specific dummy variables are included and inflate R^2. The estimation procedure applied to estimate Model[5] does not report R2 . F-test, applied to test Ho that all the coefficients are zeroes leads to huge F statistic and P-value of 0.00.

$$\Delta\sigma_{ij,t} = a_1\Delta\sigma_{ij,t-1} + \gamma_1\Delta M\sigma_{ij,t-1} + a_2\Delta p_{ij,t} + \gamma_2\Delta Mp_{ij,t} + \\ + a_3\Delta g_t + \gamma_3\Delta Mg_t + a_4\Delta\eta_t + \gamma_4\Delta M\eta_t + \sum_{m=2}^{T} l_m\Delta\tau_{m,t} + u_t \quad (5.3.1.)$$

Where the usual notation is used – $\Delta\sigma_{ij,t}$ and $\Delta\sigma_{ij,t-1}$ - differenced difference between market shares and lagged differenced difference between market shares. $\Delta p_{ij,t}$ - differenced difference of prices, Δg_t and $\Delta\eta_t$ - are differences of growth rate and penetration rate of the market.

The Arellano-Bond procedure instruments such variables as $\Delta\sigma_{ij,t-1}$, $\Delta(M\sigma_{ij,t-1})$, $\Delta p_{ij,t}$, and $\Delta(Mp_{ij,t})$ with, firstly, lags of levels of σ_{ij}, secondly, first and second lags of themselves.

The signs of the coefficients near the factors explaining the evolution of market shares of the specification Model [5] appeared to be entirely in line with the mainstream theory. But my expectations about the effect of MNP on magnitude of the explaining factors turned wrong. Let's now consider the results in more detail and analyze the findings.

Positive and strongly significant coefficient of $\sigma_{ij,t-1}$ shows that the firm with larger market share will manage to keep about 79% of the difference between market shares in the next period as well. But introduction of MNP decreases the capacity of 'Large' firm to maintain its high market share, as coefficient near $M_t\sigma_{ij,t-1}$ is negative and significant.

As predicted by the theory, $p_{ij,t}$ is negative. That is, the stronger Small firm undercuts Large one, the faster market shares converge. The other result is that

$Mp_{ij,t}$ is positive, and 'marginally' significant – at 15% s. l., meaning that marginal effect from efforts of Small firm to undercut its Large competitor decreases under implemented MNP.

Positive and significant coefficient near g_t supports the theoretical suggestions stated above. This result could be interpreted that probability that of incumbent firm to engage in penetration pricing is increasing in market growth rate. MNP seem to have decreasing effect on the probability of incumbent operator to engage in penetration pricing, as coefficient near Mg_t is negative.

Penetration rate η_t, is used in the empirical model as an 'inverted' proxy for future expected market growth, should have and actually has properties similar to the previous factor. Penetration rate is positive and significant, but MNP also decreases it.

The dummy for MNP (M_t) is positive and significant. But, according to methodology there should not be an intercept in the model after differencing. But still we could try to interpret this variable. – If there are some other mechanisms, not included in the empirical model being estimated, for example, decreased degree of information available to consumers, MNP leads towards decrease in competition through those mechanisms as marginal effect of the dummy alone is towards divergence of market shares of the firms.

So the empirical results support what most theoretical works would predict, and it would also be interesting to derive some 'requirements' for the market parameters (such as penetration rate and growth rate) that would guarantee positive outcome of MNP implementation for market competition. Some algebraic manipulations below result in a simple rule for policy-makers. Besides, based on the estimated coefficients of Model [5] some simulations are provided on figure 5.3.1. to better illustrate the meaning of the equation rule 5.3.5.

For MNP implementation to have positive outcome, in terms of improving competition, means that the difference between the market shares of the firms should decrease more than otherwise. That is, MNP portability should be implemented if and only if:

$$\sigma_{ij,t}^{MNP} \leq \sigma_{ij,t}^{NO\_MNP}, \tag{5.3.2}$$

or after substituting from the equation (5.3.1)[11]:

$$\begin{aligned}&(a_0 + b_0) + (a_1 + b_1)\sigma_{ij,t-1} + (a_2 + b_2)p_{ij,t} + (a_3 + b_3)g_t + \\ &+ (a_4 + b_4)\eta_t \leq a_0 + a_1\sigma_{ij,t-1} + a_2 p_{ij,t} + a_3 g_t + a_4 \eta_t\end{aligned} \tag{5.3.3}$$

Where b_0, b_1, b_2, b_3, b_4 are the estimated (in Model [5]) intercept coefficients of the interaction terms of MNP dummy with other variables. Variables are not differenced now, because, according to Wooldridge, 2002, differencing was needed to only for estimation purposes – to get rid of unobservable fixed effects, but for interpretation original model should be used.

After simple arithmetic transformations 5.3.3 becomes:

$$\sigma_{ij,t-1} \leq -\frac{b_0 + b_2 p_{ij,t-1} + b_3 g_t + b_4 \eta_t}{b_1} \tag{5.3.4}$$

If updated 1 period ahead (5.3.3) becomes:

[11] For the LHS value coefficients near explanatory variables are summed with the correspondent coefficients near explanatory variables interacted with the dummy for MNP. For the RHS value only coefficients near explanatory variables are used.

$$\sigma_{ij,t} \leq -\frac{b_0 + b_2 \Delta p_{ij,t} + b_3 E(g_{t+1}) + b_4 E(\eta_{t+1})}{b_1} \qquad (5.3.5)$$

Expression (5.3.5.) gives the condition for testing possible effect of MNP for market competition. As 5.3.4 is derived from inequality 5.3.2., it tells that for MNP to have positive outcome it is necessary that present difference between market shares of the two firms to be smaller than minus the expression of today's price difference, expected future growth and penetration rates.

The figure below is an additional illustration of how condition 5.3.5 works. The simulations underlying the figure are based on certain assumptions concerning magnitude of the expected penetration rate, $E(\eta_{t+1})$, and of the difference between prices charge by the two firms, $p_{ij,t}$.

Figure 5.3.1a. Dependence of required Difference of Market Shares on Market Parameters (Expected penetration: 60%).

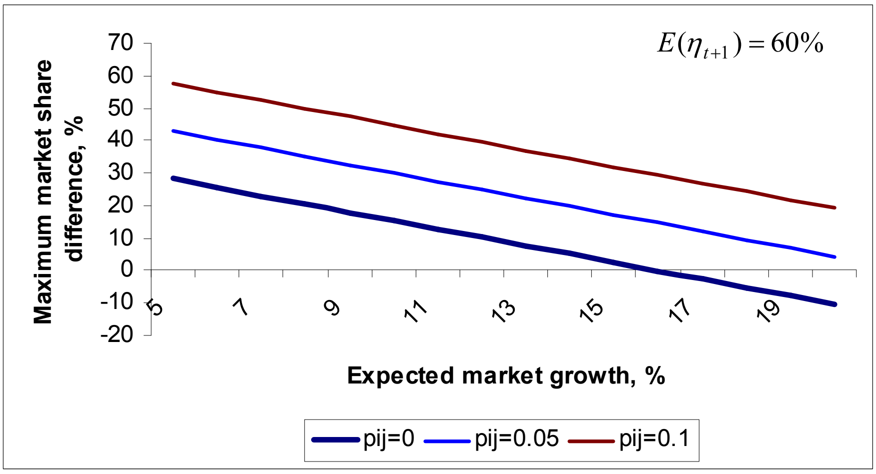


Figure 5.3.1b. Dependence of required Difference of Market Shares on Market Parameters (Expected market penetration: 80%).

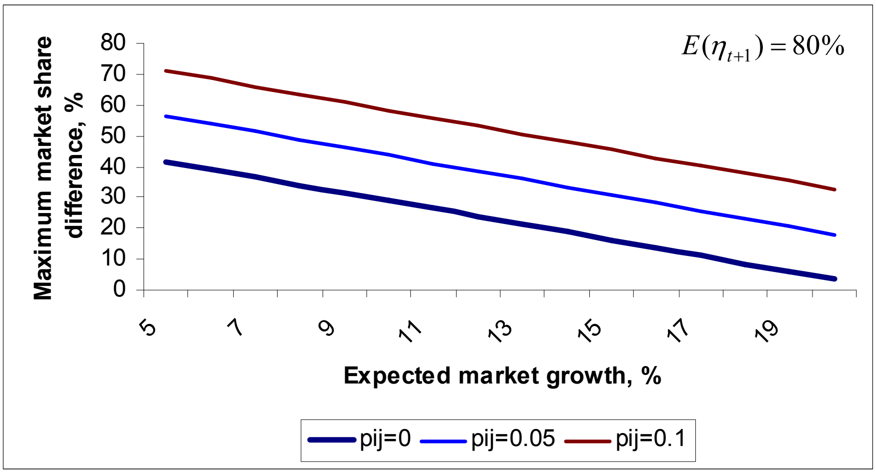
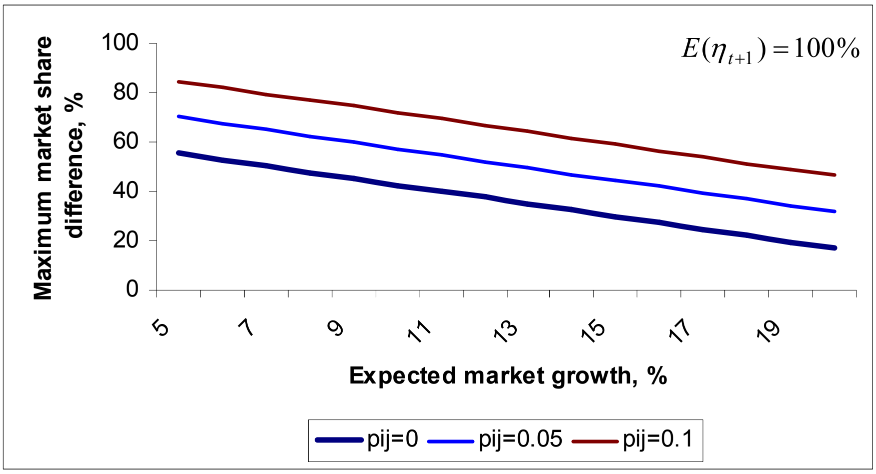


Figure 5.3.1c. Dependence of required Difference of Market Shares on Market Parameters (Expected market penetration: 100%)



Figures illustrate that on highly penetrated markets MNP is very likely to have success even if competition on the market is between extremely disproportionate players. While on markets with low penetration level and high growth MNP should be proceeded with thorough analysis, as chances are that MNP could lead towards deterioration of competition.

Chapter 6

CONCLUSION

Though MNP is usually considered as a technology that fosters competition on a mobile telecommunications market, it is mot always the case. Though in Sweden and Finland it lead to increased competition, as measured by faster convergence of market shares, in such countries as Hong Kong, Korea it caused inverse effect – market shares diverged. Therefore it looks necessary to verify whether MNP will have competition-improving or competition-deteriorating effect beforehand.

In this thesis I developed model of competition between two mobile carriers, where consumers have switching costs, and there are interconnection costs on the market. It seams that no closed solution is available for the model, but in series of simulation I found that such market variables as growth rate, interconnection costs play important role for predetermining the effect of MNP.

Also an empirical investigation was undertaken. The dynamic panel-data model was estimated by Arellano-Bond GMM estimator. The results supported suggestions of previous theoretical works and findings of the model developed in this thesis.

I believe, that MNP is still an issue to be researched much. And ideas and findings of this paper could stimulate further research and might help avoid negative consequences of MNP in some countries.

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ANNEX A: Proof of Proposition 1.

After substitution of (3.3.1.a) and (3.3.1.b) into (3.3.2.) and reshuffling it is possible to obtain:

$$n\sigma_A(v_{AA} + v_{BB} - v_{AB} - v_{BA}) = (v_{BB} - v_{AB})n - \tau - S + 2\tau X_A \qquad [1]$$

After substitution of (3.3.1.a) and (3.3.1.b) into (3.3.3.) and into (3.3.4) and reshuffling , we by the same token obtain:

$$n\sigma_A(v_{AA} + v_{BB} - v_{AB} - v_{BA}) = (v_{BB} - v_{AB})n - \tau + S + 2\tau X_B \qquad [2]$$

$$n\sigma_A(v_{AA} + v_{BB} - v_{AB} - v_{BA}) = (v_{BB} - v_{AB})n - \tau + 2\tau X \qquad [3]$$

Then from pair-wise equating the expressions [1], [2], and [3] we obtain three groups of conditions, which will be substituted into the expression for market share of A (σ_A):

(A) $X_B = X_A - \frac{S}{\tau}$, $X = X_A - \frac{S}{2\tau}$

(B) $X_A = X_B + \frac{S}{\tau}$, $X = X_B + \frac{S}{2\tau}$

(C) $X_A = X + \frac{S}{2\tau}$, $X_B = X - \frac{S}{2\tau}$

Now, it is possible to transform the expression for c(3.5.5.) in the following way:

$$\sigma_A = X_A\left(\frac{K\theta_A}{K+N}\right) + X_B\left(\frac{K\theta_B}{K+N}\right) + X\left(\frac{N}{K+N}\right) \qquad [4]$$

Then, to calculate the indifferent consumer position, we do the following: for XA we substitute conditions (A) into σ_A and into [1]; for XB we substitute conditions (B) into σ_A and into [2]; for X we substitute conditions (C) into σ_A and into [3]. After that the proportions (3.3.6.) are calculated.

ANNEX B. Proof of Proposition 2

$$\pi_A = (K+N)\overline{\sigma}_A[n\overline{\sigma}_A(p_{AA}-c_A)q_{AA} + n(1-\overline{\sigma}_A)(p_{AB}-mc_A)]$$

s.t. $n\overline{\sigma}_A v_{AA} + n(1-\overline{\sigma}_A)v_{AB} = \overline{w}_A$

Let's set up the L'Agrangian and find the first-order conditions:

$$\xi = (K+N)\overline{\sigma}_A[n\overline{\sigma}_A(p_{AA}-c_A)q_{AA} + n(1-\overline{\sigma}_A)(p_{AB}-mc_A)] -$$

$$-\lambda(\overline{w}_A - n\overline{\sigma}_A v_{AA} + n(1-\overline{\sigma}_A)v_{AB})$$

FOC:

(1) $\dfrac{\partial \xi}{\partial p_{AA}} = (K+N)\overline{\sigma}_A \cdot q_{AA} + (K+N)\overline{\sigma}_A(p_{AA}-c_A)\cdot q'_{AA} + \lambda v'_{AA} = 0$

(2) $\dfrac{\partial \xi}{\partial p_{AB}} = (K+N)\overline{\sigma}_A \cdot q_{AB} + (K+N)\overline{\sigma}_A(p_{AB}-mc_A)\cdot q'_{AB} + \lambda v'_{AB} = 0$

Express λ to RHS in each of the two equations and combine them. Then as $q'_{AA} = q'_{AB} = -B$,

$q_{AB}(p_{AA}-c_A) = q_{AA}(p_{AB}-mc_A)$,

After substituting the expressions for q_{AA} and q_{AB}, and few arithmetic transformation,
We obtain the target expression:

$p_{AB} = p_{AA}\dfrac{A - B\cdot c_A \cdot m}{A - B\cdot c_A} + \dfrac{c_A A(m-1)}{A - B\cdot c_A}$, or $p_{AB} = p_{AA}k_1^A + k_0^A$, where

$k_1^A = \dfrac{A - B\cdot c_A\cdot m}{A - B\cdot c_A}$, $\quad k_0^A = \dfrac{c_A A(m-1)}{A - B\cdot c_A}$.

By symmetry, for firm B we obtain:

$p_{BA} = p_{BB}\dfrac{A - B\cdot c_B \cdot m}{A - B\cdot c_B} + \dfrac{c_B A(m-1)}{A - B\cdot c_B}$, or $p_{BA} = p_{BB}k_1^B + k_0^B$, where

$k_1^B = \dfrac{A - B\cdot c_B\cdot m}{A - B\cdot c_B}$, $\quad k_0^B = \dfrac{c_B A(m-1)}{A - B\cdot c_B}$.

QED.

ANNEX C: Algorithm for Calculating the Nash Equilibrium

This algorithm is developed independently, and so far it has not been tasted yet for precision of results. But because of the methods it relies on, I believe that results are reasonably precise.

Obtaining Nash Equilibrium:

1) Divide range of price by B into 200 small pieces and find length of one.
   Then by iterating p_B in bounds determined by the value of marginal costs and the upper bound as defined after (3.2.3), obtain values of p_A (also bounded) which maximize profit of firm A for every value of p_B.
2) Estimate the optimal response function of firm A, by applying Chebyshev's polynomial for regressing p_A on p_B. Chebyshev's polynomial is constructed in the way to minimize collinearity among regressors. Thus the coefficients of determination obtained were rather high.
3) and 4) Do the procedures described in 2) and 3) for firm B.
4) Solve the system of nonlinear equations:

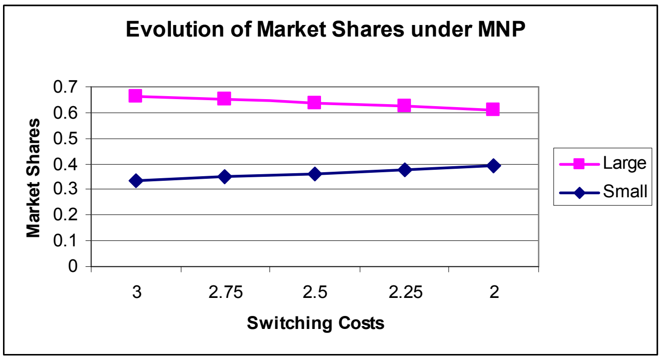
$$\begin{cases} p_{AA} = R_A(p_{BB}) \\ p_{BB} = R_B(p_{AA}) \end{cases}.$$

Chebyshev's Polinomial

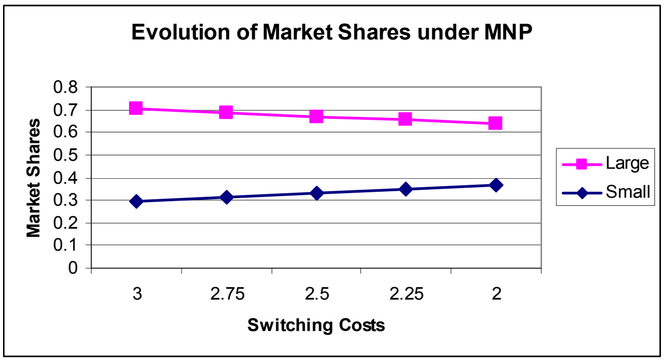
$$F(X) \approx T_0(X) + ... + T_n(X), \qquad T_n(X) = \cos(n \cdot \cos^{-1}(X))$$

ANNEX D: Evolution of Market Shares under MNP (Decreased Switching Costs)

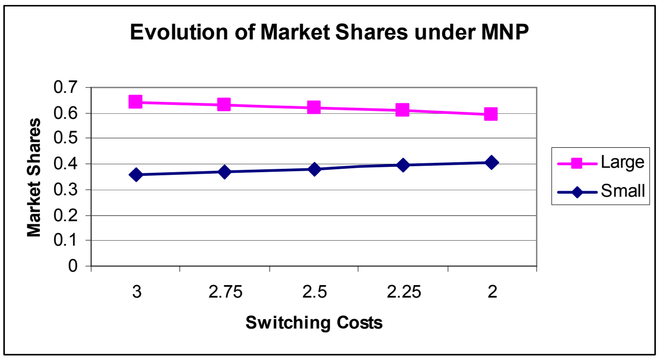
Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \dfrac{N_t}{K_t} = 30\%$, $M_t = 2$;



Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \dfrac{N_t}{K_t} = 5\%$, $M_t = 2$;

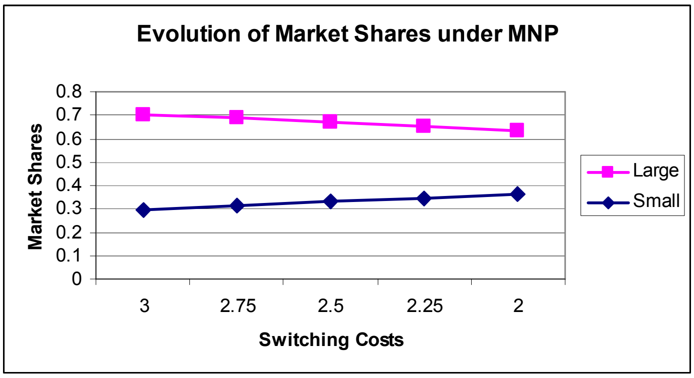


Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \dfrac{N_t}{K_t} = 50\%$, $M_t = 2$;

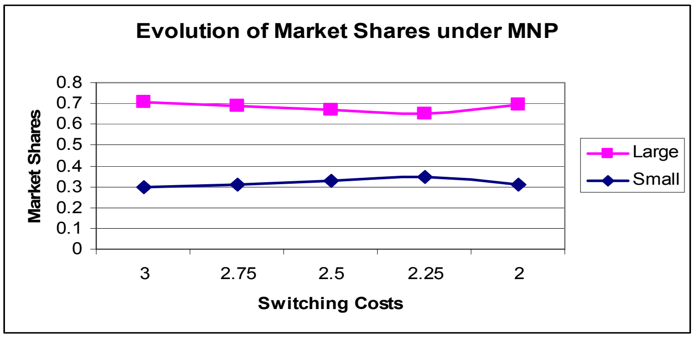


ANNEX E: Evolution of Market Shares under MNP (Decreased Switching Costs)

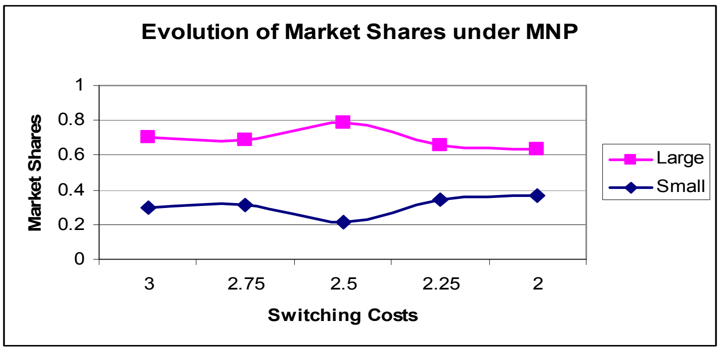
Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \frac{N_t}{K_t} = 5\%$, $M_t = 2$;



Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \frac{N_t}{K_t} = 30\%$, $M_t = 2.75$;

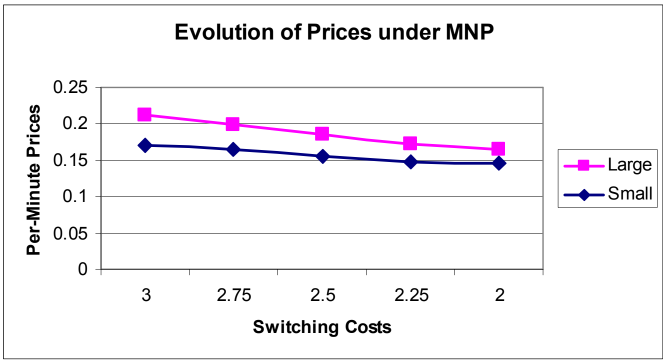


Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \frac{N_t}{K_t} = 30\%$, $M_t = 3.5$;

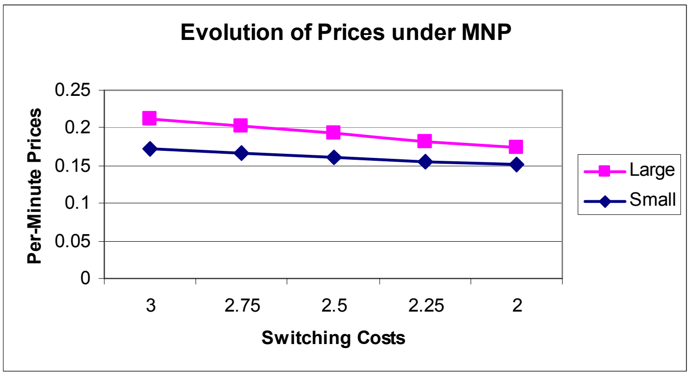


ANNEX F: Evolution of Per-Minute Prices under MNP (Decreased Switching Costs)

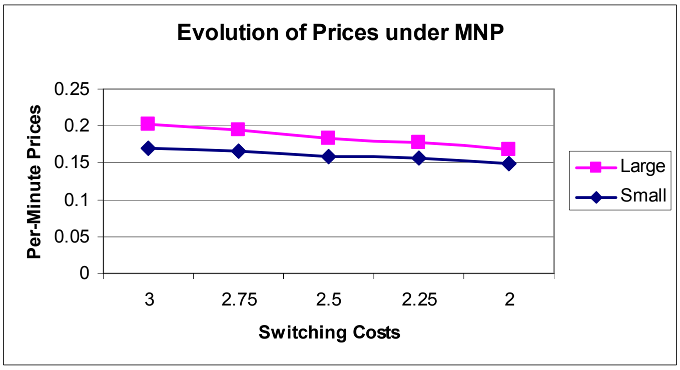
Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \frac{N_t}{K_t} = 5\%$, $M_t = 2$;



Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \frac{N_t}{K_t} = 30\%$, $M_t = 2$;

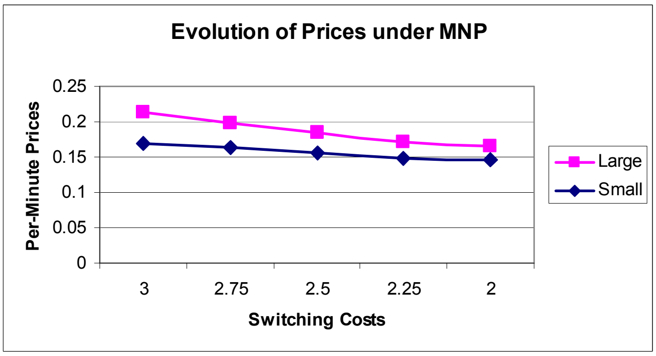


Assumptions: $\sigma_{i,t} = 75\%$ $\sigma_{j,t} = 25\%$, $g_t = \frac{N_t}{K_t} = 50\%$, $M_t = 2$;

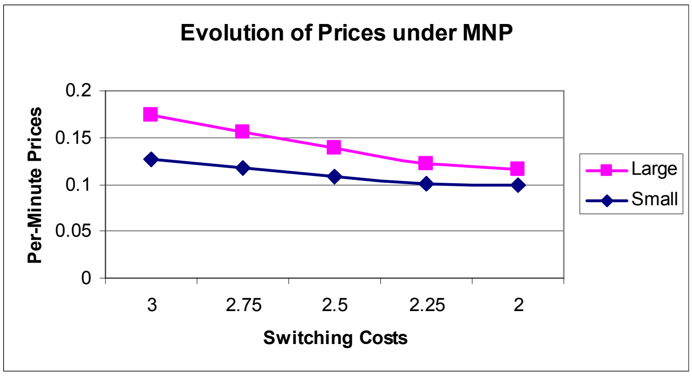


ANNEX G: Evolution of Per-Minute Prices under MNP (Decreased Switching Costs)

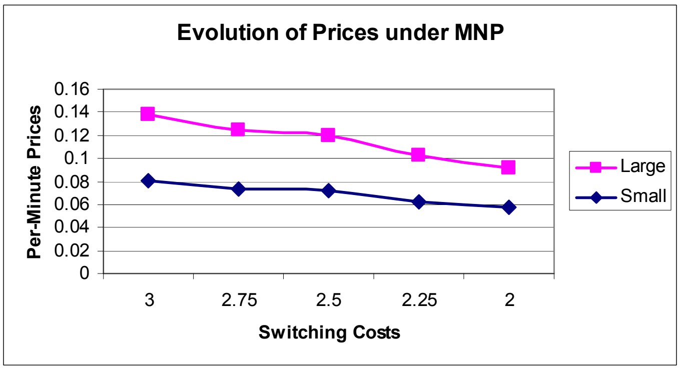
Assumptions: $\sigma_{i,t} = 75\% \quad \sigma_{j,t} = 25\%, \quad g_t = \frac{N_t}{K_t} = 5\%, \quad M_t = 2;$



Assumptions: $\sigma_{i,t} = 75\% \quad \sigma_{j,t} = 25\%, \quad g_t = \frac{N_t}{K_t} = 5\%, \quad M_t = 2.75;$



Assumptions: $\sigma_{i,t} = 75\% \quad \sigma_{j,t} = 25\%, \quad g_t = \frac{N_t}{K_t} = 5\%, \quad M_t = 3.5;$



ANNEX H: CONSTRUCTION OF VARIABLES FOR ESTIMATION

I constructed six new variables ($p_{it}, p_{ij,t}, \sigma_{ij,t}, g_{it}, \eta_{it}, M_t$) from the available data, as represented by Table 4.2. The ways to construct the variables are provided below.

(1). Prices: $p_{it} = \frac{ARPU_{it}}{MoU_{it}}$,

(2). Difference between prices of two mobile carriers: $p_{ij,t} = p_{i,t} - p_{j,t}$,

i denotes carrier with the largest market share and ***j*** – the one with the second largest market share.

In same way, difference between market shares of the two mobile carriers is:

(3). $\sigma_{ij,t} = \sigma_{i,t} - \sigma_{j,t}$

Same as above, ***i*** denotes carrier with the largest market share and ***j*** – the one with the second largest market share.

(4). Growth rate $g_t = \frac{Total\ market\ customers_t}{Total\ market\ customers_{t-1}}$;

(5). Market penetration[12] - $\eta_t = \frac{\sum_{i=1}^{N} consumers_t}{pop_t}$; $\sum_{i=1}^{N} consumers_t = \frac{consumers_{it}}{\sigma_{it}}$

Market penetration shows fraction of total number of subscriptions to mobile services to total population of the country.

(6). Dummy for MNP (M_t) was constructed in a way that it equals 1 in the periods of MNP implementation and afterwards and equals 0 in periods prior to MNP implementation.

12 When market penetration was not provided in KPIs, I constructed it based on other information, as shown in formula (5) above.

ANNEX I: ESTIMATION OUTPUT

Model [1]

```
. reg shareij l.shareij l.np_shareij pij np_pij growth np_growth pen np_pen mnp
_Itime_2-_Itime_24,  robust
Regression with robust standard errors                 Number of obs =     147
                                                       F( 29,   115) =       .
                                                       Prob > F      =       .
                                                       R-squared     =  0.9653
                                                       Root MSE      =  .02209
------------------------------------------------------------------------------
             |               Robust
shareij      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
shareij      |
          L1 |   .9825593   .0342458    28.69   0.000     .9147249    1.050394
np_shareij   |
          L1 |  -.0231348    .033712    -0.69   0.494    -.0899118    .0436422
pij          |  -.0042483   .0686726    -0.06   0.951    -.1402754    .1317788
np_pij       |  -.0058389   .0865704    -0.07   0.946    -.1773183    .1656405
growth       |   .1543966   .1035542     1.49   0.139    -.0507243    .3595175
np_growth    |  -.1080039   .1774912    -0.61   0.544    -.4595798     .243572
pen          |   .0332275   .0366008     0.91   0.366    -.0392717    .1057267
np_pen       |  -.0180473   .0393726    -0.46   0.648    -.0960369    .0599422
mnp          |   .0151726   .0320162     0.47   0.636    -.0482453    .0785905
_Itime_2     |   .0106963    .000999    10.71   0.000     .0087175     .012675

_cons        |  -.0359398   .0329675    -1.09   0.278    -.1012421    .0293625
------------------------------------------------------------------------------
```

```
. ovtest
Ramsey RESET test using powers of the fitted values of shareij
       Ho:  model has no omitted variables
                 F(3, 112) =      0.62
                  Prob > F =      0.6003
```

Model [2]

```
. xtreg shareij lshareij np_lshareij pij np_pij growth np_growth pen np_pen mnp
_Itime_2-_Itime_24, fe

Fixed-effects (within) regression               Number of obs      =       147
Group variable (i): country                     Number of groups   =        11
R-sq:  within  = 0.8425                         Obs per group: min =         5
       between = 0.7750                                        avg =      13.4
       overall = 0.8215                                        max =        23
                                                F(31,105)          =     18.11
corr(u_i, Xb)  = 0.3198                         Prob > F           =    0.0000
------------------------------------------------------------------------------
     shareij |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lshareij |   .8441014   .0564194    14.96   0.000     .7322322    .9559706
 np_lshareij |  -.0475949   .0672732    -0.71   0.481    -.1809852    .0857954
         pij |  -.0978973   .1377826    -0.71   0.479    -.3710948    .1753002
      np_pij |   .2049106   .1344787     1.52   0.131    -.0617358    .4715571
      growth |    .310961   .0507414     6.13   0.000     .2103502    .4115717
   np_growth |  -.2264536   .1497602    -1.51   0.134    -.5234004    .0704932
         pen |  -.1224278   .0426082    -2.87   0.005     -.206912   -.0379437
      np_pen |   .0387733   .0478158     0.81   0.419    -.0560365    .1335832
         mnp |  -.0151477   .0426803    -0.35   0.723    -.0997748    .0694794
    _Itime_2 |   .0046729   .0269722     0.17   0.863     -.048808    .0581537
.     .     .     .     .     .     .     .     .     .     . .. ..  .    .
       _cons |   .0961668   .0345646     2.78   0.006     .0276316    .1647021
-------------+----------------------------------------------------------------
     sigma_u |  .04851226
     sigma_e |  .01891854
         rho |  .86799526   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(10, 105) =     5.15             Prob > F = 0.0000

. hausman fixed random
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
    lshareij |    .8441014     .9896394        -.145538        .0479515
 np_lshareij |   -.0475949    -.0380391       -.0095557        .0497977
         pij |   -.0978973    -.0087706       -.0891267        .1127394
      np_pij |    .2049106    -.0106477        .2155583        .0858204
      growth |     .310961     .1588218        .1521391        .0148702
   np_growth |   -.2264536    -.1222865       -.1041671               .
         pen |   -.1224278     .0311229       -.1535507        .0369669
      np_pen |    .0387733    -.0188321        .0576054        .0333891
         mnp |   -.0151477     .0203706       -.0355183        .0306683
    _Itime_4 |   -.0001437    -.0109565        .0108128               .
.     .     .     .     .     .     .     .     .     .     . ..     .
b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
    Test:  Ho:  difference in coefficients not systematic
                 chi2(30) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       60.57
                Prob>chi2 =      0.0008
```

Model [3]

```
. xtregar shareij lshareij np_lshareij pij np_pij growth np_growth pen np_pen
mnp _Itime_2-_Itime_24, re
RE GLS regression with AR(1) disturbances       Number of obs      =       147
Group variable (i): country                     Number of groups   =        11
R-sq:  within  = 0.7969                         Obs per group: min =         5
       between = 0.9964                                        avg =      13.4
       overall = 0.9633                                        max =        23
                                                Wald chi2(32)      =   1398.33
corr(u_i, Xb)      = 0 (assumed)                Prob > chi2        =    0.0000
------------------- theta --------------------
  min      5%       median        95%      max
0.0000   0.0000     0.0000     0.0000   0.0000
------------------------------------------------------------------------------
     shareij |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lshareij |   .9819711    .040313    24.36   0.000     .9029591    1.060983
 np_lshareij |  -.0523589   .0624635    -0.84   0.402     -.174785    .0700672
         pij |   .0290602   .1051038     0.28   0.782    -.1769396    .2350599
      np_pij |  -.0811578   .1318873    -0.62   0.538    -.3396521    .1773365
      growth |   .2700865   .0460904     5.86   0.000      .179751    .3604221
   np_growth |  -.2398133   .1667744    -1.44   0.150    -.5666851    .0870585
         pen |    .058866   .0277873     2.12   0.034     .0044038    .1133281
      np_pen |   -.047964   .0489518    -0.98   0.327    -.1439077    .0479798
         mnp |   .0494714   .0414495     1.19   0.233    -.0317681    .1307108
    _Itime_2 |   .      .     .    .     .     .     .      . ...
       _cons |  -.0571856   .0292762    -1.95   0.051     -.114566    .0001947
-------------+----------------------------------------------------------------
      rho_ar |  .40003282   (estimated autocorrelation coefficient)
     sigma_u |          0
     sigma_e |  .01891746
     rho_fov |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. hausman fixed random
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
    lshareij |    .5986282     .9819711       -.3833429        .0648191
 np_lshareij |    .0831359    -.0523589        .1354948        .0688978
         pij |   -.2604969     .0290602       -.2895571        .1180856
      np_pij |    .2985256    -.0811578        .3796835        .0943567
      growth |    .3122125     .2700865         .042126               .
   np_growth |   -.2684822    -.2398133       -.0286688               .
         pen |    -.128441      .058866        -.187307        .0489464
      np_pen |    .0847856     -.047964        .1327496        .0476233
         mnp |   -.0669457     .0494714        -.116417        .0417454
    _Itime_4 |   .      .     .    .     .     .     .      . ..
   _Itime_24 |   -.0265144    -.0083419       -.0181725        .0364063
------------------------------------------------------------------------------
                         b = consistent under Ho and Ha; obtained from xtregar
          B = inconsistent under Ha, efficient under Ho; obtained from xtregar
    Test:  Ho:  difference in coefficients not systematic
                chi2(30) = (b-B)'[(V_b-V_B)^(-1)](b-B) =  38.27
                    Prob>chi2 =      0.1431
```

```
. xttest0
Breusch and Pagan Lagrangian multiplier test for random effects:
        shareij[country,t] = Xb + u[country] + e[country,t]
        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                 shareij |   .0110677       .1052031
                       e |   .0003579       .0189185
                       u |          0              0
             Test:   Var(u) = 0
                             chi2(1) =     0.27
                          Prob > chi2 =     0.6059
```

Model [4]

```
. xtivreg shareij lshareij np_lshareij (pij np_pij = l.pij l.np_pij l.growth
l.pen) growth np_growth pen np_pen mnp _Itime_2-_Itime_24, fe
Fixed-effects (within) IV regression         Number of obs      =         136
Group variable: country                      Number of groups   =          11
R-sq:  within  = 0.8336                      Obs per group: min =           4
       between = 0.7719                                     avg =        12.4
       overall = 0.8113                                     max =          22
                                             Wald chi2(30)      =  16833.34
corr(u_i, Xb)  = 0.4040                      Prob > chi2        =    0.0000

------------------------------------------------------------------------------
     shareij |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         pij |  -.3402591   .2126773    -1.60   0.110     -.757099    .0765808
      np_pij |   .6360379   .2354291     2.70   0.007     .1746053     1.09747
    lshareij |   .7659033   .0617696    12.40   0.000      .644837    .8869696
 np_lshareij |   .1234471   .0920481     1.34   0.180    -.0569639    .3038581
      growth |   .3332181   .0505238     6.60   0.000     .2341934    .4322429
   np_growth |  -.2719312   .1473705    -1.85   0.065    -.5607721    .0169098
         pen |  -.1101881   .0457614    -2.41   0.016    -.1998787   -.0204975
      np_pen |   .1340591   .0538472     2.49   0.013     .0285205    .2395977
         mnp |  -.1055297   .0492118    -2.14   0.032    -.2019831   -.0090763
    _Itime_2 |  (dropped).    .    .       .     .     .       . .
       _cons |   .1213362   .0370553     3.27   0.001     .0487091    .1939633
-------------+----------------------------------------------------------------
     sigma_u |  .05074291
     sigma_e |  .01818947
         rho |  .88613523   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F  test that all u_i=0:     F(10,95) =     7.20          Prob > F    = 0.0000
------------------------------------------------------------------------------
Instrumented:   pij np_pij
Instruments:    lshareij np_lshareij growth np_growth pen np_pen mnp _Itime_2
_Itime_4 _Itime_5 _Itime_6 _Itime_7 _Itime_8 _Itime_9 _Itime_10 _Itime_11
_Itime_12 _Itime_13 _Itime_14 _Itime_15 _Itime_16 _Itime_17 _Itime_18 _Itime_19
_Itime_20 _Itime_21  _Itime_22 _Itime_23 _Itime_24 L.pij L.np_pij L.growth L.pen
```

```
. hausman fixed random
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random        Difference          S.E.
-------------+----------------------------------------------------------------
         pij |   -.3402591     .0258646       -.3661237        .1858187
      np_pij |    .6360379    -.0050613        .6410992        .1850994
    lshareij |    .7659033     .9767099       -.2108066        .0518851
 np_lshareij |    .1234471    -.0081314        .1315785        .0782762
      growth |    .3332181     .1581609        .1750573               .
   np_growth |   -.2719312    -.1782609       -.0936703               .
         pen |   -.1101881     .0355442       -.1457323        .0393562
      np_pen |    .1340591    -.0169221        .1509812         .039682
         mnp |   -.1055297     .0131538       -.1186835        .0379693
    _Itime_4 |   .     .     .     .     .     .     .     . ..
    ------------------------------------------------------------------------------
chi2(30) = (b-B)'[(V_b-V_B)^(-1)](b-B)=   89.83
                      Prob>chi2 = 0.0000
```

Model [5]

```
. xtabond shareij l.np_shareij  growth np_growth pen np_pen mnp _Itime_2-
_Itime_24, lags(1) robust small  pre(pij, lags(0,1)) pre(np_pij, lags(0,1))
Arellano-Bond dynamic panel-data estimation     Number of obs      =       131
Group variable (i): country                     Number of groups   =        10
                                                F(9, 100)          =   8162.18
Time variable (t): time                         Obs per group: min =         4
                                                               avg =      13.1
                                                               max =        22
One-step results
------------------------------------------------------------------------------
             |               Robust
D.shareij    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
shareij   LD |   .8396867   .0676623    12.41   0.000     .7054465    .9739268
pij       D1 |  -.0625794   .1057979    -0.59   0.556    -.2724795    .1473206
np_pij    D1 |   .1927261   .1282476     1.50   0.136    -.0617135    .4471656
np_shareij   |
          LD |  -.0656957   .0275772    -2.38   0.019    -.1204081   -.0109834
growth    D1 |   .3077421   .0394939     7.79   0.000     .2293874    .3860969
np_growth D1 |  -.1678088   .1698341    -0.99   0.326    -.5047549    .1691372
pen       D1 |  -.1295962   .0446919    -2.90   0.005    -.2182637   -.0409287
np_pen    D1 |   .0447205   .0359981     1.24   0.217    -.0266988    .1161398
mnp       D1 |  -.0205487   .0338833    -0.61   0.546    -.0877721    .0466748
_Itime_3  D1 |  -.0014994   .0015755    -0.95   0.344    -.0046252    .0016263
_Itime_5  D1 |   .0107548    .009359     1.15   0.253    -.0078133    .0293228
_Itime_6  D1 |  -.0145311   .0137504    -1.06   0.293    -.0418114    .0127493
_Itime_7  D1 |   .0107986   .0083427     1.29   0.199    -.0057531    .0273503
_Itime_8  D1 |   .0008364   .0076433     0.11   0.913    -.0143278    .0160005
_Itime_9  D1 |   .0316822   .0156827     2.02   0.046     .0005683    .0627962
_Itime_10 D1 |   .0253362    .008145     3.11   0.002     .0091768    .0414957
_Itime_11 D1 |   .0246859   .0092652     2.66   0.009      .006304    .0430678
_Itime_12 D1 |   .0270643   .0099194     2.73   0.008     .0073846     .046744
_Itime_13 D1 |   .0291184    .009547     3.05   0.003     .0101775    .0480594
_Itime_14 D1 |   .0370308   .0124183     2.98   0.004     .0123932    .0616685
_Itime_15 D1 |   .0452663   .0136029     3.33   0.001     .0182785    .0722542
_Itime_16 D1 |   .0545365   .0132764     4.11   0.000     .0281966    .0808765
_Itime_17 D1 |   .0570643   .0191025     2.99   0.004     .0191654    .0949631
_Itime_18 D1 |   .0522475   .0185597     2.82   0.006     .0154257    .0890694
_Itime_19 D1 |     .05266   .0171178     3.08   0.003     .0186987    .0866212
_Itime_20 D1 |   .0601501   .0176119     3.42   0.001     .0252086    .0950915
_Itime_21 D1 |   .0615704   .0193101     3.19   0.002     .0232597    .0998811
_Itime_22 D1 |   .0640012   .0202767     3.16   0.002     .0237729    .1042296
_Itime_23 D1 |    .071407   .0241944     2.95   0.004      .023406     .119408
_Itime_24 D1 |   .0661107   .0232764     2.84   0.005      .019931    .1122904
_cons        |  -.0022741   .0020309    -1.12   0.266    -.0063033    .0017552
------------------------------------------------------------------------------
Arellano-Bond test that average autocovariance in residuals of order 1 is 0:
         H0: no autocorrelation   z =  -1.76   Pr > z = 0.0785
Arellano-Bond test that average autocovariance in residuals of order 2 is 0:
         H0: no autocorrelation   z =  -0.96   Pr > z = 0.3352
```