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**Conference Paper**

# Estimating call externalities in mobile telephony

27th European Regional Conference of the International Telecommunications Society (ITS): "The Evolution of the North-South Telecommunications Divide: The Role for Europe", Cambridge, United Kingdom, 7th-9th September, 2016

**Provided in Cooperation with:**

International Telecommunications Society (ITS)

*Suggested Citation:* Czajkowski, Mikołaj; Sobolewski, Maciej (2016) : Estimating call externalities in mobile telephony, 27th European Regional Conference of the International Telecommunications Society (ITS): "The Evolution of the North-South Telecommunications Divide: The Role for Europe", Cambridge, United Kingdom, 7th-9th September, 2016, International Telecommunications Society (ITS), Calgary

This Version is available at:
https://hdl.handle.net/10419/148706

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# Estimating call externalities in mobile telephony

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*CONFERENCE PAPER. VERSION 01/09/2016*

## ABSTRACT

Recent theoretical models of network competition with call externalities demonstrate strategic incentives of incumbent providers to reduce receiver benefits in rival network by excessive off-net pricing. Such anti-competitive pricing practices have a potentially damaging impact on financial standing of a late entrant, leading to non-convergence of long-run market shares – an outcome that has been observed in many European mobile markets. The theoretical reasoning behind call externalities assumes that receiving calls contribute to consumer utility hence, receiver benefits drive subscription choices. So far no attempts have been made to test this critical assumption in a rigorous manner. We use data elicited from prepaid and postpaid users of mobile telephony in Poland in a discrete choice experiment designed specifically to model subscription choices when operators set termination-based discriminatory tariffs under calling party pays regime. Receiver benefits are controlled with an incoming price – a variable informing about the cost of off-net calls paid by subscribers originating a call from other networks. The model also accounts for switching costs and network effects. We find that call externalities are significant driver of subscription choices, albeit their influence has smaller magnitude than direct price effects. Next, we assess the impact of excessive off-net pricing on the structure of market shares of mobile operators in Poland and estimate customer base stealing effect encountered by the late entrant. Our empirical findings support a widespread view that call externalities might have indeed limited market competition and late entrants' growth in many European countries.

## HIGHLIGHTS

- Call externalities and personal network effects in the mobile telephony market are jointly examined
- A discrete choice experiment is applied to model individuals' decisions on two representative samples of prepaid and postpaid users of mobile telephony in Poland
- The impact of call externalities on market shares is assessed for two scenarios – assuming reduced asymmetry and full symmetry in off-net prices between incumbent networks and late entrant

## KEYWORDS

Call externalities, personal network effects, switching costs, mobile telephony, stated preference, discrete choice experiment, random parameters logit model

## JEL CLASSIFICATION

L1; L86; O3

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# 1. INTRODUCTION

Economic externalities play a significant role in network industries. As network services generate various types of benefits to their users, service providers can increase profits and improve competitive position by trying to maintain at least partial control over the way external benefits are internalized. In mobile telephony, the two primary sources of economic externalities are call and network benefits. Call externalities arise because telecommunication services generate two-sided benefits. For example, when a voice connection is established, not only the calling party but also receiving party derive some positive utility. Under the calling-party-pays (CPP) regime, receiver benefits turn into a positive economic externality.

Network externalities, on the other hand, arise as a benefit generated by the network for its users. While network benefits make take many forms, in mobile telephony they arise mainly as savings from cheaper on-net calls.[4] Pricing strategies based on discriminatory tariffs are a good example of how operators maintain control over both types of external benefits, to improve profitability and defend market share. A combination of low on-net rate and high off-net rate serves as a strategy to maximize the amount of network benefits available to own consumers while minimizing receiver benefits available to current or potential clients of rival firms.

Network effects have attracted the attention of researchers for almost three decades. There is a large body of theoretical literature and empirical evidence documenting their impact on consumer behavior and competition between providers in various network industries, including mobile telephony. On the other hand, call externalities which belong to a narrower context of telecommunication industry entered economic research agenda much later. The interest in call externalities has been inspired by the wave of entry which took place in several European countries as a result of 3G licensing in 2001-2002. Since then some theoretical studies suggested that call externalities can be strategically used to maintain competitive advantage of incumbents over smaller networks by reducing the number of incoming calls and hence lowering attractiveness of the latter in eyes of current and future subscribers (Jeon, Laffont, & Tirole, 2004). This intriguing possibility requires that receiver benefits have a significant contribution to consumer utility and thus can drive subscription choices. So far no attempts have been made to test this critical assumption empirically. To the best of our knowledge, Harbord and Pagnozzi (2010) is the only study which uses industry level data on price differentials and traffic imbalances from several European mobile markets to speculate that incumbent networks have strategically used call externalities to restrict growth and weaken competitive position of late entrants. Thus, at present, we have intriguing predictions from the well-elaborated theory of call externalities but still miss empirical evidence documenting its practical relevance.

Our study aims to fill this gap by estimating the effect of call externalities on utility from subscription. To achieve this goal, we apply a discrete choice experiment (DCE) designed specifically to model subscription choices on large representative samples of prepaid and postpaid mobile phone users in Poland. There have been no previous attempts to identify and measure the strength of receiver benefits in particular mobile market and thus little is known about the actual contribution of this effect to utility derived from subscription by individual users. Our study offers a clear value added by quantifying and valuing this effect.

[4] Besides pecuniary nature, network effects in mobile telecommunications are localized in the sense that positive contribution to subscriber utility function comes mainly from the frequently called parties such as family and friends.

We introduce a model of subscriber choice which controls for a price of off-net calls paid by other users while originating calls to a chosen network. We control for call externalities with incoming price because it directly impacts call volumes originating in other networks to a particular subscriber. Our econometric framework utilizes a dataset collected in a large-scale DCE survey, where we could conveniently include other important choice parameters such as termination-based discriminatory tariffs, personal network effects and brand loyalty, and ensure their sufficient variability.[5] This adds reliability to our results and enables us to test for counterfactual scenarios of practical relevance to operators and regulatory authorities in Poland but also in other European countries like France or UK, where the discussion about the anti-competitive impact of call externalities has been lively. In the policy exercise for the Polish mobile market, we show would be the market share of a late entrant under two hypothetical scenarios assuming reduced asymmetry and full symmetry in off-net prices between large and small networks. The latter variant is implied by symmetric termination rates – a solution advocated as a more useful instrument for entry assistance policy than adopted asymmetric regulation.

The remainder of the paper is organized as follows. In the next section, we review relevant literature devoted to call externalities. In section 3, we present the design of our study and characterize data samples collected for modelling call externalities. Section 4 provides a description of the econometric framework, model specifications and estimation results. Section 5 reports simulation results and discusses policy implications related to the impact of alternative levels of off-net price asymmetry for market share changes. The last section offers discussion and conclusions.

## 2. LITERATURE REVIEW

Large part of early literature tend to ignore the existence of call externalities. However Hermalin and Katz (2004) point that omitting receiver benefits is unrealistic because it implies that the receiving party would be generally reluctant to answer (and pay for) incoming calls. The non-existence assumption is also clearly contradicted by the smooth operation of receiving party pays (RPP) regime in a number of countries, including the US and Canada. Of course receiver benefits are not uniform and for unwanted calls, for example from telemarketing companies, might be even negative (Littlechild, 2006).

Call externalities have been studied in economics for over a decade as a component of two important theoretical problems: network competition under discriminatory tariffs and optimal interconnection regime. In what follows, we focus mainly on the first stream of literature, which motivates our study. With regards to the interconnection issue the main conclusion from the literature is that the optimal network utilization requires that both sender and the receiver share the cost of a call. However, given non-homogeneity of benefits, optimal pricing scheme is not implementable in practice (DeGraba, 2003; Hermalin & Katz, 2006).

Receiver benefits were introduced in the analysis of competition between interconnected networks by Jeon et al. (2004). They showed in a duopoly setting that equilibrium on-net prices decrease and off-net prices increase with the magnitude of call externalities. As a consequence of excessive on-net/off-net price differential, a network reduces receiver benefits of rival networks' users by limiting the level of off-net traffic and, while increasing network externalities available to their own subscribers.

[5] Revealed behavioral data (assuming we had access to it) exhibit lower variability in explanatory variables and suffers from co-linearity, resulting in larger standard errors of the estimates and a risk of biased results (Louviere, Hensher, & Swait, 2006).

Importantly, off-net/on-net price differentials grow with the market share, indicating that strategic motives rise with network size.[6]

Armstrong and Wright (2009) extended the model of Jeon et al. (2004) to represent oligopolistic mobile market with interconnected single fixed network. They showed that equilibrium mobile off-net price increases with both the strength of receiver benefits and a level of access charge but decreases with the number of mobile competitors. Call externalities in their model have also an impact on the socially optimal levels of fixed-to-mobile and mobile-to-mobile termination fees, pushing them below marginal termination costs. However, large incumbent firms will prefer higher access charges if threatened by an entry. Armstrong and Write explicitly point that incumbent networks have greater incentive to overprice off-net calls to deter or limit the entry.

Hoernig (2007) analyzed the impact of call externalities on duopoly competition between asymmetrically-sized networks with two-part tariffs and regulated access charge. He found that while both networks fully internalize receiver utility of own subscribers and set equal below-cost on-net prices, the larger (incumbent) network will strategically set higher off-net price than a smaller network. This pricing structure harms smaller competitor not only through reduced receiver benefits but also through creation of interconnection deficit which may even push new entrant off the market. Calzada and Valletti (2008) analyzed predatory behavior of incumbent networks in the presence of call externalities and negotiated access charges. They showed that incumbents prefer to set high access charges to lower ex-post profitability of new entrant. High off-net prices implied by an access charges act in favor of incumbents in the presence of call externalities and network effects, making it less attractive for incumbents' subscribers to switch to a new entrant.[7]

Harbord and Pagnozzi (2010) reviewed several theoretical studies which focus on strategic effects of call externalities on network competition. Based on the insights from theoretical literature they provide some evidence for selected countries suggesting that call externalities indeed induced excessive off-net/on-net price differentials in many European markets. Their reasoning is based on (i) comparisons between off-net / on-net price differentials with mobile termination rates; (ii) calling-patterns; and (iii) implicit traffic imbalances. In the authors' opinion, all three measures point to a likely existence of call externalities, but are too noisy for rigorous identification.

In summary, two main conclusions follow from theoretical literature on call externalities. Firstly, in equilibrium on-net / off-net price difference is higher in markets with call externalities than in otherwise identical markets without receiver benefits. Secondly, a larger network will set higher off-net price than the smaller network to strategically utilize call externalities against smaller competitors. The latter conclusion has been demonstrated under reciprocal access charges. In the case of asymmetric access fees established to assist entry in many countries – call externalities is a source of an excessive off-net price differential between large and small operators. Below, we document with historical pricing data excessive off-net price asymmetry in Poland which can be attributable to call externalities.

## 2.1. Evidence for Poland

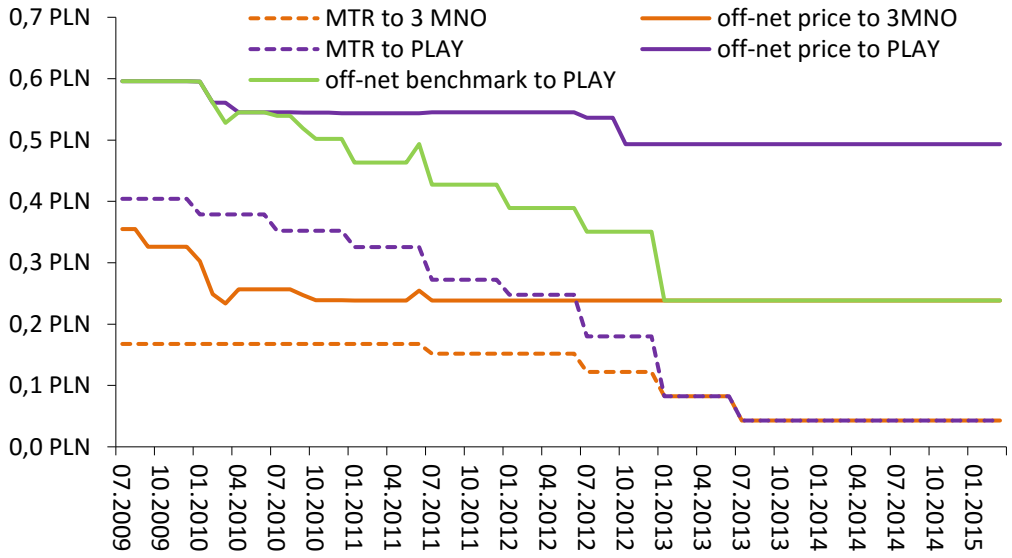
According to the theoretical considerations, call externalities can be strategically used by incumbent operators to weaken competitive position of a late entrant. Thus, we should observe excessive price

[6] In addition, Cambini and Valletti (2008) show that networks have reduced incentives to use off-net price discrimination to induce a connectivity breakdown when calls originated and received are complements.

[7] Two other studies extending the analysis of the possibility of market foreclosure or increasing the incumbents' dominance in the presence of tariff-mediated network effects when access charge is set above marginal cost are Cabral (2011); and López and Rey (2012).

asymmetry between off-net calls terminated in entrant's network and off-net calls terminated by incumbents. Because the majority of European markets, including Poland, experienced a period of asymmetric regulation of mobile termination rates post entry[8], a proper measure of 'excessive' difference needs to accommodate for this asymmetry. Following the above remarks, we measure the degree of excessive incumbent pricing, with a simple benchmark based on a common markup rule. Benchmark off-net prices of incumbents for calls terminated in entrant's network are set according to the same percentage markup (over higher termination rate for new entrant) as off-net prices for calls terminated in other incumbent networks (over lower termination rate in those networks).

Figure 1. Marginal prices of off-net calls to Play versus common markup benchmark (postpaid)




source: Market monitoring provided by Audytel S.A.

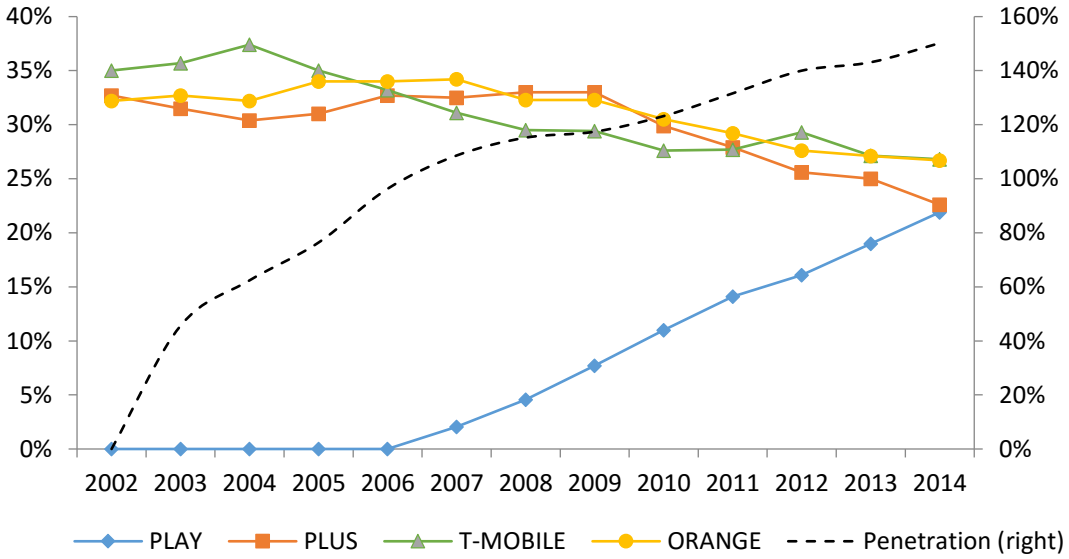
Historical data for Poland indicates that prices of off-net calls originated from incumbent networks (Orange, Plus, T-Mobile) were indeed excessive in comparison to the benchmark levels (see Fig.1).[9] Excessive off-net calls asymmetry between incumbent networks and P4 (Play) started in April 2010 and continued beyond the period of asymmetric termination rates. In 2007, national regulatory authority (UKE) introduced asymmetric termination rates to support new entrant and announced a scheme for gradual reduction of asymmetry. Two years later, incumbent MNOs started to mark out higher off-net prices to Play in their price lists but during first few months the level of asymmetry in prices of off-net calls was consistent with asymmetry of termination rates. Later on, however, incumbents kept their prices unchanged despite gradual reductions in MTR to Play. As a result since April 2010, actual off-net prices markup of incumbent operators over MTR to Play was higher than the markup over MTR for off-net calls to other operators. According to the benchmark, prices for off-net calls to Play set by incumbents (green line) should have been on average 29% lower throughout the period 04.2010-03.2015 compared to the actual levels in that period (violet line). Interestingly large off-net price differences continued to exist, even after introducing full symmetry of MTR in 2013, disclosing strategic motives of incumbent operators. As suggested by the theoretical literature, in the presence of call externalities,

[8] This was an entry-assistance policy introduced to correct for large traffic imbalances between networks.

[9] In a nutshell, Polish mobile telephony market consist of three incumbent infrastructural operators: PTK Centertel (Orange), PTC (T-Mobile) and Polkomtel (Plus) operating since 1996. In 2007, the fourth operator P4 (Play) entered the market with UMTS license and internal roaming agreement for 2G services. Currently, four main operators jointly have 98% market share pointing to a negligible role of virtual operators.

excessive off-net pricing has a negative impact on a market share of a new entrant. Fig. 2 shows the evolution of market shares in the Polish mobile market. What strikes about these data, is that P4 maintained significantly lower market share than incumbent operators throughout eight years of post-entry competition.[10] In section 5 we assess how market shares would change if incumbent operators set off-net prices to Play in accordance with a common markup benchmark.

*Figure 2. Penetration and MNO market shares in mobile telephony market in Poland.*




source: Authors own, based on data from annual reviews of telecommunication market in Poland provided by Office of Communications (UKE).

# 3. Empirical Study

## 3.1. Development of the stated preference survey

To understand consumers' demand for mobile plans in markets with call and network externalities, switching costs and termination-based price discrimination, we designed a discrete choice experiment study. These data are usually collected in the form of a survey that is administered to a sample representing certain population. In our case we have worked with two samples, each drawn from different population of individual, private users of mobile services. One sample represented subscribers with postpaid contracts and another one represented users having prepaid service. Because we excluded from our analysis those subscribers who use exclusively or predominantly mobile services paid by employer, our samples are not representative for the whole prepaid and postpaid segments as defined by mobile operators.

The questionnaire typically starts with some general introductory questions and collects status-quo information – in our case, questions referred to the current use of a mobile phone. Next, it introduces a

[10] In the explanatory note to its regulatory recommendation, EC states that the period of catching-up is expected to be four years (European Commission (2009)). Of course, call externalities are certainly just one of the factors explaining why advantage of incumbents is so persistent in mobile telephony. Other important factors include switching costs and network effects which induce consumer lock-in, see for example (Czajkowski & Sobolewski, forthcoming)

hypothetical scenario and the choices that are about to follow; at this point, the choice alternatives, attributes, and their levels are described. The respondent is then asked to review the choice situations and select the alternative that he or she prefers from among those presented. In the last part of the questionnaire, the respondent's socio-demographic characteristics are collected.

Our study aimed at investigating factors that influence the choice of a mobile phone plan. Therefore, we presented each respondent with a choice of four new mobile phone plans, each hypothetically provided by one of the four major providers operating in Poland. The choices were hypothetical, so we requested that respondents disregard any penalty fees that can apply when they prematurely terminate their current agreement.

Each of the new mobile phone plans was described with a set of attributes that we selected through a process of thorough qualitative pre-testing. The pre-testing phase took two steps. During first step we have identified major drivers of subscription choices, based on discussions within several focus groups composed of actual prepaid and postpaid users. Next, in a series of in-depth individual interviews we have tested various substantive and technical aspects of survey questionnaire. Consequently, we are confident that choice attributes used in the experiment were indeed significant and understandable to consumers.

In choice experiments people can hardly make effective comparisons of alternatives with more than 5 or 6 attributes (Louviere et al., 2006). Because of such cognitive limitations we could not include all choice characteristics, that have been deemed important during the pre-test phase – such as for example handsets. Doing so was not particularly harmful to the results of our choice experiment, because all network operators offer the same models of handsets with similar level of subsidies. Hence, adding handset attribute would not additionally differentiate offers in any systematic way. More importantly it would not alter differences in choice probabilities between policy scenarios.

Based on the outcomes from pre-testing as well as formats used in previous studies we have finally included 6 attributes into our choice experiment design. These were as follows:

(1) A brand name of the mobile operator's network.[11]

(2 & 3) The average on-net and off-net price of a call.

(4) The average price of incoming calls from other network.

(5 & 6) The size of the 'family and friends' and 'other people' in the same network.

First attribute is nearly always present in preference studies regarding mobile services, for example: Maicas, Polo, and Javier Sese (2009), (Maicas, Polo, & Sese, 2009), Grzybowski and Pereira (2011), (Sobolewski & Czajkowski, 2012). We introduce brand effects as operating specific constants, hence we can jointly control for all systematic differences in perception of qualitative factors such as call quality, network coverage or customer service. The next two attributes (on-net and off-net prices) implement the basic structure of termination-based tariffs, under which call and network externalities become crucial drivers for customer behavior. The remaining three attributes introduce both effects to our choice model.

The fourth attribute, termed price of incoming calls from other network has been chosen to indirectly indicate the magnitude of receiver benefits. We argue that under calling party pays regime, call originating operator maintains the full control over the size of call externalities generated in his network. With his off-net pricing policy he can increase or decrease call benefits received by the subscribers of

[11] In our preliminary interviews, respondents seemed to associate various qualities with different operators (brands). For this reason, we have included the four brands of infrastructural operators on the Polish market: Orange, T-Mobile, Plus and Play.

competing networks. Therefore, price of incoming calls is an appropriate control variable for call externalities, as long as subscribers adjust their call volumes to price changes. On the other hand, our treatment of call externalities requires from a respondent to make an assessment about how particular price change affects originating party demand for calls. This is a difficult task and most likely subscribers will attribute their own demand response to assess changes in others' people aggregate traffic. Such attribution introduces potential bias in the measurement of call externalities. Alternatively, one could use traffic-based approach, which directly focuses on actual source of receiver benefits. We decided to utilize less accurate price-based approach because it is more suitable for conducting assessment exercises related to various access charge policies.

The last two attributes introduce personal and absolute network effects. The category 'family and friends' was defined as all persons with whom the respondent maintains regular contact on private grounds. 'Others' consisted of all other people whom a respondent contacts irregularly, such as shops, offices, and distant friends, or people who she or he does not contact at all but are still connected to the same network. This attribute was basically equivalent to each operator's customer base. We have differentiated between those two sources of network benefits, because according to numerous research, network effects are not homogenous across all individuals in the same network, but are localized within small subset constituting social network of a particular subscriber (Corrocher & Zirulia, 2009; Czajkowski & Sobolewski, 2011; Maicas & Sese, 2011).

The levels of the attributes, particularly on-net, off-net and incoming call prices, and the share of 'family and friends' in the same network, reflected actual market conditions. They are summarized in Table 1. Variation of attribute levels was tested in the qualitative analysis to ensure sufficient responsiveness of respondents.

*Table 1. The list of attributes and attribute levels used to describe choice alternatives.*

| | |
|---|---|
| Brand of the operator | • Orange<br>• T-Mobile<br>• Plus<br>• Play |
| On-net price (PLN per minute) | • 0.10<br>• 0.20<br>• 0.30 |
| Off-net price (PLN per minute) | • 0.20<br>• 0.30<br>• 0.50 |
| Price of call incoming from other networks, paid by person originating connection (PLN per minute) | • 0.20<br>• 0.30<br>• 0.50 |
| % of 'family and friends' in the same network | • 25%<br>• 50%<br>• 75% |
| % of 'others' in the same network | • 25%<br>• 50%<br>• 75% |

The attributes and their levels were carefully explained to respondents. They were asked to assume that the alternatives were exactly the same with respect to any characteristics that were not explicitly listed in the choice situations (e.g., the price of a text message).

In our study, each respondent was faced with 12 choice tasks, each consisting of four variants of a 'new plan' for consideration. Each alternative was described with the six attributes specified above. The combinations of attribute levels presented in each of the choice tasks (i.e., the experimental design) were

selected in a Bayesian efficient way (Ferrini & Scarpa, 2007; Scarpa & Rose, 2008), i.e., to minimize the determinant of the AVC matrix of the parameters (*D-error*) given the priors on the parameters of a representative respondent's utility function, which were derived from a pilot survey. An example of a choice card shown to respondents is given in Table 2.

*Table 2. Example of a choice card (translation).*

Which of the following mobile phone operators' offers would you consider the best for yourself?

| Operator | ORANGE | T-MOBILE | PLUS | PLAY |
|---|---|---|---|---|
| On-net price per minute (PLN) | 0.2 | 0.1 | 0.3 | 0.2 |
| Off-net price per minute (PLN) | 0.2 | 0.5 | 0.5 | 0.2 |
| Price of incoming off-net call, per minute (PLN) | 0.3 | 0.3 | 0.3 | 0.3 |
| 'Family and Friends' in the same network | 25% | 25% | 75% | 75% |
| 'Others' in the same network | 50% | 50% | 25% | 75% |
| **Your choice** | □ | □ | □ | □ |

The main survey was conducted on two random samples of mobile phone users representing individual, private prepaid and postpaid customers of mobile operators in Poland. Finally, complete data from 1,001 and 1029 individuals representing respective segments was collected. The survey had CAWI format and was administered by professional agency.[12] Because each respondent was faced with 12 choices (consisting of 5 alternatives), our data set contained respectively 12,012 and 12,348 choice observations. Both samples are representative with respect to age structure (18-65 years) and geographical spread, so our empirical findings can be generalized to the population of individual mobile phone users in Poland.

## 3.2. Characteristics of prepaid and postpaid samples

Demographic and usage profiles clearly differ between main segments of Polish telecommunication subscribers (see Table 3, panel A). Prepaid users are less educated and have smaller earnings than postpaid users. Although average age is similar, both segments exhibit the difference in age distributions. While the postpaid segment is characterized by a larger share of middle-aged users, the prepaid segment contains a larger share of individuals from the youngest (below 22) and the oldest (above 55) age groups. The difference of usage profiles is also substantial. Prepaid users generate much smaller traffic than postpaid customers and hence pay lower bills per month. Almost 50% of prepaid users still use tariff plans with limited calls. In postpaid segment, such plans are already withdrawn and postpaid users have at least partially unlimited plans with free on-net calls. As much as 60% of postpaid

[12] IPSOS Poland. Response rate in the survey was 29%.

subscribers already use lump sum plans with fully unlimited on-net and off-net calls. These results imply that discriminatory tariffs become rapidly obsolete after the introduction of symmetric, close to zero termination charges. The prepaid segment groups twice as many people who mainly receive connections, as is suggested by lower share of calls to family and friends in total outgoing traffic which might be an indication of their greater sensitivity to call externalities. Both segments have similar exposition to network effects. The median share of connections to family and friends in total time of outgoing calls is above 70% in both groups, while an average size of the social network is only slightly smaller in the prepaid segment (7.8 vs 9.2 persons).

*Table 3. Descriptive statistics of prepaid and postpaid samples.*

| **A. Demographics** (*) | | | | | |
|---|---|---|---|---|---|
| *age distribution [years]* | 18-22 years | 23-35 | 36-55 | 56-65 | Mean |
| *postpaid N=1029* | 6% | 36% | 47% | 12% | 39,3 |
| *prepaid N=1001* | 13% | 32% | 41% | 14% | 28,2 |
| *sex* | women | men | | | |
| *postpaid N=1029* | 50% | 51% | | | |
| *prepaid N=1001* | 53% | 47% | | | |
| *education* | primary | vocational | secondary | higher | |
| *postpaid N=1029* | 1% | 7% | 43% | 49% | |
| *prepaid N=1001* | 2% | 10% | 48% | 41% | |
| *income distribution [PLN]* | 0-2000 | 2001-3000 | 3001-4000 | above 4000 | no answer |
| *postpaid N=1029* | 32% | 29% | 15% | 12,1% | 12% |
| *prepaid N=1001* | 50% | 21% | 8% | 7,3% | 14% |
| **B. User profile** (*) | | | | | |
| *operator* | ORANGE | PLAY | PLUS | T-MOBILE | Other |
| *postpaid N=1029* | 30% | 28% | 21% | 20% | 1% |
| *prepaid N=1001* | 35% | 27% | 19% | 16% | 4% |
| *daily duration of outgoing calls [min]* | 0-20 min | 20-40 | 40-60 | above 60 | Mean |
| *postpaid N=1029* | 44% | 22% | 18% | 16% | 43,4 |
| *prepaid N=1001* | 64% | 18% | 10% | 9% | 27,3 |
| *type of tariff plan* | unlimited off-net & on-net | limited off-net, unlimited on-net | limited off-net & on-net | don't know | |
| *postpaid N=1029* | 60% | 36% | 0% | 5% | |
| *prepaid N=1001* | 17% | 29% | 49% | 6% | |
| *average monthly expenditure [PLN]* | 0-20 PLN | 20-40 | 40-60 | above 60 | Mean |
| *postpaid N=1029* | 8% | 25% | 33% | 34% | 63,5 |
| *prepaid N=1001* | 40% | 45% | 11% | 4% | 29,1 |
| *number of operator changes* | 0 | 1 | 2 | more than 2 | Mean |
| *postpaid N=1029* | 39% | 38% | 16% | 8% | 1% |
| *prepaid N=1001* | 46% | 30% | 15% | 8% | 1% |
| *size of F&F group [persons]* (**) | 1-3 pers. | 4-5 | 6-10 | 11-15 | above 15 |
| *postpaid N=1029* | 12% | 24% | 38% | 10% | 16% |
| *prepaid N=1001* | 20% | 29% | 34% | 8% | 10% |
| *share of calls to F&F in total outgoing traffic [%]* | 0-20% | 21-40 | 41-60 | 61-80 | above 80 |
| *postpaid N=1029* | 4% | 12% | 22% | 41% | 22% |
| *prepaid N=1001* | 8% | 13% | 18% | 34% | 27% |

(*) All differences in means and proportions between prepaid and postpaid samples are significant at 1% level.
(**) F&F – family and friends.

In summary, prepaid service is better adjusted to the needs of youngest respondents as well as older people who originate fewer connections but receive more calls. On the other hand, postpaid subscribers are more intensive users. They maintain regular contacts with a larger group of family and friends and originate more calls to people outside their social network. With respect to demographics, postpaid users are on average better educated and have higher earnings from a professional activity. Observed differences in demographic and usage profiles of prepaid and postpaid customers are consistent with

general knowledge following from marketing segmentations and suggest that our samples correctly represent the whole population. In what follows, we model preferences in both groups and see how they differ with respect to specific components of mobile services.

# 4. RESULTS

In this section, we use the discrete choice experiment data to formally model respondents' utility functions, i.e., to quantify the extent to which each attribute influences choices of prepaid and postpaid subscribers. In addition, given estimated choice models, we conduct a scenario analysis to evaluate how subscribers from both segments would change their choices in response to alternative levels of asymmetry in prices of incoming calls. In this way, we can assess the impact of call externalities on market shares of mobile operators.

## 4.1. ECONOMETRIC MODEL

Formally, discrete choice modeling is based on the random utility model (McFadden, 1974). In this framework, the utility function of consumer $i$ from alternative $j$ can be expressed as:

$$U_{ij} = \boldsymbol{\beta}' \mathbf{x}_{ij} + \varepsilon_{ij}, \tag{1}$$

where $\boldsymbol{\beta}$ is the vector of utility parameters, $\boldsymbol{x}$ is the vector of observed attributes specific to the consumer and the alternative $j$, and $\varepsilon$ is the random component, representing the joint influence of all unobserved factors that influence decision-making (Manski, 1977). By assuming that the random component has extreme value type I distribution, the multinomial logit (MNL) model is obtained which has a familiar, closed-form expression for the choice probabilities of each alternative. In this study, we apply a mixed logit extension in order to take the respondents' preference heterogeneity into account. This approach has been successfully applied to telecommunications (Czajkowski & Sobolewski, forthcoming). MXL model treats that consumer $i$ has specified, albeit non-observable, parameters of the utility function which follow a priori specified distributions in a population $\boldsymbol{\beta}_i \sim f(\boldsymbol{b}, \boldsymbol{\Sigma})$, where $\boldsymbol{b}$ is the vector of the mean values of parameters and $\boldsymbol{\Sigma}$ is their variance-covariance matrix. By assuming a structured variation of individual tastes in the sample, in the form of individual-based parameters, the MXL model is more realistic and typically yields a much better fit to the data (Greene & Hensher, 2007). This comes at the cost of a more complicated estimation procedure. In a discrete choice experiment, $P_{ijt}$ – the unconditional mixed logit probability of choosing alternative $j$ in situation $t$ by consumer $i$ - is an integral of standard logit probabilities over a density individual utility parameters (Train, 2009). Since mixed logit probabilities involve integrals which do not have closed forms, unconditional probabilities must be simulated by taking multiple random draws from respective joint distribution and averaging. Next, the sequence of choices made by each person during the experiment leads to the following log-likelihood function from which estimators of $\boldsymbol{b}, \boldsymbol{\Sigma}$ can be obtained numerically:

$$\log L = \sum_{i=1}^{N} \ln \left( \int_{\boldsymbol{\beta}} \prod_{t=1}^{T} P_{ijt}(\boldsymbol{\beta}) \, f\left(\boldsymbol{\beta} \middle| \mathbf{b}, \boldsymbol{\Sigma}\right) d\boldsymbol{\beta} \right) \tag{2}$$

One of the extensions of MXL allows to capture the impact of choice invariant characteristics on utility. This is achieved by letting the distributions of random parameters to be heterogeneous with observed respondent characteristics $(\boldsymbol{z}_i)$. Formally, $\boldsymbol{\beta}_i \sim f(\mathbf{b} + \boldsymbol{\Delta}\mathbf{z}_i, \boldsymbol{\Sigma} + \boldsymbol{\Gamma}\mathbf{z}_i)$, where $\boldsymbol{\Delta}$ and $\boldsymbol{\Gamma}$ are estimable

vectors of parameters that enter heterogeneous means and variances of random parameters (Greene, 2011).

## 4.2. Estimation Results

The final dataset consisted of 12,012 and 12,348 choice observations made by respectively 1001 prepaid and 1029 postpaid users. We used these data to estimate a series of three different models (MNL, MXL, GMXL) separately for each segment. In MXL and GMXL models we assumed that all of the preference parameters were random, following normal ad lognormal distributions. We took the following general form of the utility function of respondent *i* representing segment $s = (prepaid, postpaid)$ from choosing alternative *r*:[13]

$$U_{i,s,r} = \beta_{SQ}SQ + \beta_{ORA}ORA + \beta_{TMB}TMB + \beta_{PLU}PLU + \beta_{PLA}PLA + \beta_{P_ON}P_{ON} + \beta_{P_OFF}P_{OFF} + \beta_{P_INCOFF}P_{INCOFF} + \beta_{FF}FF + \beta_{OTH}OTH + \varepsilon_{i,s,r} \quad (2)$$

In expression (3), $\beta$ is the vector of parameters associated with respective variables and $\varepsilon_{isr}$ is random component of utility associated with the choice of alternative. The interpretation of variables in the choice model is given in Table 4.

*Table 4. Definition of variables used to model respondents' mobile operator choice.*

| Variable name and definition | Measurement | Assumed type parameter distribution |
|---|---|---|
| *SQ* – status quo inertia (switching cost variable) | Dummy: 1 = if the plan requires switching from current operator; 0 = otherwise | Lognormal |
| *ORA* – operator-specific constant for Orange | Dummy: 1 = Orange; 0 = otherwise | Normal |
| *TMB* – operator-specific constant for T-Mobile | Dummy: 1 = T-Mobile; 0 = otherwise | Normal |
| *PLU* – operator-specific constant for Plus | Dummy: 1 = Plus; 0 = otherwise | Normal |
| *PLA* – operator-specific constant for Play | Dummy: 1 = Play; 0 = otherwise | Normal |
| *P_ON* – on-net price per minute (in PLN) | Continuous | Lognormal |
| *P_OFF* – off-net price per minute (in PLN) | Continuous | Lognormal |
| *P_INCOFF* – price of incoming off-net call, per minute (PLN) | Continuous | Lognormal |
| *FF* – share of friends and family using the same operator (in %) | Continuous | Normal |
| *OTH* – share of other people using the same operator (in %) | Continuous | Normal |

Besides variables related to choice attributes, the specification of equation (3) includes SQ dummy, which directly allows us to control for switching costs arising from a reluctance of customers to change

[13] For simplicity, in right hand side of equation (x) we omit subscript *s* denoting segment in the description of parameters $\beta$.

their current operator. Such status quo inertia has been confirmed in previous research (Czajkowski & Sobolewski, forthcoming) and might occur because of brand loyalty or transaction costs.

The estimation results – coefficients of MNL as well as means and standard deviations of the preference parameters for MXL and GMXL – are reported in Tables 5 (for postpaid subscribers) and 6 (prepaid users) [14] [15]. The parameters describe the relative importance (utility) associated with the attribute levels that were used in the DCE. Their absolute values do not have an interpretation, but their sign, relative values, and statistical significance can be used to illustrate the characteristics of which the respondents from both segments paid the greatest attention. Parameters from different models maintain the same order and magnitude which points to the robustness of our results to different assumptions regarding functional form of the discrete choice model. In what follows, we refer to the results of XML because it has superior fit properties in comparison to other models, as indicated by log-likelihood and $R^2$ statistics.

*Table 5. Estimates of utility function parameters for postpaid subscribers.*

| | **MNL** | **MXL_d** | | **GMXL_d** | | **MXL** | |
|---|---|---|---|---|---|---|---|
| | **coefficient (s.e.)** | **Mean (s.e.)** | **St. Dev. (s.e.)** | **Mean (s.e.)** | **St. Dev. (s.e.)** | **Mean (s.e.)** | **St. Dev. (s.e.)** |
| SQ operator (SQ) | 1,3207*** (0,0204) | 0,1088 (0,0904) | 1,8844*** (0,1284) | 0,2518*** (0,0927) | 1,9215*** (0,1420) | 0,2149*** (0,0838) | 1,5661*** (0,1065) |
| Orange vs. Play | -0,2996*** (0,0279) | -0,5445*** (0,0639) | 1,0605*** (0,0700) | -0,6113*** (0,0738) | 1,1878*** (0,0816) | -0,2746*** (0,1123) | 1,5055*** (0,0891) |
| T-Mobile vs. Play | -0,2780*** (0,0285) | -0,6572*** (0,0630) | 1,0558*** (0,0671) | -0,7591*** (0,0738) | 1,1840*** (0,0763) | -0,4320*** (0,1107) | 1,5203*** (0,0897) |
| Plus vs. Play | -0,2303*** (0,0281) | -0,5328*** (0,0602) | 0,9819*** (0,0691) | -0,6288*** (0,0708) | 1,0889*** (0,0815) | -0,2592*** (0,1085) | 1,4262*** (0,0865) |
| On-net price (P_ON) | 6,6729*** (0,1481) | 2,2407*** (0,0436) | 0,8637*** (0,0411) | 2,4322*** (0,0478) | 0,7994*** (0,0417) | 2,1814*** (0,0577) | 1,1412*** (0,0540) |
| Off-net price (P_OFF) | 4,8642*** (0,1468) | 1,8512*** (0,0574) | 0,9957*** (0,0596) | 2,0678*** (0,0583) | 0,8980*** (0,0485) | 1,5915*** (0,0832) | 1,4283*** (0,0675) |
| Incoming off-net price (P_INCOFF) | 1,6027*** (0,1400) | 0,6950*** (0,1212) | 0,8834*** (0,0955) | 0,9709*** (0,1113) | 0,7920*** (0,0856) | 0,5138*** (0,1691) | 1,4786*** (0,1071) |
| Family & Friends (FF) | 0,4470*** (0,0544) | 1,0536*** (0,1546) | 3,7206*** (0,1590) | 1,2365*** (0,1826) | 4,2326*** (0,2003) | 0,9718*** (0,2023) | 4,1352*** (0,1993) |
| Others (OTH) | -0,0844 (0,0526) | -0,1489 (0,1077) | 2,0590*** (0,1253) | -0,1712 (0,1254) | 2,3391*** (0,1506) | -0,0091 (0,1476) | 2,2718*** (0,1506) |
| Tau | | | | 3.1675*** (0.2708) | | | |
| **Model characteristics** | | | | | | | |
| Log-likelihood (constants) | -17011,1598 | -17011,1598 | | -17011,1598 | | -17011,1598 | |
| Log-likelihood | -13449,5980 | -10487,7399 | | -10459,2453 | | -10082,3011 | |
| McFadden Pseuro-$R^2$ | 0,2094 | 0,3835 | | 0,3852 | | 0,4073 | |
| Ben-Akiva Lerman Pseuro-$R^2$ | 0,3541 | 0,4694 | | 0,4701 | | 0,4830 | |
| AIC/n | 2,1799 | 1,7016 | | 1,6972 | | 1,6418 | |
| *n* (# observations) | 12348 | 12348 | | 12348 | | 12348 | |
| *k* (# parameters) | 9 | 18 | | 19 | | 54 | |

[14] The model was estimated using custom code in Matlab. Software codes are available online at czaj.org.

[15] In case of lognormally distributed preference parameters, we provide parameters of underlying normal distribution. Log-price coefficients for means have reverse signs.

Source: Own calculations. ***, **, * Significance at 1%, 5%, 10% level

The results for the postpaid segment can be interpreted in the following way. Negative coefficients for binary variables denoting ORANGE, T-Mobile and PLUS indicate that new entrant is on average the most preferred operator (PLAY was set as a baseline level). Other things equal, brand effects represent systematic differences in perception of soft prerequisites such as call quality, customer service or brand image. Independently of brand effects, we explicitly account for customer inertia with status quo variable. On average, subscribers have positive attitudes towards the currently subscribed operator, which points to the existence of switching costs, despite the availability of quick and costless portability procedure. Observed switching costs represent non-pecuniary barriers such as loyalty, transaction or learning costs. We note that status quo inertia has considerably larger magnitude than brand effects[16], which indicates that subscribers will decide to remain with their current (incumbent) operator even though they perceive his brand as inferior. Status quo inertia implies that with limited space for price cuts, branding will not be an effective tool for attracting rivals' subscribers.

As expected, all three (minus) price coefficients are significant and negative, indicating lower utility from more expensive mobile plans. The price of on-net calls is the most important factor for customers, which is not surprising given that people tend to group in the same network and make the dominant share of calls to their friends and family. The price of incoming calls - paid by other subscribers for calling a respondent in a chosen network- has third highest impact on utility in our choice model. This result confirms the sensitivity of subscribers to the receiver benefits and opens the floor for considerations about the impact of call externalities on operator choice and competition between operators. Like in other studies (Czajkowski & Sobolewski, forthcoming; Maicas, Polo, & Sese, 2009; Sobolewski & Czajkowski, 2012), network effects also drive customer choices but are limited to members of family and friends on the same network. The impact of local network externalities on subscribers' behavior is much smaller than the price effects and also a little bit weaker than switching costs.

*Table 6. Estimates of utility function parameters for prepaid users.*

| | MNL | MXL_d | | GMXL_d | | MXL | |
|---|---|---|---|---|---|---|---|
| | coefficient (s.e.) | Mean (s.e.) | St. Dev. (s.e.) | Mean (s.e.) | St. Dev. (s.e.) | Mean (s.e.) | St. Dev. (s.e.) |
| SQ operator (SQ) | 1,4302*** (0,0223) | 0,3116*** (0,0861) | 1,7583*** (0,0875) | 0,4802*** (0,0894) | 1,7520*** (0,1065) | 0,3206*** (0,0835) | 1,4688*** (0,1039) |
| Orange vs. Play | -0,2635*** (0,0283) | -0,4662*** (0,0723) | 1,1492*** (0,0786) | -0,5590*** (0,0848) | 1,3283*** (0,0959) | -0,3364*** (0,1174) | 1,5929*** (0,1027) |
| T-Mobile vs. Play | -0,3948*** (0,0306) | -0,7377*** (0,0718) | 1,2213*** (0,0774) | -0,8517*** (0,0847) | 1,3827*** (0,0908) | -0,5623*** (0,1171) | 1,7902*** (0,1009) |
| Plus vs. Play | -0,2403*** (0,0292) | -0,4381*** (0,0658) | 1,0623*** (0,0716) | -0,5284*** (0,0786) | 1,2042*** (0,0884) | -0,3111*** (0,1122) | 1,5633*** (0,0990) |
| On-net price (P_ON) | 7,1761*** (0,1553) | 2,3297*** (0,0497) | 1,0621*** (0,0471) | 2,5010*** (0,0542) | 1,0006*** (0,0473) | 2,1776*** (0,0667) | 1,3144*** (0,0637) |
| Off-net price (P_OFF) | 4,7900*** (0,1495) | 1,6811*** (0,0769) | 1,2580*** (0,0802) | 1,8920*** (0,0755) | 1,1783*** (0,0557) | 1,4897*** (0,0913) | 1,6918*** (0,0782) |
| Incoming off-net price (P_INCOFF) | 1,6995*** (0,1441) | 0,8746*** (0,1184) | 0,8098*** (0,1030) | 1,0975*** (0,1105) | 0,7312*** (0,0999) | 0,3645*** (0,1375) | 1,6471*** (0,0878) |
| Family & Friends (FF) | 0,4471*** (0,0552) | 0,6910*** (0,1493) | 3,3908*** (0,1541) | 0,8031*** (0,1726) | 3,8171*** (0,1879) | 0,5746*** (0,2030) | 3,8925*** (0,1906) |

[16] SQ is lognormally distributed hence, its mean equals EXP(0,2149)=1,2397 (for postpaid subscribers).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Others (OTH) | -0,2842*** (0,0551) | -0,5168*** (0,1087) | 1,7660*** (0,1333) | -0,5896*** (0,1256) | 1,9300*** (0,1569) | -0,1722 (0,1485) | 2,1344*** (0,1599) |
| Tau | | | | 3.1007*** (0.2761) | | | |
| **Model characteristics** | | | | | | | |
| Log-likelihood (constants) | -16458,0658 | -16458,0658 | | -16458,0658 | | -16458,0658 | |
| Log-likelihood | -12459,8454 | -9387,7385 | | -9366,8290 | | -9014,8818 | |
| McFadden Pseuro-$R^2$ | 0,2429 | 0,4296 | | 0,4309 | | 0,4523 | |
| Ben-Akiva Lerman Pseuro-$R^2$ | 0,3741 | 0,5021 | | 0,5028 | | 0,5171 | |
| AIC/n | 2,0761 | 1,5661 | | 1,5627 | | 1,5100 | |
| *n* (# observations) | 12012 | 12012 | | 12012 | | 12012 | |
| *k* (# parameters) | 9 | 18 | | 19 | | 54 | |

Source: Own calculations. ***, **, * Significance at 1%, 5%, 10% level

Estimates of parameters for prepaid users are largely similar to the results obtained for postpaid subscribers with one notable exception. The coefficient for others in the same network is surprisingly negative, while in the postpaid segment the share of 'others' on the same network had no impact on the utility function. The three price variables together with status quo inertia are the strongest determinants of choice, while network and brand effects have a smaller impact on the utility of prepaid users. Finally, we note that the results indicate the presence of substantial unobserved preference heterogeneity with respect to most choice characteristics. This is indicated by large and significant estimates of the standard deviations (relative to the means) associated with choice characteristics.

To provide better insight into consumers' preferences, we can express both types of externalities and switching costs in monetary terms. By calculating the marginal rate of substitution between effects in question and the on-net price we obtain willingness to pay (WTP), which serves as a meaningful measure to compare preferences of prepaid and postpaid users (see Table 7).[17] Looking at results for postpaid subscribers, an increase of 'family and friends' in the same network from 0 to 100% is equivalent to an increase of 0.06 PLN in on-net price for postpaid subscribers. On the other hand, a 0.10 PLN increase of the price of incoming calls could be outweighed by 0.02 PLN decrease in on-net price. WTP. Based on the calculation of WTP in Table 7, we conclude that both segments value network effects and switching costs in a similar manner. Non-pecuniary switching cost tends to be a prominent determinant of choice in both groups. Hence, enlarging market share and increasing customer loyalty should remain the fundamental goals of the business strategy.

[17] We calculate median willingness to pay with Krinsky and Robb simulation. We account for sampling variance by taking 10k random draws of distribution parameters. Then for each vector of model parameters we draw 10k individual utility parameters out of which we obtain entire distribution of wtp. For more details see (Hensher & Greene, 2003)

*Table 7. Willingness-to-pay for switching costs, call externalities and network effects [PLN]*

| | Expressed as an increase of the on-net price | |
|---|---|---|
| | **Prepaid Median WTP (95% c.i.)** | **Postpaid Median WTP (95% c.i.)** |
| Status quo inertia (SQ) | 0.156 (0.124;0.196) | 0.140 (0.113;0.173) |
| Incoming off-net price (P_INCOFF) | 0.163 (0.128;0.206) | 0.188 (0.134;0.262) |
| Family & Friends (FF) | 0.030 (0.008;0.056) | 0.062 (0.035;0.094) |

Source: Own calculations.

## 4.3. POLICY EXERCISE

We have shown that the magnitude of receiver benefits is indeed an important determinant of choice behavior. But what could be the implications of this result for the structure of market shares, if indeed operators engage in strategic overpricing of off-net calls to reduce receiver benefits in rival networks?

We answer this question in an impact assessment exercise for the Polish market where such strategic overpricing took place as we document in section 2.1. We show how call externalities affect the market share of each under different scenarios related to the magnitude of off-net price difference between incumbent operators and the new entrant. The analysis in this section is based on predictions of respondents subscription decisions from estimated discrete choice model for different levels of the incoming off-net price (P_INCOFF) attribute. Results of our exercise are important for regulatory authorities to justify potential mitigation actions, as well as for new entrant to evaluate damages in market shares resulting from incumbents' strategic use of call externalities.

Our baseline scenario reproduces actual market conditions in years 2010-2012, during which operators competed with discriminatory tariffs and the difference between off-net prices to P4 and the three incumbents were excessive. Actual, average off-net price asymmetry between incumbents and new entrant amounted to 254% in the postpaid segment and 244% in prepaid segment, while MTR asymmetry was only 189%. We consider two counterfactual scenarios. Scenario 1 assumes that off-net price asymmetry is equal to actual MTR asymmetry throughout the period 2010-2012. Hence, there is no excessive off-net pricing by incumbents and operator earn common markup on off-net calls in all directions. Scenario 1 requires simply recalculation of off-net prices set by incumbent operators for calls terminated in Play network. Consequently, average incoming price to Play would be reduced by 0.13 PLN in the postpaid segment and 0.15 in prepaid segment, compared to the baseline levels. Scenario 2 assumes fully uniform off-net pricing, implied by the symmetry of mobile termination rates in the period 2010-2012. Under this scenario, MTR to Play drops to 0.15 PLN and hence off-net price to Play set by incumbents is equal to the off-net rates for calls terminated in incumbent networks. We assume that all on-net prices, as well as off-net price set by Play, are unaffected in both alternative scenarios. In Table 8 we summarize all necessary data to calculate simulated changes in subscription decisions.

For the purpose of simulation we used two different measurements of network effects captured by variables: 'Family & Friends' and 'others'. The first one takes the value of both variables equal to the average market shares of corresponding operators. This approach implies that people whom respondent calls are randomly distributed between networks. This assumption is very naïve, as in the presence of termination-based price discrimination people belonging to family and friends tend to group in the same network. Hence, our second approach took the levels of 'family and friends' and 'others' reported by

respondents in the survey.[18] This measurement, while being more realistic, considerably increases the complexity of simulation due to handling empirical distributions of individual level data.

*Table 8. Scenarios for call externality impact assessment.*

| | postpaid | | | | prepaid | | | |
|---|---|---|---|---|---|---|---|---|
| **baseline: asym.** MTR=1,89; asym. OFF-NET_POST=2,44; asym. OFF-NET_PRE=2,54 | ORANGE | T-MOBILE | PLUS | PLAY | ORANGE | T-MOBILE | PLUS | PLAY |
| ON-NET price | 0,13 | 0,18 | 0,11 | 0,02 | 0,07 | 0,01 | 0,05 | 0,01 |
| OFF-NET PRICE to incumbents | 0,24 | 0,26 | 0,24 | 0,18 | 0,21 | 0,21 | 0,27 | 0,21 |
| OFF-NET PRICE to PLAY | 0,60 | 0,61 | 0,59 | - | 0,56 | 0,52 | 0,65 | - |
| INCOMING OFF-NET price (from 3 MNO) | 0,24 | 0,23 | 0,24 | 0,60 | 0,24 | 0,24 | 0,21 | 0,58 |
| MTR | 0,15 | 0,15 | 0,15 | 0,29 | 0,15 | 0,15 | 0,15 | 0,29 |
| scenario 1: asym. MTR=1,89; asym. OFF-NET_POST=1,89; asym. OFF-NET_PRE=1,89 | ORANGE | T-MOBILE | PLUS | PLAY | ORANGE | T-MOBILE | PLUS | PLAY |
| ON-NET price | 0,13 | 0,18 | 0,11 | 0,02 | 0,07 | 0,01 | 0,05 | 0,01 |
| **OFF-NET PRICE to** incumbents | 0,24 | 0,26 | 0,24 | 0,18 | 0,21 | 0,21 | 0,27 | 0,21 |
| OFF-NET PRICE to PLAY | 0,45 | 0,50 | 0,46 | - | 0,39 | 0,39 | 0,52 | - |
| INCOMING OFF-NET price (from 3 MNO) | 0,24 | 0,23 | 0,24 | 0,47 | 0,24 | 0,24 | 0,21 | 0,43 |
| MTR | 0,15 | 0,15 | 0,15 | 0,29 | 0,15 | 0,15 | 0,15 | 0,29 |
| scenario **2:** sym. MTR; sym. OFF-NET_POST; sym. OFF-NET_PRE | ORANGE | T-MOBILE | PLUS | PLAY | ORANGE | T-MOBILE | PLUS | PLAY |
| ON-NET price | 0,13 | 0,18 | 0,11 | 0,02 | 0,07 | 0,01 | 0,05 | 0,01 |
| **OFF-NET PRICE to** incumbents | 0,24 | 0,26 | 0,24 | 0,18 | 0,21 | 0,21 | 0,27 | 0,21 |
| OFF-NET PRICE to PLAY | 0,24 | 0,26 | 0,24 | - | 0,21 | 0,21 | 0,27 | - |
| INCOMING OFF-NET price (from 3 MNO) | 0,24 | 0,23 | 0,24 | 0,25 | 0,24 | 0,24 | 0,21 | 0,23 |
| MTR | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 |

Source: Data for baseline scenario is taken from market monitoring provided by Audytel SA.

Changes in market shares of four networks under the two alternative scenarios are shown in Table 9 and Table 10 respectively for the two measurements of network effects (market shares vs survey based). We again focus only on the results from preferred MXL model. Under scenario 1, without excessive off-net pricing against new entrant, PLAY's market share would increase by 2.8 percentage points in postpaid segment and 1.7 p.p. in the prepaid segment. Interestingly lost subscribers would not split equally among the three incumbent operators. Around 50% of postpaid users lost by PLAY would subscribe PLUS network, while even 60% of prepaid users would flow to T-Mobile. Under scenario 2, where mobile termination rates would be fully symmetric, PLAY would have even greater gains in market share in

[18] Survey-based averages presented in Table 8 are invariant and hence shown only for the baseline.

both segments (respectively 9.1 and 6.5 p.p). The above results suggest that paradoxically, not only strategic behavior of incumbents but also policy of asymmetric termination rates contributed to the potential loss of market shares. The fact that the widespread asymmetric regulation of MTR might be so costly for its beneficiaries has largely been overlooked in practical considerations. Finally, we note that way in which network effects are measured in our exercise has very little influence on the outcomes. This could be expected because network effects have a relatively weak impact on the utility function in our model.

# 5. Discussion and Conclusions

Under calling party pays (CPP) principle, receiver benefits become an externality for which the call originating party fully pays. In such case, theoretical literature on network competition identifies an incentive for strategic overpricing of off-net calls to reduce receiver benefits and hence lower attractiveness of rival networks. This predatory incentive grows with the market share and hence, will be much stronger for incumbent providers against new entrants. Because call externalities remain under the control of call originating operator, rational consumers will care about the prices of incoming calls, when deciding which network to choose. Consumers will recognize the direct impact of incoming prices on the number of calls received from their peers subscribing to other networks as long as receiver benefits are sufficiently valuable.

Building on that reasoning, our discrete choice experiment study proved that receiver benefits are indeed important for the choice of the mobile network operator. This finding has important implications for the regulatory authorities and mobile providers, operating on all CPP European markets which experienced a late entry. Incumbent mobile operators can no more claim that call externalities are irrelevant. Regulatory authorities gain empirical confirmation that call externalities are indeed a real challenge. It looks that this challenge has not been properly addressed with the recommended access policy in the EU (European Commission, 2009). Some national regulatory authorities in selected member states which discussed a shift from CPP towards RPP regime to mitigate call externalities. Eventually neither RPP nor bill-and-keep regimes have been implemented because of concerns related to switching-off effect and lack of control over unwanted calls (Littlechild, 2006). Under CPP principle, one possible way to address those concerns is to cut access charges to zero. This solution has been debated for years but never implemented in the EU. Only recently, the levels of MTR eventually have dropped below 1 cent per minute in most European countries, incentivizing operators to withdraw from termination-based price discrimination and eliminating distortions to connectivity. Nevertheless the destructive impact of excessive off-net/on-net price differentials had lasted for many years, reducing entry and weakening competition in a dynamic sense.

In our study we have assessed retrospectively the scale of possible distortions caused by call externalities in the Polish market. The evidence provided in our study suggests that failure to properly address strategic off-net overpricing by incumbents at least partially explains why PLAY maintained significantly lower market share than incumbent operators throughout eight years of post-entry competition. In particular we have calculated a market share stealing effect experienced by late entrant and caused by (i) strategic overpricing of incumbents and (ii) asymmetric MTR regulation. According to simulations from our choice model, excessive off-net pricing by incumbent networks reduced the market share of late entrant by 2-3 percentage points during the first three years of operation, in both prepaid and postpaid segments. This led to damages in revenue and considerably extended catching-up period. Interestingly, the policy of asymmetric termination rates contributed to the loss of market share even in greater part, leading to a loss of 9.1 and 6.5 p.p respectively. The fact that the widespread asymmetric regulation of MTR might have been so costly for its beneficiaries has largely been overlooked in practical considerations.

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*Table 9. Differences in choice probability between scenarios for prepaid and postpaid subscribers. Network effects variables measured with market shares.*

difference in choice probability dP (scenario 1- baseline): Postpaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 0,71%***(0,11%) | 0,61%***(0,09%) | 0,89%***(0,12%) | 0,82%***(0,13%) |
| | 95% c.i. | (0,49%;0,93%) | (0,43%;0,81%) | (0,67%;1,15%) | (0,59%;1,11%) |
| tmobile | dP (s.e.) | 0,77%***(0,08%) | 0,55%***(0,06%) | 0,67%***(0,07%) | 0,58%***(0,06%) |
| | 95% c.i. | (0,61%;0,93%) | (0,43%;0,68%) | (0,55%;0,82%) | (0,47%;0,71%) |
| plus | dP (s.e.) | 1,03%***(0,13%) | 0,87%***(0,11%) | 1,25%***(0,15%) | 1,43%***(0,17%) |
| | 95% c.i. | (0,78%;1,28%) | (0,66%;1,1%) | (0,98%;1,56%) | (1,12%;1,8%) |
| play | dP (s.e.) | -2,51%***(0,32%) | -2,02%***(0,26%) | -2,82%***(0,33%) | -2,83%***(0,32%) |
| | 95% c.i. | (-3,13%;-1,88%) | (-2,57%;-1,53%) | (-3,5%;-2,2%) | (-3,51%;-2,26%) |

difference in choice probability dP (scenario 1- baseline): Prepaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 0,36%***(0,09%) | 0,02%(0,1%) | 0,16%(0,11%) | 0,16%**(0,08%) |
| | 95% c.i. | (0,19%;0,53%) | (-0,17%;0,22%) | (-0,04%;0,38%) | (0,02%;0,33%) |
| tmobile | dP (s.e.) | 0,91%***(0,1%) | 0,7%***(0,15%) | 1,06%***(0,16%) | 1,09%***(0,15%) |
| | 95% c.i. | (0,71%;1,1%) | (0,43%;0,99%) | (0,76%;1,38%) | (0,8%;1,4%) |
| plus | dP (s.e.) | 0,67%***(0,07%) | 0,61%***(0,08%) | 0,74%***(0,08%) | 0,47%***(0,06%) |
| | 95% c.i. | (0,53%;0,82%) | (0,47%;0,77%) | (0,58%;0,91%) | (0,36%;0,61%) |
| play | dP (s.e.) | -1,95%***(0,26%) | -1,32%***(0,31%) | -1,96%***(0,34%) | -1,72%***(0,26%) |
| | 95% c.i. | (-2,45%;-1,43%) | (-1,96%;-0,75%) | (-2,65%;-1,32%) | (-2,28%;-1,24%) |

difference in choice probability dP (scenario 2 - baseline): Postpaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 2,36%***(0,32%) | 2,15%***(0,28%) | 3,16%***(0,39%) | 2,77%***(0,38%) |
| | 95% c.i. | (1,74%;2,97%) | (1,65%;2,74%) | (2,44%;3,97%) | (2,12%;3,61%) |
| tmobile | dP (s.e.) | 1,81%***(0,24%) | 1,49%***(0,18%) | 1,97%***(0,23%) | 1,65%***(0,2%) |
| | 95% c.i. | (1,35%;2,28%) | (1,15%;1,88%) | (1,54%;2,44%) | (1,29%;2,08%) |
| plus | dP (s.e.) | 2,88%***(0,37%) | 2,64%***(0,33%) | 3,88%***(0,47%) | 4,1%***(0,49%) |
| | 95% c.i. | (2,16%;3,6%) | (2,03%;3,33%) | (3,03%;4,85%) | (3,23%;5,14%) |
| play | dP (s.e.) | -7,05%***(0,92%) | -6,28%***(0,77%) | -9%***(1,06%) | -8,53%***(0,9%) |
| | 95% c.i. | (-8,84%;-5,24%) | (-7,91%;-4,87%) | (-11,18%;-7,04%) | (-10,48%;-6,93%) |

difference in choice probability dP (scenario 2 - baseline): Prepaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 1,52%***(0,22%) | 0,8%***(0,26%) | 1,47%***(0,3%) | 1,35%***(0,25%) |
| | 95% c.i. | (1,08%;1,95%) | (0,32%;1,33%) | (0,92%;2,09%) | (0,9%;1,88%) |
| tmobile | dP (s.e.) | 2,27%***(0,25%) | 1,94%***(0,38%) | 3,2%***(0,47%) | 3,82%***(0,54%) |
| | 95% c.i. | (1,76%;2,77%) | (1,23%;2,72%) | (2,35%;4,18%) | (2,81%;4,95%) |
| plus | dP (s.e.) | 1,06%***(0,2%) | 1,39%***(0,21%) | 1,87%***(0,27%) | 0,95%***(0,19%) |
| | 95% c.i. | (0,66%;1,45%) | (1,01%;1,81%) | (1,38%;2,42%) | (0,6%;1,35%) |
| play | dP (s.e.) | -4,85%***(0,67%) | -4,13%***(0,82%) | -6,54%***(1,01%) | -6,12%***(0,85%) |
| | 95% c.i. | (-6,16%;-3,52%) | (-5,81%;-2,62%) | (-8,61%;-4,67%) | (-7,89%;-4,56%) |

Source: Own calculations.

*Table 10. Differences in choice probability between scenarios for prepaid and postpaid subscribers. Network effects variables measured with survey-based data.*

difference in choice probability dP (scenario 1- baseline): Postpaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 0,73%***(0,11%) | 0,66%***(0,1%) | 0,95%***(0,13%) | 0,84%***(0,15%) |
| | 95% c.i. | (0,5%;0,95%) | (0,47%;0,86%) | (0,71%;1,21%) | (0,59%;1,15%) |
| tmobile | dP (s.e.) | 0,78%***(0,08%) | 0,56%***(0,06%) | 0,69%***(0,07%) | 0,56%***(0,06%) |
| | 95% c.i. | (0,61%;0,94%) | (0,45%;0,7%) | (0,56%;0,84%) | (0,45%;0,69%) |
| plus | dP (s.e.) | 1,07%***(0,14%) | 0,97%***(0,12%) | 1,35%***(0,16%) | 1,65%***(0,2%) |
| | 95% c.i. | (0,8%;1,33%) | (0,75%;1,22%) | (1,06%;1,68%) | (1,29%;2,09%) |
| play | dP (s.e.) | -2,59%***(0,33%) | -2,19%***(0,28%) | -2,99%***(0,35%) | -3,06%***(0,35%) |
| | 95% c.i. | (-3,22%;-1,92%) | (-2,75%;-1,68%) | (-3,71%;-2,35%) | (-3,8%;-2,43%) |

difference in choice probability dP (scenario 1- baseline): Prepaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 0,37%***(0,09%) | 0,01%(0,11%) | 0,16%(0,11%) | 0,17%**(0,08%) |
| | 95% c.i. | (0,19%;0,55%) | (-0,19%;0,23%) | (-0,05%;0,38%) | (0,01%;0,34%) |
| tmobile | dP (s.e.) | 0,95%***(0,1%) | 0,74%***(0,15%) | 1,11%***(0,17%) | 1,14%***(0,17%) |
| | 95% c.i. | (0,75%;1,15%) | (0,47%;1,06%) | (0,8%;1,46%) | (0,81%;1,48%) |
| plus | dP (s.e.) | 0,69%***(0,08%) | 0,66%***(0,08%) | 0,77%***(0,09%) | 0,51%***(0,07%) |
| | 95% c.i. | (0,54%;0,84%) | (0,52%;0,83%) | (0,61%;0,96%) | (0,38%;0,66%) |
| play | dP (s.e.) | -2,02%***(0,27%) | -1,41%***(0,33%) | -2,05%***(0,35%) | -1,81%***(0,29%) |
| | 95% c.i. | (-2,53%;-1,48%) | (-2,1%;-0,82%) | (-2,76%;-1,39%) | (-2,39%;-1,26%) |

difference in choice probability dP (scenario 2 - baseline): Postpaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 2,41%***(0,33%) | 2,34%***(0,3%) | 3,34%***(0,41%) | 2,84%***(0,43%) |
| | 95% c.i. | (1,76%;3,05%) | (1,81%;2,93%) | (2,59%;4,2%) | (2,12%;3,79%) |
| tmobile | dP (s.e.) | 1,84%***(0,24%) | 1,55%***(0,18%) | 2,02%***(0,23%) | 1,59%***(0,2%) |
| | 95% c.i. | (1,36%;2,32%) | (1,23%;1,93%) | (1,58%;2,51%) | (1,23%;2,01%) |
| plus | dP (s.e.) | 3%***(0,39%) | 2,95%***(0,36%) | 4,19%***(0,5%) | 4,72%***(0,58%) |
| | 95% c.i. | (2,22%;3,73%) | (2,3%;3,69%) | (3,28%;5,23%) | (3,7%;5,96%) |
| play | dP (s.e.) | -7,25%***(0,96%) | -6,83%***(0,81%) | -9,55%***(1,11%) | -9,15%***(0,98%) |
| | 95% c.i. | (-9,09%;-5,35%) | (-8,5%;-5,38%) | (-11,85%;-7,51%) | (-11,31%;-7,4%) |

difference in choice probability dP (scenario 2 - baseline): Prepaid

| | | MNL | MXL_d | GMXL_d | MXL |
|---|---|---|---|---|---|
| orange | dP (s.e.) | 1,56%***(0,23%) | 0,85%***(0,28%) | 1,53%***(0,31%) | 1,41%***(0,27%) |
| | 95% c.i. | (1,12%;2%) | (0,33%;1,44%) | (0,96%;2,16%) | (0,92%;1,96%) |
| tmobile | dP (s.e.) | 2,38%***(0,27%) | 2,09%***(0,41%) | 3,39%***(0,49%) | 4,1%***(0,59%) |
| | 95% c.i. | (1,85%;2,89%) | (1,32%;2,96%) | (2,48%;4,42%) | (2,98%;5,28%) |
| plus | dP (s.e.) | 1,08%***(0,21%) | 1,53%***(0,22%) | 1,98%***(0,28%) | 1,03%***(0,22%) |
| | 95% c.i. | (0,68%;1,48%) | (1,13%;1,99%) | (1,47%;2,56%) | (0,63%;1,48%) |
| play | dP (s.e.) | -5,02%***(0,69%) | -4,47%***(0,87%) | -6,9%***(1,06%) | -6,53%***(0,92%) |
| | 95% c.i. | (-6,36%;-3,65%) | (-6,32%;-2,89%) | (-9,07%;-4,96%) | (-8,43%;-4,79%) |

Source: Own calculations.

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