



UNIVERSITY OF WARSAW

Faculty of Economic Sciences

WORKING PAPERS

No. 27/2016 (218)

MIKOŁAJ CZAJKOWSKI
MACIEJ SOBOLEWSKI

STRATEGIC USE OF EXTERNAL BENEFITS FOR ENTRY DETERRENCE: THE CASE OF A MOBILE TELEPHONY MARKET

WARSAW 2016



Strategic use of external benefits for entry deterrence: the case of a mobile telephony market

MIKOŁAJ CZAJKOWSKI
Faculty of Economic Sciences
University of Warsaw
e-mail: miq@wne.uw.edu.pl

MACIEJ SOBOLEWSKI
Faculty of Economic Sciences
University of Warsaw
e-mail: maciej.sobolewski@uw.edu.pl

Abstract

Recent models of network competition demonstrate the incentives of incumbents to reduce receiver benefits in rival networks through excessive off-net pricing. Theoretical reasoning behind strategic use of call externalities assumes that receiving calls contributes to consumer utility. This paper tests this critical assumption with choice data elicited from users of mobile telephones. We find that receiver benefits are a significant driver of subscription choices and assess customer base stealing effect encountered by the late entrant. Our findings confirm that call externalities can be used to limit late entrants' growth as has been observed in many European mobile telephony markets.

Keywords:

call externalities, personal network effects, entry deterrence, mobile telephony, stated preferences, discrete choice experiment

JEL:

L1, L86, D62

1. INTRODUCTION

Economic externalities play a significant role in network industries. As network services generate various types of benefits to their users, theoretically, service providers can increase profits and improve their competitive position by controlling the extent to which external benefits are internalized. In this paper, we show this empirically. We use mobile telephony market data to investigate how call externalities can be strategically used to maintain a competitive advantage of incumbents over smaller networks. We also simulate and discuss the efficiency of making mobile termination rates (MTRs) asymmetric, which may increase entrants' short-term profits but slows down their market share growth.

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 the receiving party derives some positive utility. Under the *calling-party-pays* regime, receiver benefits turn into a positive economic externality. Network externalities arise as a benefit generated by the network for its users. Although network benefits make take many forms, in mobile telephony they arise mainly as savings from cheaper on-net calls.¹ 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. The combination of a low on-net rate and high off-net rate serves as a strategy to maximize the amount of network benefits available to a firm's 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. In contrast, call externalities, which belong to the narrower context of the telecommunications industry, entered the economic research agenda much later. The interest in call externalities has been inspired by the wave of entry that took place in several European countries as a result of 3G licensing in 2001-2002.

Theoretical studies suggested that call externalities can be strategically used to maintain the competitive advantage of incumbents over smaller networks by reducing the number of incoming calls and hence lowering the attractiveness of the latter in the eyes of current and future subscribers (Jeon, Laffont and Tirole, 2004). This intriguing possibility requires that receiver benefits have a significant contribution to consumer utility and thus drive subscription choices. So far, no attempts have been made to test this critical assumption empirically.² Thus, at present, we have intriguing predictions from the well-elaborated theory of call externalities but lack 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 do this, we use stated preference data and apply a discrete choice experiment (DCE; Carson, 2012) designed specifically to model the subscription choices of large representative samples of prepaid and postpaid mobile phone users in Poland. There have been

¹ In addition to their pecuniary nature, network effects in mobile telecommunications are localized, in the sense that the positive contribution to the subscriber utility function comes mainly from frequently called parties, such as family and friends.

² To the best of our knowledge, Harbord and Pagnozzi (2010) is the only study that 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 the competitive position of late entrants.

no previous attempts to identify and measure the strength of receiver benefits in the mobile market; thus, little is known about the actual contribution of this effect to the utility derived from subscription by individual users and hence their operator choice probabilities. Our study presents a framework that can be used to quantify and value this effect.

We introduce a model of subscribers' choice that incorporates the price of off-net calls paid by other users. We use the incoming price (paid by people who call the subscriber) to control for call externalities because it directly impacts call volumes to the subscriber that originate in other networks. The model is estimated using a dataset collected from a large-scale stated preference survey that conveniently allowed for the inclusion and variance³ of all the important determinants of choice, such as termination-based discriminatory tariffs, personal network effects and brand loyalty. This enables us to investigate counterfactual scenarios of practical relevance to operators and regulatory authorities in Poland and other countries where the discussion about the anti-competitive impact of call externalities has been lively. In the policy exercise for the Polish mobile market, we simulate 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 scenario is implied by symmetric MTRs – a solution advocated as a more effective instrument for entry assistance policy than the adopted asymmetric regulation.

The remainder of the paper is organized as follows. In the next section, we review relevant literature devoted to call externalities. Section 3 presents the design of our study, characterizes the data and provides a description of the econometric framework. Section 4 reports the empirical results, and section 5 is devoted to the simulation of the counterfactual scenarios and policy implications related to the impact of alternative levels of off-net price asymmetry for market share changes. The last section discusses the results and concludes the paper.

2. LITERATURE REVIEW

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 an optimal interconnection regime. In what follows, we focus mainly on the first stream of literature, which motivates our study.⁴

Hermalin and Katz (2004) were the first to argue that omitting receiver benefits is unrealistic and would imply that the receiving party is generally reluctant to answer (and pay for) incoming calls.⁵ Receiver benefits were introduced in the analysis of competition between interconnected networks by Jeon, Laffont and Tirole (2004). They showed that in a duopoly setting, the equilibrium on-net prices decrease and off-net prices increase with the magnitude of call externalities. An excessive on-net/off-net price differential limits the level of off-net traffic,

³ Revealed behavioral data (assuming we had access to it) exhibit lower variability in explanatory variables and suffer from co-linearity, resulting in larger standard errors of the estimates and a risk of biased results (Louviere, Hensher and Swait, 2006).

⁴ With regards to the interconnection issue, the main conclusion from the literature is that the optimal network utilization requires that both the sender and the receiver share the cost of a call. However, given the non-homogeneity of benefits, an optimal pricing scheme is not implementable in practice (DeGraba, 2003; Hermalin and Katz, 2006).

⁵ The non-existence assumption is also clearly contradicted by the smooth operation of the receiving-party-pays regime in a number of countries, including the US and Canada. Receiver benefits are not uniform, of course, and in some cases (e.g., calls from telemarketing companies) could even be negative (Littlechild, 2006).

which reduces the receiver benefits of rival networks' users and increases network externalities available to a firm's own subscribers. Importantly, off-net/on-net price differential grows with the market share, indicating that the strategic motives rise with network size.⁶

Armstrong and Wright (2009) extended the model of Jeon, Laffont and Tirole (2004) to represent the oligopolistic mobile market with an interconnected single fixed network. They showed that the equilibrium mobile off-net price increases with the strength of receiver benefits and level of access charge and decreases with the number of mobile competitors. Call externalities in their model also have 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 prefer higher access charges if threatened by an entry. Armstrong and Wright explicitly predict that incumbent networks have a greater incentive to overprice off-net calls to deter or limit 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 the receiver utility of own subscribers and set equal below-cost on-net prices, the larger (incumbent) network strategically sets higher off-net price than a smaller network. This pricing structure harms smaller competitors not only through reduced receiver benefits but also through the creation of an interconnection deficit, which may even push the entrant out of the market. Calzada and Valletti (2008) analyzed the 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 the ex-post profitability of new entrants. High off-net prices implied by an access charge 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 that focus on the strategic effects of call externalities on network competition. Based on the insights from the theoretical literature, they provide evidence that call externalities 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 (MTRs), (ii) calling patterns, and (iii) implicit traffic imbalances. In the authors' opinion, all three measures point to the likely existence of call externalities but are too noisy for rigorous identification.

In summary, the theoretical literature offers two main conclusions regarding call externalities. Firstly, in an equilibrium, the 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 a higher off-net price than a smaller network to strategically utilize call externalities against smaller competitors. The latter conclusion has been demonstrated under reciprocal access charges but also holds in the case of asymmetric access fees, which are established in many countries to assist entry.

In what follows, we test these predictions using a microeconomic model of consumers' mobile operator choice. An empirical analysis, made possible by eliciting consumers' stated preferences in a state-of-the-art DCE study administered to a representative sample of the population of Poland, allows us to quantify and value these effects and simulate counterfactual

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 the originated and received calls 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 the access charge is set above the marginal cost are Cabral (2011) and López and Rey (2012).

scenarios of (1) off-net/on-net price differential reflecting asymmetric MTRs, and (2) fully symmetric MTRs and off-net/on-net prices.

3. EMPIRICAL EVIDENCE FROM THE POLISH MOBILE TELEPHONY MARKET

3.1. OVERVIEW OF THE MARKET

According to the theory, call externalities can be strategically used by incumbent operators to weaken the competitive position of a late entrant. Observing this empirically is complicated by the fact that the majority of European markets, including Poland, experienced a period of asymmetric regulation of MTRs post entry,⁸ which in itself provides a rationale for asymmetric off-net prices. Taking this into account, is the price asymmetry between off-net calls terminated in entrants' network and off-net calls terminated by incumbents 'excessive'? That is, does it go beyond what is justified by asymmetric MTRs?

To answer this question, we construct a benchmark of the degree of excessive pricing. Using a common markup rule, the benchmark off-net prices of incumbents for calls terminated in an entrant's network are dictated by an equal percentage markup (over a higher termination rate for a new entrant) as off-net prices for calls terminated in incumbent networks (over a lower termination rate in those networks).

Figure 1 provides an illustration using historical data for Poland. In a nutshell, the Polish mobile telephony market consist of three incumbent infrastructural operators⁹ operating since 1996 and the fourth operator¹⁰ who entered the market in 2007.¹¹ The national regulatory authority (Office of Electronic Communications) introduced asymmetric termination rates to support the new entrant and announced a scheme for the gradual reduction of asymmetry (see *MTRs to incumbents* and *MTRs to entrant* in Figure 1). Two years later, the incumbents started to mark out higher off-net prices to the entrant than to each other (see the *off-net price to entrant* and *off-net price to incumbents* in Figure 1). Interestingly, the level of asymmetry of the off-net calls prices was consistent with the asymmetry of MTRs during the first few months. Later on, however, incumbents kept their prices unchanged despite gradual reductions in MTRs.

Our benchmark (see the *off-net price to entrant benchmark* in Figure 1) illustrates the off-net prices to entrants if they were proportional to the MTRs in the same way as off-net prices between incumbents (i.e., if the markup were the same). It clearly shows that the asymmetry of off-net call prices between incumbent networks and P4 (Play) started in April 2010 and continued beyond the period of asymmetric termination rates, disclosing strategic motives of incumbent operators.

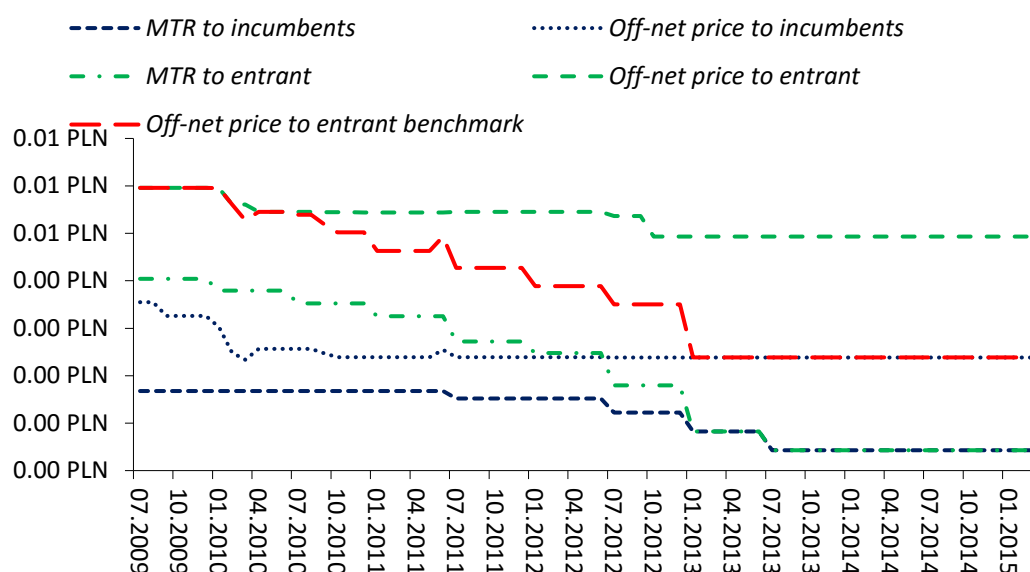
⁸ This was an entry-assistance policy introduced to correct for large traffic imbalances between networks.

⁹ PTK Centertel (Orange), PTC (T-Mobile) and Polkomtel (Plus)

¹⁰ P4 (Play)

¹¹ Currently, the four operators jointly have 98% market share pointing to a negligible role of virtual operators.

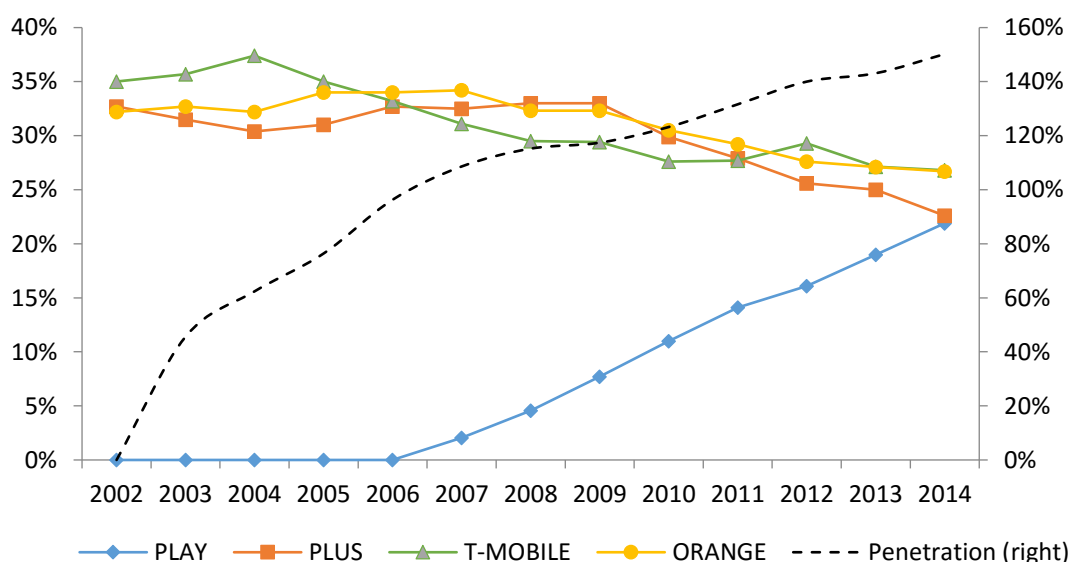
Figure 1. MTRs and marginal prices of off-net calls to incumbent networks and the entrant versus the common markup benchmark (postpaid)



Source: Market monitoring provided by Audytel S.A.

As stated above, in the presence of call externalities, excessive off-net pricing can be expected to have a negative impact on the market share of a new entrant. Figure 2 shows the evolution of market shares in the Polish mobile market. It shows that the entrant (*PLAY*) maintained a significantly lower market share than incumbent operators throughout the eight years of post-entry competition.¹²

Figure 2. Penetration and the operators' market shares in the mobile telephony market in Poland



Source: annual reviews of the telecommunications market in Poland provided by the Office of Electronic Communications.

¹² 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). Call externalities are obviously only one of the factors explaining why the advantages of incumbents are so persistent in mobile telephony; other important factors include switching costs and network effects, which induce consumer lock-in (see e.g., Czajkowski and Sobolewski, 2016).

In what follows, we explicitly model consumers' operator choices and simulate what the market shares would be if incumbent operators set off-net prices to the entrant in accordance with a common markup benchmark. To model consumers' mobile telephone operator choices while taking call and network externalities, switching costs and termination-based price discrimination into account, we designed and administered a study of consumers' stated preferences. The data that made this possible were collected via a carefully designed DCE (Carson and Czajkowski, 2014). The survey was administered to two samples of individual consumers representative of private users of prepaid and postpaid mobile services.¹³

3.2. DEVELOPMENT OF THE EMPIRICAL STUDY

A stated preference questionnaire that encompasses hypothetical choices revealing respondents' true preferences typically starts with general introductory questions and collects status-quo information – in our case, questions referring to respondents' current use of a mobile phone. Next, it introduces a contingent 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.

In our case, respondents were asked to choose a new mobile phone plan that they thought was the best for them out of the four hypothetical alternatives. The hypothetical new plans could be provided by one of the four major providers operating in Poland. Each of the alternatives was described with the following 6 attributes:

- (1) A brand name of the mobile operator's network.¹⁴
- (2 & 3) The average on-net and off-net price of a call.
- (4) The average price of incoming calls from other networks.
- (5 & 6) The size of the 'family and friends' and 'other people' in the same network.

The first attribute is almost always included in preference studies regarding mobile services, for example Maicas, Polo and Javier Sese (2009), Grzybowski and Pereira (2011) and Sobolewski and Czajkowski (2012). We introduce brand effects as alternative specific constants; hence, we can jointly control for all systematic differences in the perception of qualitative factors such as call quality, network coverage or customer service.

The next two attributes (on-net and off-net prices) reflected the basic structure of termination-based tariffs, which allowed us to incorporate call and network externalities as the drivers of customer behavior.

The fourth attribute, i.e., the price of incoming calls from other networks, was included to indirectly indicate the magnitude of receiver benefits. Because other subscribers can be expected to adjust their call volumes to price changes, this attribute can be used to control for call externalities.¹⁵

¹³ Because subscribers whose mobile phones are exclusively or predominantly paid by their employer were excluded from the analysis, our samples are not representative of the entire prepaid and postpaid segments.

¹⁴ In our preliminary qualitative in-depth interviews, respondents associated 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.

¹⁵ Alternatively, one could use a traffic-based approach, which directly focuses on the actual source of receiver benefits. We decided not to use this approach, however, because it seems more suitable for conducting assessment exercises related to various access charge policies.

The last two attributes reflect personal and absolute network effects associated with each of the alternatives. 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 the respondent contacts irregularly, such as shops, offices, and distant friends, or people whom she or he does not contact at all but are still connected to the same network. This attribute was therefore equivalent to each operator’s hypothetical customer base. We have differentiated between those two sources of network benefits because, according to the growing body of empirical evidence, network effects are not homogenous across all individuals in the same network but are localized within a small subset constituting the social network of a particular subscriber (Corrocher and Zirulia, 2009; Czajkowski and Sobolewski, 2011; Maicas and 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 reflect actual market conditions and the average levels actually experienced by respondents. These levels are summarized in Table 1. Variation in attribute levels was tested in the qualitative analysis to ensure sufficient responsiveness of respondents.

Table 1. List of attributes and attribute levels used to describe choice alternatives.

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

The attributes and their levels were carefully explained to respondents in the survey. 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).¹⁶

Each respondent was presented with 12 choice tasks, each consisting of four alternative ‘new plans’. The combinations of the attribute levels presented in each of the choice tasks (i.e., the experimental design) were selected in a Bayesian efficient way (Ferrini and Scarpa, 2007; Scarpa and Rose, 2008), i.e., to minimize the determinant of the expected AVC matrix of the

¹⁶ The development of the questionnaire was conducted according to the state-of-the-art recommendations for stated preference studies, including thorough qualitative pre-testing, to make sure the discrete choice experiment was understandable and credible to respondents.

estimates (*D-error*) given the priors on the parameters of a representative respondent's utility function derived from a pilot survey. An example of a choice card 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 administered to a representative sample¹⁷ of 1,001 prepaid and 1,029 postpaid mobile phone users in Poland. The survey had a computer-assisted-web-interview format, which lasted approximately 20 minutes and was conducted by a professional public opinion polling agency.¹⁸ Because each respondent was faced with 12 choices, our data set consists of 12,012 and 12,348 choice observations, respectively.

3.3. CHARACTERISTICS OF THE SAMPLE

The demographic and usage profiles clearly differ between the prepaid and postpaid segments of Polish subscribers (see Table 3, panel A).¹⁹ Prepaid users are less educated and have lower earnings than postpaid users. Although the average age is similar, the segments differ with respect to the age distribution. Whereas 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 in usage profiles is also substantial. Prepaid users generate much less traffic than postpaid customers and hence pay lower bills per month. The prepaid segment groups twice as many people who mainly receive connections, as suggested by a lower share of calls to family and friends in the 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 the total time of outgoing calls is above 70% in both groups, whereas the

¹⁷ Both samples were representative with respect to the age structure (18-65 years) and region.

¹⁸ IPSOS Poland. The response rate was 29%.

¹⁹ All differences in the characteristics of the prepaid and postpaid samples presented in Table 3 are significant at the 1% level.

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 the prepaid and postpaid samples.

A. Demographics					
age [years]	18-22	23-35	36-55	56-65	mean
postpaid	6%	36%	47%	12%	39.3
prepaid	13%	32%	41%	14%	28.2
sex	women	men			
postpaid	50%	51%			
prepaid	53%	47%			
education	primary	vocational	secondary	higher	
postpaid	1%	7%	43%	49%	
prepaid	2%	10%	48%	41%	
income distribution [PLN]	0-2000	2001-3000	3001-4000	above 4000	no answer
postpaid	32%	29%	15%	12%	12%
prepaid	50%	21%	8%	7%	14%
B. User profile					
operator	Orange	Play	Plus	T-Mobile	other
postpaid	30%	28%	21%	20%	1%
prepaid	35%	27%	19%	16%	4%
duration of outgoing calls per day [min]	0-20 min	20-40	40-60	above 60	mean
postpaid	44%	22%	18%	16%	43,4
prepaid	64%	18%	10%	9%	27,3
average monthly expenditure [PLN]	0-20 PLN	20-40	40-60	above 60	mean
postpaid	8%	25%	33%	34%	63,5
prepaid	40%	45%	11%	4%	29,1
number of past operator changes	0	1	2	more than 2	mean
postpaid	39%	38%	16%	8%	1%
prepaid	46%	30%	15%	8%	1%
size of 'family and friends' group [persons]	1-3 pers.	4-5	6-10	11-15	above 15
postpaid	12%	24%	38%	10%	16%
prepaid	20%	29%	34%	8%	10%
share of calls to 'family and friends' in total outgoing traffic [%]	0-20%	21-40	41-60	61-80	above 80
postpaid	4%	12%	22%	41%	22%
prepaid	8%	13%	18%	34%	27%

In summary, the prepaid service is better adjusted to the needs of the youngest and the oldest respondents, who originate fewer connections but receive more calls. In contrast, postpaid subscribers are more intensive users. They maintain regular contact 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 incomes. In what follows, we model preferences of both groups separately and investigate how sensitive they are with respect to specific components of mobile services.

3.4. ECONOMETRIC FRAMEWORK

The discrete choice experiment data can be used to formally model respondents' utility functions, i.e., to quantify the extent to which each attribute influences the choices of prepaid and postpaid subscribers. Given estimated choice models, it is possible to conduct a scenario analysis and evaluate how subscribers from prepaid and postpaid segments will change their choices in response to alternative levels of asymmetry in the prices of incoming calls. This makes it possible to assess the impact of call externalities on the market shares of mobile operators.

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

$$U_{ijt} = \mathbf{x}_{ijt}\boldsymbol{\beta} + \varepsilon_{ijt}, \quad (1)$$

where $\boldsymbol{\beta}$ is the vector of utility parameters, $\mathbf{x}$ is the vector of alternative-specific attributes, and ε is the random component, representing the joint influence of all unobserved factors that influence decision-making (Manski, 1977). By assuming that the random component is standard type-1 extreme value distributed, the multinomial logit (MNL) model is obtained with a convenient closed-form expression for the choice probability:

$$P(j|J) = \frac{\exp(\mathbf{x}_{ijt}\boldsymbol{\beta})}{\sum_{k=1}^J \exp(\mathbf{x}_{ikt}\boldsymbol{\beta})} \quad (2)$$

In what follows, we apply a mixed logit (MXL) extension of the model which allows us to take the respondents' preference heterogeneity into account, as it has been shown to substantially improve model performance in the case of preferences for mobile telecommunications (Czajkowski and Sobolewski, 2016). In the MXL model, the preference parameters are individual specific, following an a priori specified multivariate distribution $\boldsymbol{\beta}_i \sim f(\mathbf{b}, \boldsymbol{\Sigma})$, where $\mathbf{b}$ is a vector of population means and $\boldsymbol{\Sigma}$ represents a (possibly non-diagonal) 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 (Hensher, Rose and Greene, 2015). This comes at the cost of a more complicated estimation procedure; however, the unconditional probability of individual i choosing alternative j in situation t is an integral of standard logit probabilities over a density individual utility parameter (Train, 2009). Because mixed logit probabilities involve integrals that do not have closed forms, estimation requires the application of e.g., the maximum simulated likelihood method. As a result, the simulated log-likelihood function becomes the following:

$$\log L = \sum_{i=1}^I \log \frac{1}{D} \sum_{d=1}^D \prod_{t=1}^{T_i} \sum_{j=1}^J y_{ijt} \frac{\exp(\mathbf{x}_{ijt}\boldsymbol{\beta}_i)}{\sum_{j=1}^J \exp(\mathbf{x}_{ijt}\boldsymbol{\beta}_i)}, \quad (3)$$

where y_{ijt} is a dummy variable equal to 1 if respondent i selected alternative j in choice situation t and 0 otherwise and D represents the number of simulated points. Maximizing the log-likelihood function in (3) gives estimates for the parameters.²⁰

3.5. RESULTS

Table 4 presents the results of the MXL model used to estimate the parameters of subscribers' utility functions.²¹ The estimated coefficients reflect respondents' marginal utilities associated with changes in the levels of the attributes (e.g., price increase), and as a result, changes in the probability of selecting an alternative. Consumers' preference heterogeneity is incorporated into the model by making the utility function parameters random according to some a priori

²⁰ The models were estimated in Matlab. The software used here (estimation package for DCE data) is available at github.com/czaj/DCE under CC BY 4.0 license.

²¹ The dataset, additional results and estimation codes are available from the authors upon request.

selected parametric distribution – for this reason, each attribute is associated with the estimate of the mean and standard deviation of its distribution in the population.²² Although the coefficients do not have a direct interpretation,²³ their signs reflect whether the attributes are perceived goods or bads whereas their relative values indicate their relative importance. In addition, by calculating the ratios of the parameters, it is possible to derive marginal rates of substitution; if the attribute in the denominator is monetary, the result can be interpreted as the marginal willingness to pay, i.e., the exchange rate at which a respondent is willing to trade the change in an attribute for money.

The first of the attributes (status quo inertia) is an alternative specific constant associated with each respondent's current operator. Its sign and significance show that, on average, respondents prefer their current operator to the alternatives – a sign of consumers sorting themselves into the operators they prefer, growing accustomed to their current operator and not wanting to change, or any other inconveniences associated with switching (despite the availability of quick and costless portability procedures). Status quo inertia has been confirmed in previous studies (Czajkowski and Sobolewski, 2016) and might be interpreted as brand loyalty or transaction costs.

The negative coefficients of the means of the normally distributed parameters for operator-specific constants show that Orange, T-Mobile and Plus are all (on average) less preferred than the reference (Play), although in each case there is substantial heterogeneity of brand preferences, as indicated by the relatively high estimates of the standard deviations. All else equal (and controlling for status quo inertia²⁴), brand effects represent systematic differences in the perception of soft prerequisites such as call quality, customer service or brand image between the operators.

As expected, all three (negatively log-normally distributed) price coefficients show that consumers' utility decreases with price. The price of on-net calls is the most important, 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 to call a respondent in a different network – has the lowest, albeit significant impact on respondents' utility, and hence the probability of choosing an operator off-net calls to whom are more expensive. This result confirms the sensitivity of subscribers to receiver benefits and opens the floor for considerations about the impact of call externalities on the choice of operator and competition between operators.

Finally, similarly to a few earlier studies (Maicas, Polo and Sese, 2009; Sobolewski and Czajkowski, 2012; Czajkowski and Sobolewski, 2016), we find that network effects can be an important driver of consumers' choices but are largely limited to the 'friends and family' group.

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.

²² We selected the parametric distribution for each attribute based on the model fit criteria. For log-normally distributed parameters, the coefficients of the underlying normal distribution are reported. The price coefficients are log-normal.

²³ The utility function is ordinal; the coefficients are confounded with the scale coefficient, because the variance of the utility function error term is normalized.

²⁴ We note that the status quo inertia has a considerably larger magnitude than brand effects (median effect equal $\exp(0.2149) = 1.2397$) which indicates that subscribers may be reluctant to change their current operator even if they perceive it as inferior to the competitors.

Table 4. Estimates of the utility function parameters for postpaid subscribers.

	Distribution	Postpaid		Prepaid	
		Mean (s.e.)	Standard Deviation (s.e.)	Mean (s.e.)	Standard Deviation (s.e.)
Status quo inertia	Lognormal	0.2149*** (0.0838)	1.5661*** (0.1065)	0.3206*** (0.0835)	1.4688*** (0.1039)
Orange vs. Play (operator-specific constant)	Normal	-0.2746*** (0.1123)	1.5055*** (0.0891)	-0.3364*** (0.1174)	1.5929*** (0.1027)
T-Mobile vs. Play (operator-specific constant)	Normal	-0.4320*** (0.1107)	1.5203*** (0.0897)	-0.5623*** (0.1171)	1.7902*** (0.1009)
Plus vs. Play (operator-specific constant)	Normal	-0.2592*** (0.1085)	1.4262*** (0.0865)	-0.3111*** (0.1122)	1.5633*** (0.0990)
On-net calls price per minute (PLN)	- Lognormal	2.1814*** (0.0577)	1.1412*** (0.0540)	2.1776*** (0.0667)	1.3144*** (0.0637)
Off-net calls price per minute (PLN)	- Lognormal	1.5915*** (0.0832)	1.4283*** (0.0675)	1.4897*** (0.0913)	1.6918*** (0.0782)
Incoming off-net calls price per minute (PLN)	- Lognormal	0.5138*** (0.1691)	1.4786*** (0.1071)	0.3645*** (0.1375)	1.6471*** (0.0878)
Share of friends and family using the same operator (%)	Normal	0.9718*** (0.2023)	4.1352*** (0.1993)	0.5746*** (0.2030)	3.8925*** (0.1906)
Share of other people using the same operator (%)	Normal	-0.0091 (0.1476)	2.2718*** (0.1506)	-0.1722 (0.1485)	2.1344*** (0.1599)
Model diagnostics					
Log-likelihood (constants)		-17,011.16		-16,458.07	
Log-likelihood		-10,082.30		-9,014.88	
McFadden's Pseudo-R ²		0.4073		0.4523	
Ben-Akiva Lerman's Pseudo-R ²		0.4830		0.5171	
AIC/n		1.6418		1.5100	
n (no. of observations)		12,348		12,012	
k (no. of parameters)		54		54	

***, **, * Significance at 1%, 5%, 10% level

3.6. SIMULATED POLICY SCENARIOS

The results presented in the preceding section showed that the magnitude of receiver benefits is indeed a significant determinant of consumers' operator choice. In contrast, operators engage in strategic overpricing of off-net calls to reduce receiver benefits in rival networks, as documented in section 3.1. In this section, we investigate the market effects of this strategy. To do this, we simulate operators' market shares under (0) the baseline, excessive off-net price discrimination, and two counterfactual scenarios: (1) assuming reduced asymmetry (reflecting asymmetry in MTRs) and (2) assuming full symmetry in off-net prices between large and small networks.

Our baseline scenario reproduces average market conditions in 2010-2012, when incumbent operators engaged in excessive (as defined in section 3.1) discriminatory off-net pricing.²⁵ Scenario 1 assumes off-net price asymmetry equal to the MTR asymmetry. Hence, there is no excessive off-net pricing by incumbents, and operators earn common markup on off-net calls in all directions. Scenario 2 assumes fully uniform off-net pricing. Under this scenario, the MTRs to incumbents and entrant are the same and so are the off-net rates of each operator.

²⁵ The average off-net price asymmetry between incumbents and the new entrant amounted to 254% in the postpaid segment and 244% in prepaid segment, whereas the average MTR asymmetry in that period was 189%.

Table 5 summarizes main characteristics of the baseline and two counterfactual scenarios. We assume that all other determinants of choice (attributes, respondent-specific characteristics) remain the same.

Table 5. Differences between the baseline and the two counterfactual scenarios

	Postpaid				Prepaid			
	Orange	T-Mobile	Plus	Play	Orange	T-Mobile	Plus	Play
Baseline								
Actual situation in 2010-2012								
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 entrant	0.60	0.61	0.59	-	0.56	0.52	0.65	-
MTR	0.15	0.15	0.15	0.29	0.15	0.15	0.15	0.29
Scenario 1								
No excessive off-net price asymmetry								
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 entrant	0.45	0.50	0.46	-	0.39	0.39	0.52	-
MTR	0.15	0.15	0.15	0.29	0.15	0.15	0.15	0.29
Scenario 2								
Fully symmetrical MTR and off-net prices								
On-net price	0.13	0.18	0.11	0.02	0.07	0.01	0.05	0.01
Off-net price	0.24	0.26	0.24	0.18	0.21	0.21	0.27	0.21
MTR	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

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

Knowledge of respondents' utility function parameters and their individual-specific characteristics (such as the share of friends and family using the same operator or their current subscription) allows us to calculate the operator choice probabilities. We are able to simulate how these probabilities would change if one of the counterfactual scenarios took place. The results are presented in Table 6a and Table 6b for Scenarios 1 and 2, respectively.

The results show that with no excessive off-net price asymmetry against the entrant (Play), the probability with which it would be chosen by consumers (and hence its market share) would increase by 2.8 percentage points in the postpaid segment and by 1.7 percentage points in the prepaid segment. Interestingly, new subscribers would not be split equally among the three incumbents – almost 50% of Play's new postpaid users would come from Plus, whereas 60% of Play's new prepaid users would come from T-Mobile.

If the MTRs and off-net prices were fully symmetric (Scenario 2), Play's market share would increase by even more – the probability of choosing the entrant would increase by 8.5 and 6.1 percentage points in the postpaid and prepaid segments, respectively. This result indicates that not only did the incumbents' strategic actions reduce the entrant's market share but the policy involving asymmetric MTRs (and off-net prices) was largely ineffective – it may have increased Play's short-term profits but it made its market share grow slower than it could have grown otherwise. We believe that the fact that the widespread asymmetric regulation of MTRs might be socially costly has largely been overlooked in practical considerations as well as the theoretical literature, but it appears to be of substantial policy relevance.

Table 6a. Operator choice probability differential (ΔP) between Scenario 1 (no excessive off-net price asymmetry) and the baseline

		Postpaid					Prepaid				
		Orange subscribers	T-Mobile subscribers	Plus subscribers	Play subscribers	Overall	Orange subscribers	T-Mobile subscribers	Plus subscribers	Play subscribers	Overall
Orange	ΔP	1.34***	0.64***	0.52***	0.77***	0.82***	0.11	0.17***	0.14**	0.32***	0.16**
	s.e.	(0.21)	(0.12)	(0.09)	(0.14)	(0.13)	(0.11)	(0.07)	(0.07)	(0.08)	(0.08)
	95% c.i.	(0.96;1.78)	(0.43;0.91)	(0.36;0.72)	(0.55;1.10)	(0.59;1.11)	(-0.10;0.34)	(0.05;0.32)	(0.01;0.28)	(0.17;0.50)	(0.02;0.33)
T-Mobile	ΔP	0.36***	1.10***	0.34***	0.48***	0.58***	1.07***	1.01***	0.93***	1.57***	1.09***
	s.e.	(0.05)	(0.13)	(0.05)	(0.07)	(0.06)	(0.14)	(0.18)	(0.15)	(0.19)	(0.15)
	95% c.i.	(0.28;0.46)	(0.87;1.38)	(0.26;0.44)	(0.36;0.62)	(0.47;0.71)	(0.79;1.36)	(0.65;1.37)	(0.64;1.24)	(1.24;1.95)	(0.80;1.4)
Plus	ΔP	1.08***	1.32***	1.86***	1.42***	1.43***	0.40***	0.37***	0.64***	0.52***	0.47***
	s.e.	(0.14)	(0.17)	(0.23)	(0.19)	(0.17)	(0.06)	(0.05)	(0.09)	(0.08)	(0.06)
	95% c.i.	(0.83;1.37)	(1.01;1.69)	(1.45;2.35)	(1.07;1.83)	(1.12;1.8)	(0.31;0.52)	(0.28;0.49)	(0.47;0.83)	(0.39;0.69)	(0.36;0.61)
Play	ΔP	-2.77***	-3.06***	-2.72***	-2.67***	-2.83***	-1.58***	-1.56***	-1.70***	-2.42***	-1.72***
	s.e.	(0.32)	(0.36)	(0.31)	(0.31)	(0.32)	(0.27)	(0.26)	(0.27)	(0.30)	(0.26)
	95% c.i.	(-3.45;-2.20)	(-3.82;-2.43)	(-3.38;-2.16)	(-3.36;-2.14)	(-3.51;-2.26)	(-2.14;-1.09)	(-2.10;-1.08)	(-2.27;-1.20)	(-3.05;-1.89)	(-2.28;-1.24)

Table 6b. Operator choice probability differential (ΔP) between Scenario 2 (fully symmetrical MTRs and off-net prices) and the baseline

		Postpaid					Prepaid				
		Orange subscribers	T-Mobile subscribers	Plus subscribers	Play subscribers	Overall	Orange subscribers	T-Mobile subscribers	Plus subscribers	Play subscribers	Overall
Orange	ΔP	4.78***	2.15***	1.70***	2.13***	2.77***	1.66***	1.16***	1.16***	1.45***	1.35***
	s.e.	(0.64)	(0.35)	(0.28)	(0.36)	(0.38)	(0.34)	(0.22)	(0.22)	(0.25)	(0.25)
	95% c.i.	(3.68;6.18)	(1.55;2.93)	(1.22;2.3)	(1.54;2.93)	(2.12;3.61)	(1.04;2.37)	(0.77;1.63)	(0.77;1.62)	(1.00;1.98)	(0.90;1.88)
T-Mobile	ΔP	0.99***	3.25***	0.94***	1.22***	1.65***	3.55***	3.7***	3.68***	4.91***	3.82***
	s.e.	(0.17)	(0.41)	(0.17)	(0.21)	(0.20)	(0.54)	(0.61)	(0.56)	(0.60)	(0.54)
	95% c.i.	(0.7;1.36)	(2.54;4.14)	(0.66;1.31)	(0.85;1.69)	(1.29;2.08)	(2.53;4.64)	(2.46;4.9)	(2.63;4.8)	(3.81;6.16)	(2.81;4.95)
Plus	ΔP	2.93***	3.63***	5.87***	3.38***	4.10***	0.81***	0.79***	1.19***	1.13***	0.95***
	s.e.	(0.42)	(0.48)	(0.68)	(0.52)	(0.49)	(0.17)	(0.17)	(0.29)	(0.21)	(0.19)
	95% c.i.	(2.19;3.81)	(2.76;4.65)	(4.67;7.35)	(2.46;4.49)	(3.23;5.14)	(0.52;1.17)	(0.50;1.15)	(0.67;1.79)	(0.76;1.58)	(0.60;1.35)
Play	ΔP	-8.70***	-9.03***	-8.51***	-6.73***	-8.53***	-6.02***	-5.66***	-6.03***	-7.48***	-6.12***
	s.e.	(0.92)	(0.99)	(0.90)	(0.84)	(0.90)	(0.88)	(0.84)	(0.89)	(0.85)	(0.85)
	95% c.i.	(-10.66;-7.06)	(-11.17;-7.3)	(-10.43;-6.91)	(-8.54;-5.23)	(-10.48;-6.93)	(-7.82;-4.39)	(-7.38;-4.06)	(-7.88;-4.37)	(-9.29;-5.93)	(-7.89;-4.56)

4. SUMMARY AND CONCLUSIONS

In this paper, we empirically tested whether external benefits can be strategically used to lower the attractiveness of an entrant. Using the case of Polish mobile telephony market, we observed that the price asymmetry between off-net calls terminated in the entrant's network and off-net calls terminated by incumbents exceeded the asymmetry justified by the MTR differential. To explain this phenomenon, we build on the theoretical model of Armstrong and Wright (2009) and apply stated preference methods to econometrically model mobile phone subscribers' utility functions, which allows us to show that incumbent networks do have an incentive to overprice off-net calls to an entrant.

Under the calling-party-pays principle, receiver benefits become an externality fully paid for by the call-originating party. In such a case, the theoretical literature on network competition identifies an incentive for strategic overpricing of off-net calls to reduce receiver benefits and hence lower the attractiveness of rival networks. This predatory incentive grows with the market share and hence is stronger for incumbent providers against entrants. Because call externalities remain under the control of the call-originating operator, rational consumers care about the prices of incoming calls when deciding which network to choose. Recognizing the direct impact of incoming prices on the number of calls received from their peers subscribing to other networks, consumers will be less likely to choose discriminated network. We confirm all these predictions empirically.

The evidence provided in our study suggests that failure to properly address strategic off-net overpricing by incumbents at least partially explains why in the case of the Polish mobile telephony market, the entrant maintained significantly a lower market share than incumbent operators throughout eight years of post-entry competition. In particular, we calculated a market share stealing effect experienced by the entrant by simulating the operator choice probabilities under two counterfactual scenarios – (1) no excessive off-net price asymmetry and (2) fully symmetrical MTRs and off-net prices – and comparing them with the baseline. We find that excessive off-net pricing by incumbent networks reduced the market share of a late entrant by 2-3 percentage points during the first three years of operation in both prepaid and postpaid segments. This led to reduced revenue and a considerably extended catching-up period. Interestingly, the policy of asymmetric termination rates contributed to the loss of market share further; without asymmetric MTRs and off-net prices, consumers' probability of choosing the entrant would be 6-9 percentage points higher.

Our findings have important implications for the regulatory authorities in countries with a calling-party-pays regime. Our results provide evidence that externalities are indeed a real challenge. First, late entrants are clearly vulnerable to strategically overpriced off-net calls from incumbent networks. Second, even though the recommended access policy has been addressed on numerous occasions (for a European example, see European Commission, 2009), the fact that the widespread asymmetric regulation of MTRs limits an entrant's market share growth has largely been overlooked in practical and theoretical considerations.

One way to address the strategic use of external benefits for entry deterrence in mobile telephony markets, advocated by regulatory authorities in some countries, is shifting from a regime of the calling party pays to the receiving party pays. Receiving-party-pays or bill-and-keep regimes are rarely implemented, however, mostly because of concerns related to switching-off effect and the lack of control over unwanted calls (Littlechild, 2006). Under the calling-party-pays principle, the problem could be addressed by cutting access charges to zero. This solution has been debated for years but – so far – has never been implemented. However, the MTR levels in the EU have recently dropped below 1 euro cent per minute, incentivizing

operators to withdraw from termination-based price discrimination and eliminating distortions to connectivity. In any case, the problem of excessive off-net/on-net price differentials had lasted for many years and, as we show in this study, was used to reduce entry and weaken competition in a dynamic sense.

5. REFERENCES

- Armstrong, M., and Wright, J., 2009. Mobile Call Termination. *The Economic Journal*, 119(538):F270-F307.
- Cabral, L., 2011. Dynamic price competition with network effects. *The Review of Economic Studies*, 78(1):83-111.
- Calzada, J., and Valletti, T. M., 2008. Network competition and entry deterrence. *The Economic Journal*, 118(531):1223-1244.
- Cambini, C., and Valletti, T. M., 2008. Information Exchange and Competition in Communications Networks. *The Journal of Industrial Economics*, 56(4):707-728.
- Carson, R. T., 2012. Contingent Valuation: A Practical Alternative When Prices Aren't Available. *Journal of Economic Perspectives*, 26(4):27-42.
- Carson, R. T., and Czajkowski, M., 2014. The Discrete Choice Experiment Approach to Environmental Contingent Valuation. In: *Handbook of choice modelling*, S. Hess and A. Daly, eds., Edward Elgar, Northampton, MA.
- Corrocher, N., and Zirulia, L., 2009. Me and you and everyone we know: An empirical analysis of local network effects in mobile communications. *Telecommunications Policy*, 33(1):68-79.
- Czajkowski, M., and Sobolewski, M., 2011. Measuring network effects in mobile telecommunications markets with stated-preference valuation methods. *International Journal of Management and Network Economics*, 2(2):197-215.
- Czajkowski, M., and Sobolewski, M., 2016. How much do switching costs and local network effects contribute to consumer lock-in in mobile telephony? *Telecommunications Policy*, 40(9):855-869.
- DeGraba, P., 2003. Efficient intercarrier compensation for competing networks when customers share the value of a call. *Journal of Economics & Management Strategy*, 12(2):207-230.
- European Commission. (2009). "Explanatory Note to Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU." In: *SEC(2009) 600*, Brussels.
- Ferrini, S., and Scarpa, R., 2007. Designs with a priori information for nonmarket valuation with choice experiments: A Monte Carlo study. *Journal of Environmental Economics and Management*, 53(3):342-363.
- Grzybowski, L., and Pereira, P., 2011. Subscription Choices and Switching Costs in Mobile Telephony. *Review of Industrial Organization*, 38(1):23-42.
- Harbord, D., and Pagnozzi, M., 2010. Network-Based Price Discrimination and Bill-and-Keep vs. Cost-Based Regulation of Mobile Termination Rates. *Review of Network Economics*, 9(1).
- Hensher, D. A., Rose, J. M., and Greene, W. H., 2015. *Applied Choice Analysis*. 2 Ed., Cambridge University Press.
- Hermalin, B. E., and Katz, M. L., 2004. Sender or Receiver: Who should pay to exchange an electronic message? *RAND Journal of Economics*, 35(3):423-448.
- Hermalin, B. E., and Katz, M. L., 2006. Customer or complementor? Intercarrier compensation with two-sided benefits. *Competition Policy Center*.
- Hoernig, S., 2007. On-net and off-net pricing on asymmetric telecommunications networks. *Information Economics and Policy*, 19(2):171-188.

- Jeon, D.-S., Laffont, J.-J., and Tirole, J., 2004. On the "receiver-pays" principle. *RAND Journal of Economics*, 35(1):85-110.
- Littlechild, S. C., 2006. Mobile termination charges: calling party pays versus receiving party pays. *Telecommunications Policy*, 30(5):242-277.
- Louviere, J. J., Hensher, D. A., and Swait, J. D., 2006. Stated Choice Methods: Analysis and Applications. Cambridge University Press, Cambridge.
- López, A. L., and Rey, P. (2012). "Foreclosing Competition through Access Charges and Price Discrimination." In: *IDEI Working Papers*.
- Maicas, J. P., Polo, Y., and Javier Sese, F., 2009. Reducing the level of switching costs in mobile communications: The case of Mobile Number Portability. *Telecommunications Policy*, 33(9):544-554.
- Maicas, J. P., Polo, Y., and Sese, F. J., 2009. The role of (personal) network effects and switching costs in determining mobile users' choice. *Journal of Information Technology*, 24(2):160-171.
- Maicas, J. P., and Sese, F. J., 2011. Network effects in the mobile communications industry: an overview. In: *Recent Developments in the Mobile Communications Industry: A Multidisciplinary Approach*. Croatia: *InTech*, 131-140.
- Manski, C. F., 1977. The structure of random utility models. *Theory and Decision*, 8(3):229-254.
- McFadden, D., 1974. Conditional Logit Analysis of Qualitative Choice Behaviour. In: *Frontiers in Econometrics*, P. Zarembka, ed., Academic Press, New York, NY, 105-142.
- Scarpa, R., and Rose, J. M., 2008. Design Efficiency for Non-Market Valuation with Choice Modelling: How to Measure it, What to Report and Why. *Australian Journal of Agricultural and Resource Economics*, 52(3):253-282.
- Sobolewski, M., and Czajkowski, M., 2012. Network effects and preference heterogeneity in the case of mobile telecommunications markets. *Telecommunications Policy*, 36(3):197-211.
- Train, K. E., 2009. Discrete Choice Methods with Simulation. Cambridge University Press, New York.



FACULTY OF ECONOMIC SCIENCES
UNIVERSITY OF WARSAW
44/50 DŁUGA ST.
00-241 WARSAW
WWW.WNE.UW.EDU.PL