IMPACTS OF CHANGES IN THE BRAZILIAN MOBILE TERMINATION RATES

Carlos M. Baigorri
Agência Nacional de Telecomunicações - ANATEL
baigorri@anatel.gov.br

Wilfredo F. L. Maldonado
Universidade Católica de Brasília
wilfredo@ucb.br

BIOGRAPHIES
Master in Economics by the Catholic University of Brasilia (UCB) and specialist in regulation telecommunications services in the Brazilian Telecommunications Regulatory Agency (Anatel).
Director of the Graduate Program in Economics at UCB where he also teaches. It has national and international publications in Economics Dynamics, Dynamic Programming, General Equilibrium and Macroeconomics.

ABSTRACT
This paper presents a study of the impacts of changes in the mobile termination rate in Brazil using 2008 as the base year. For this we use an extension of the monopolistic competition model used by Wright et al (2007) allowing for the charge of interconnection fee also from calls originating on mobile networks and differentiated prices for on-net and off-net calls. After calibration of the model parameters and estimation of the price elasticity of demand for mobile services, we conducted a comparative static analysis varying the mobile termination rate. As a result, we provide the optimal mobile termination rates for each regulator’s objective function.

Keywords
Mobile termination rate, waterbed effect, monopolistic competition in mobile telephony.

INTRODUCTION
In the last years the cell phone market has shown high growth rates worldwide, especially in Brazil. Data from the Brazilian regulatory agency (ANATEL) indicates that in the last ten years the number of customers of mobile services have risen at a Compound Annual Growth Rate (CAGR) of 35%, reaching more than 150 million customers in 2008 (in a population of 190 million). On a global level, data from the International Telecommunication Union indicates that the number of mobile service customers has risen at a CAGR of 19% between 2000 and 2008.

That considerable increase in the consumer base and the small number of operators may produce inefficiency in that market. In particular, the market power exhibited by the operators when fixing a mobile termination rate (MTR) is a concern for the National Regulatory Agencies (NRA) of the countries.

1 CAGR is a term for the geometric mean growth rate on an annualized basis.
For instance, the European Commission (CEC 2008), India (TRAI 2008), European Union (ERG 2007), Colombia
(CRT 2007), Brazil (SDE 2007, ANATEL 2005b and BRASIL 2003a) and the USA (FCC 2004) decided to establish a cost-
based MTR in order to attain welfare optimality.

In spite of that policy may work in some markets, as pointed out by Priest (2007), in network industries it may fail
because of the presence of positive externality that derives from the participation of new customers in the network.

In that vein, Wright (2000) proposed a model of competition between two interconnected cellular networks and
analyzed the effect of changes in MTR on competition and market penetration in the cellular sector. In Valletti and Houpis
(2005) it is proved that the optimal termination rate depends on the heterogeneity of customers, the intensity of competition
and the level of network externality. Littlechild (2006) analyzed an alternative framework where the receiving party pays and
show that under this principle the price of calls decreases and the average minutes of usage increase leaving the mobile
penetration rate almost unchanged. In a survey on the theory and applications of access pricing it is included a work of
Wright, Thompson and Renard (2007) where they developed a more general model with several firms and heterogeneous
customers to analyze the effect of changes in the MTR on variables as the penetration rate and consumers and total surplus.
Finally, Armstrong & Wright (2009) concluded that in a differentiated interconnection charge framework, fix-to-mobile
charges are too high and the mobile-to-mobile termination charges are too low. In all those works, the authors claims that,
under certain conditions, the optimal MTR is not that one equal to the cost of the interconnection. The main reason for this
result is the called waterbed effect, from which derives a positive externality of the growth of the mobile telecommunication
market over the landline telephony.

In particular, Wright et al (2007) conclude that the increase (decrease) of the interconnection rate provokes a
decrease (increase) of the rentals charged to the customers. The explanation for this can be summarized as follows. As the
mobile operators compete for the interconnection revenues they subsidize, through low rental charges, the entrance of new
customers in their networks, increasing their number of customers and also the number of receiving calls from other
networks, and consequently, raising the operators interconnection revenues. This subsidy used for attracting customers makes
that new people become mobile service consumers, raising the total of mobile service customers. Since that the possibility of
communicating with more people through telecommunication services increases the utility of mobile and landline customers,
the entrance of new customers generates a positive externality over the already customers of telecommunication services.

In this work we extend the Wright et al (2007) model in order to include some features of the Brazilian market
structure. Namely, we make the following extensions:

- Consider the charge of the MTR among mobile networks, and not only between landline and mobile
  networks;
- Allow the differentiation of prices between on net and off net calls;

Once that we modify the theoretical model, we adjust the model to the Brazilian market data. Then we make an
exercise of comparative statics aiming to assess the optimal MTR.

---

2 “effect whereby regulation of one of the prices of a multiproduct firm causes one or more of its other unregulated prices to
change as a result of the firm’s profit-maximising behaviour”. Schiff (2007, p.1).
A parameter which is useful to conduct this exercise is the price-elasticity of the mobile telecommunication demand. This is estimated using a panel data model in that sector from 2004 to 2008.

The results obtained from the comparative statics exercise are consistent with those presented by Wright et al (2007), finding that the optimal values for the MTR are higher than the marginal cost of the interconnection. However, we shall stress that the optimal MTR varies according to the welfare metric utilized.

In Section 2 of this paper we will present the theoretical model to be applied to the Brazilian market. Section 3 presents the estimation of the price-elasticity of the demand for mobile services and the calibration of the theoretical model. Section 4 presents the main results of the model and the welfare analysis. In Section 5 we present the conclusions.

2. THE THEORETICAL MODEL

We will adapt the model used by Wright et al (2007) in order to adjust some features of the Brazilian market. Next we proceed to describe the model.

There are “N” potential consumers of mobile telephony services and “J” operators in the market. There is a monopolistic operator on the landline telephony market, being a non-integrated operator. Operator \( j \in J \) competes with their peers maximizing its profit by choosing their rentals \( (r_j) \) and their unitary prices \( (p_{mn}^j; p_{mf}^j; p_f^j) \), as defined in subsection 2.1, given the rental and the prices chosen by the other operators.

Individuals have utility arising from making telephone calls and from subscribing to the \( j \in J \) network (network benefits).

The following subsections will detail the consumer’s and operator’s characteristics, defining their parameters, variables and optimization problems.

2.1 – Consumer’s description

The consumers of mobile telecommunication services will be able to make three types of calls. The consumer can call to a cell phone of another mobile network (M2M on-net), of the same mobile network (M2M off-net), and to a landline number (M2F). Their unitary prices are \( p_{mn} \), \( p_{mf} \) and \( p_f \) respectively. On the other hand, the landline consumers will make calls only to the mobile customers (F2M) at a unitary price \( P \). Evidently landline customers are able to call to other

---

3 The non-integrated operators are those one that operates only on the landline telecommunication market.

4 Wright et al (2007) considers the unit prices \( (p_{mn}^j; p_f^j) \), once that he considers \( p_{mn}^j = p_{mf}^j \).
landline customers; however, the price of that type of call is not influenced by the MTR, being irrelevant in our analysis. The whole population \( N \) has access to landline services\(^5\).

Suppose that individual \( i \) is affiliated to the operator \( j \). Let \( q_{ij}^{mn} \) be the annual quantity of minutes of calls from individual \( i \) to each customer of operator \( j \). Analogously, let \( q_{ij}^{mf} \) be the annual quantity of minutes of calls from individual \( i \) to each customer of operators different from \( j \). Finally, \( q_{ij}^{f} \) has an analogous definition. Thus, the total of minutes of calls made by \( i \) during the year will be:

\[
Q_{ij} = q_{ij}^{mn} \cdot n_j + q_{ij}^{mf} \cdot n_{xj} + q_{ij}^{f} \cdot N, \tag{1}
\]

where \( n_j \) and \( n_{xj} \) are the quantity of customers of the operator \( j \) and the quantity of customers from other operators respectively. Dividing the total of minutes by \( N \) we get:

\[
\frac{Q_{ij}}{N} = \frac{q_{ij}^{mn} \cdot s_j + q_{ij}^{mf} \cdot s_{xj} + q_{ij}^{f}}{N}, \tag{2}
\]

where \( s_j = \frac{n_j}{N} \) and \( s_{xj} = \frac{n_{xj}}{N} \) are the share of the population served by the operator \( j \) and the share of the population served by other operators respectively.

We then can define the consumer’s problem which is affiliated to operator \( j \) as:

\[
\max_{q^{mn},q^{mf},q^{f}} [u_i (q^{mn}) - q^{mn} \cdot s_j \cdot P_j^{mn} ] + [u_i (q^{mf}) - q^{mf} \cdot s_{xj} \cdot P_j^{mf} ] + [u_i (q^{f}) - q^{f} \cdot P_j^{mf} ], \tag{3}
\]

where \( u_i (q^{mn}) \), \( u_i (q^{mf}) \) and \( u_i (q^{f}) \) are the consumer utilities due to on-net, off-net and landline calls respectively. As usual, the quasi-linear form of the utility function allows us to analyze and adding up the consumer and the producer surplus of the economy.

This modification to the model of Wright et al (2007) is made because in the Brazilian case the MTR is charged also from the mobile networks when terminating their calls in another mobile network. In this context does not make sense the hypothesis of a same price for the M2M off-net and the M2M on-net calls.

The utility function to be used is that corresponding to a constant price-elasticity demand:

\[
u_i(q) = \rho \cdot a_i \cdot (q)^{-\frac{\varepsilon - 1}{\varepsilon}}, \tag{4}\]

\(^5\)This hypothesis is made in view of the General Plan of Goals for Universal Services (PGMU), established through the Decree Nº 4.769 (BRASIL 2003b), which guarantees that all the cities with more than 300 inhabitants must have access to landline telecommunications.
where $\rho \in [0,1]$ is the mobile telecommunication service penetration rate\(^6\), $a_i \sim U[a_{\text{min}}, a_{\text{max}}]$ is a parameter of individuals heterogeneity ($0 \leq a_{\text{min}} \leq a_{\text{max}} < \infty$) and $\varepsilon > 0$ is the demand price-elasticity. This functional form adopted for the utility function will be tested in section 3.

Solving problem (3), we obtain the demand functions:

$$q_{i,j}^{mn} = \left(\frac{\rho a_i \delta}{s_j \cdot p_j^{mn}}\right)^{\varepsilon} \text{ and } q_{i,j}^{mf} = \left(\frac{\rho a_i \delta}{s_j \cdot p_j^{mf}}\right)^{\varepsilon} \text{ and } q_{i,j}^{r} = \left(\frac{a_i \delta}{p_j^{r}}\right)^{\varepsilon}, \text{ where } \delta = \frac{\varepsilon - 1}{\varepsilon}$$

To model the utility of being a subscriber of a specific operator (network benefit) we follow the Wright et al (2007) approach assuming that each operator is located on a vertex of a $J$-simplex and that the individuals are uniformly distributed along the edges of this simplex. Normalizing the total edge length of the simplex by one, each edge will have the length $L = 2/(J(J - 1))$.

Thus, if individual $i$ is located in one of these edges, the number $x_{i \rightarrow j} \in [0, L]$ will represent the distance between individual $i$ and the vertex of operator $j$. So, the payoff of an individual being a customer of operator $j$ is:

$$\theta_j = \beta_j - tx_{i \rightarrow j}$$

Where $\beta_j$ is the maximum benefit from being a customer of operator $j$, what happens when $x_{i \rightarrow j} = 0$. The parameter $t$ represents a rate at which the maximum benefit $\beta_j$ declines as the distance $x_{i \rightarrow j}$ increases. This parameter $t$ may be understood as a displacement cost (a preference parameter) incurred by the consumer to reach the vertexes.

Therefore, the net utility of consumer $i$ when being a customer of operator $j$ results from substituting (5) in the objective function of (3), adding up (6) and subtracting $r_j$, the annual rental charged by the operator $j$:

$$U_{i,j}(x_i, a_i) = (\rho a_i)^{\varepsilon} \delta^{\varepsilon - 1} \varepsilon^{-1} \left(\frac{s_j \cdot p_j^{mn}}{s_j \cdot p_j^{mf}}\right)^{\varepsilon - 1} + \left(\frac{s_j \cdot p_j^{mf}}{p_j^{r}}\right)^{\varepsilon - 1} + \beta_j - tx_{i \rightarrow j} - r_j,$$

where $x_i = \left(x_{i \rightarrow j}\right)_{j=1}^{J}$ is the relative position of $i$ with respect to operator $j$ and $r_j$ is the annual rental charged by the operator $j$. Therefore, each consumer will be characterized by a pair $(x_i; a_i)$.

The decision rule for individual $i$ choosing the mobile operator $j$ (which is represented by $i \in j$) is given by (8):

$$\text{If } \left(U_{i,j}(x_i, a_i) > 0, \text{ and } U_{i,j}(x_i, a_i) > U_{i,k}(x_i, a_i), \forall k \neq j \right) \Rightarrow i \in j$$

\(^6\) The mobile penetration rate is formally defined as $\rho = \left(\sum_{j=1}^{J} n_j\right)/N$. 

---

The demand for calls originated in the landline network to mobile network customers will be modeled through a linear demand function defined as:

\[ Q = B_1 - B_2 P \]  

(9)

where \( P \) is the price charged per minute when making calls from landline networks to mobile networks and \( Q \) is the demand of these kind of calls.

### 2.2 – Operator’s description

The mobile operators aim to maximize their profits, given the pricing decisions of the competitors. Thus, the decision variables of an operator are the rentals \((r_j)\) and the unitary prices \(p_{jm}^{mn}, p_{jm}^{mf} \) and \(p_{jf}^{f}\) (M2M on-net calls, M2M off-net calls and M2F calls). Operator’s cost comes from the establishment of calls within its network and from the payment of the MTR to other operators when the call targets a customer of another network. The variables and parameters are summarized in Table 2.1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p_{jm}^{mn})</td>
<td>Price charged by operator (j) for each minute of a M2M on-net call.</td>
<td>Revenue</td>
</tr>
<tr>
<td>(p_{jm}^{mf})</td>
<td>Price charged by operator (j) for each minute of a M2M off-net call.</td>
<td>Revenue</td>
</tr>
<tr>
<td>(p_{jf}^{f})</td>
<td>Price charged by operator (j) for each minute of a M2F call.</td>
<td>Revenue</td>
</tr>
<tr>
<td>(r_j)</td>
<td>Annual rental charged by the mobile operators (j) to each of it’s customer.</td>
<td>Revenue</td>
</tr>
<tr>
<td>(A)</td>
<td>Mobile termination rate charged per minute by mobile operator (j) to other operators that terminate calls in operator’s (j) network.</td>
<td>Revenue/Cost</td>
</tr>
<tr>
<td>(C)</td>
<td>Cost of originating a call in the mobile network.</td>
<td>Cost</td>
</tr>
<tr>
<td>(C)</td>
<td>Cost of originating a call in the landline network.</td>
<td>Cost</td>
</tr>
<tr>
<td>(F)</td>
<td>Annual fixed-cost per-customer to mobile firm of non-call service provision.</td>
<td>Cost</td>
</tr>
</tbody>
</table>

Table 1 – Operator’s sources of revenue and costs

We are going to assume that the MTR (variable \(A\)) is the same for mobile network operators and defined by the NRA. This simplifying assumption appears reasonable in the Brazilian case, since the MTR charged by operators vary between R$ 0.41 and R$ 0.39.

Therefore, we can define operator’s profit from originating calls as:
\[
\Pi_j^I = \sum_{i=1}^{N} [(p_{i,j}^{mn} - c)q_{n,j}^{mn} + (p_{i,j}^{mf} - c - A)q_{n,j}^{mf} + (p_{i,j}^{f} - c - C)q_{i,j}^{f}N]j_{i\in j}
\]  

Where \( I_{(i\in j)} \) is the indicator function which assumes the value 1 if \( i \) is a customer of \( j \) and 0 otherwise.

Dividing (10) by \( N \) we obtain the per capita profit from originating calls:

\[
\pi_j = \frac{\Pi_j^I}{N} = \sum_{i=1}^{N} [(p_{i,j}^{mn} - c)q_{n,j}^{mn} + (p_{i,j}^{mf} - c - A)q_{n,j}^{mf} + (p_{i,j}^{f} - c - C)q_{i,j}^{f}N]j_{i\in j}
\]

The profit made from rentals and its per capita expression can be defined as:

\[
\Pi_j^a = n_j(r_j - F) \quad \text{and} \quad \pi_j^a = \frac{\Pi_j^a}{N} = s_j(r_j - F)
\]

The profit made from charging the MTR to the landline network and to other mobile operators are:

\[
\Pi_j^{mf} = N.n_j.(A - c).Q \quad \text{and} \quad \Pi_j^{im} = n_j.(A - c).\sum_{k \neq j}^{J} \sum_{i=1}^{N} q_{i,k}^{mf}I_{(i\in j)}
\]

Their per capita correspondents are:

\[
\pi_j^{mf} = \frac{\Pi_j^{mf}}{N} = n_j.(A - c).Q \quad \text{and} \quad \pi_j^{im} = \frac{\Pi_j^{im}}{N} = s_j.(A - c).\sum_{k \neq j}^{J} \sum_{i=1}^{N} q_{i,k}^{mf}I_{(i\in j)}
\]

Finally, the total profit and the per capita total profit of mobile operator \( j \) are:

\[
\Pi_j = \Pi_j^I + \Pi_j^{a} + \Pi_j^{mf} + \Pi_j^{im} \quad \text{and} \quad \pi_j = \pi_j^I + \pi_j^a + \pi_j^{mf} + \pi_j^{im}
\]

We assume, according to Wright et al (2007), that the price \( P \) is defined by the NRA at the level of the first-best price, namely, equal to the cost of originating a call in the landline network and terminating it in the mobile network. Thus, \( P \) is defined as:

\[
P = C + A
\]

2.3 – Model solution

An equilibrium for the model described in Sub-Sections 2.1 and 2.2 is a vector of prices 
\( p = (p_{j}^{mn})_{j=1}^{J}; (p_{j}^{mf})_{j=1}^{J}; (p_{j}^{f})_{j=1}^{J}; (r_{j})_{j=1}^{J} \in R^{J} \) and for each operator \( j \) a subset \( N_j \subseteq N \) of consumers \( (n_j = \#(N_j) \), the number of elements of \( N_j \), such that for each \( j \in J \):

i) \( \forall i \in N_j : U_{i,j}(x_i,a_i) > 0 \) and \( \forall k \neq j, U_{i,j}(x_i,a_i) > U_{i,k}(x_i,a_i) \)
ii) \( p_j \) maximizes \( \pi_j(p'_j, p_{-j}) \) in the variable \( p'_j \).

In order to facilitate the numerical procedure to find the equilibrium, we will suppose that competition in the mobile network market is in the Stackelberg sense, where the degree of leadership is given by the share of the market the operator attends. That assumption seems reasonable since consumers (in general) prefer operators with greater share of the market.

Therefore, under that assumption on the form of competition, we propose the following algorithm to find the equilibrium: Define an index \( l \) with initial value \( l = 1 \). Choose initial values for prices \( p(l-1) \in R^{4J} \) and penetration rate \( \rho(l-1) \in [0,1] \). Select the parameters which define consumers by choosing an “\( N \)” sample in \([a_{\text{min}}, a_{\text{max}}] \) (to define the \( a_i \)'s) and positions in a partition of \([0, L] \) with \( 2N/(J(J-1)) \) points (to define the \( x_i \)'s). The iteration in \( l \) is as follows:

a) Let \( N_j(l) = \frac{1}{l} \in N; U_{i,j}(x_i, a_j) > 0 \) and \( \forall k \neq j, U_{i,j}(x_i, a_j) > U_{i,k}(x_i, a_k) \).

Define \( n_j(l) = \#(N_j(l)) \) and reorder \( J \) such that \( n_1(l) < \cdots < n_J(l) \).

b) Find sequentially the new prices: for each \( j = 1, \ldots, J \) define:

\[
    p_j(l) = \text{ArgMax}_{p_j \in R^L} \pi_j(p(l), \ldots, p_{j-1}(l), p_j, p_{j+1}(l-1), \ldots, p_J(l-1))
\]

c) Compute the new penetration rate:

\[
    \rho(l) = \sum_{j=1}^J n_j(l)/N
\]

d) If \( |\rho(l) - \rho(l-1)| > \tau \) (a given tolerance level) then put \( l = l+1 \) and restart the proceeding in “a”;

otherwise keep the values of \( p = p(l) \in R^{4J} \) and \( (N_j)^J_{j=1} = (N_j(l))^J_{j=1} \) as the equilibrium of the model.

2.4 WELFARE ANALYSIS

To assess the impact of the MTR over welfare we will analyze the consumer total surplus (EC) which is the sum of the mobile telephony customer surplus \( (EC_m) \) and the fixed telephony customer surplus \( (EC_f) \):

\[
    EC_m = \sum_{i=1}^N U_i(x_i, a_i) I_{[U_i > 0]}
\]

and

\[
    EC_f = \frac{1}{2} \left( \sum_{j=1}^J n_j \right) \left( \frac{B_1^2}{B_2} - 2B_1P + B_2P^2 \right)
\]

The producer surplus \( (EP) \) is:

\[
    EP = \sum_{j=1}^J \Pi_j - n_j F = N \left( \sum_{j=1}^J \pi_j - s_j F \right)
\]

---

7 The following notation is used: \( p_j \) is de vector formed by the components of \( p \) corresponding to the \( j \) operator, \( p_{-j} \) is de
Thus, the economic total surplus \((EE)\) is:

\[
EE = EC + EP
\]

(19)

3. PRICE-ELASTICITY ESTIMATION AND MODEL CALIBRATION

3.1 – Price-elasticity estimation

We use panel data to estimate the price elasticity of demand in Brazil. The functional form and specifications are standard in the literature as can be seen in Farooq, Ullah and Rahmani (2010). Thus, the theoretical model is:

\[
\ln Min_{it} = \phi_0 + \phi_1 \ln RPM_{it} + \lambda_2 (D_{2i} \ln RPM_{it}) + \lambda_3 (D_{3i} \ln RPM_{it}) + \lambda_4 (D_{4i} \ln RPM_{it}) + \pi_2 D_{2i} + \pi_3 D_{3i} + \pi_4 D_{4i} + \omega_{it}
\]

where \(Min_{it}\) is the number of minutes of calls originating from a mobile operator \(i\) in period \(t\); \(RPM_{it}\) corresponds to the average real price charged by the minute from calls originated in the network of mobile operator \(i\) in period \(t\); \(D_{ji}\) are dummy variables which assume \(D_{ji} = 1\) if the observation belongs to firm \(j\) so that \(\pi_j D_{ji}\) and \(\lambda_j (D_{ji} \ln RPM_{it})\) represent dummy variables of differential intercept and slope, respectively. At last, \(\omega_{it}\) represents the errors that are not correlated with the explanatory variables of the models.

We will use six specifications for the model. The Model 1 is more general and considers that both the intercepts and the slopes vary among all operators. Model 2 assumes that the intercepts are constant among the operators, but the slopes vary among them. Model 3 in turn considers that the intercepts vary among operators, but the slope is the same for all operators. The Model 3 is expanded to assess the existence of structural change in the data, as presented below. Thus, the Model 4 considers a structural change in level, while the Model 5 considers a structural change in slope. The Model 6 considers that both the slopes and the intercepts do vary neither among the mobile operators nor over time and uses the random effects to estimate the price elasticity.

The first five models are estimated by the OLS method and the sixth is estimated by the random effects model and using the test proposed by Hausman (1978) we choose between models of fixed and random effects.

It is used quarterly data from 1Q04 to 4Q08 of the mobile operators Vivo, Claro, Tim and Other, which represented, on average, 88% of the Brazilian mobile market.

---

vector formed by the components of \(p\) corresponding to all the operators different from \(j\).

\(^8\) MERRILL LYNCH (2009) consolidated the data from small operators (Amazonia Celular, Telemig Celular and Brazil Telecom GSM) in a series entitled “Others”. As of 3Q08, with the incorporation of Telemig Celular and Amazonia Celular by Vivo and Oi, respectively, the “Others” series have contained data from Brazil Telecom GSM only.
These data were obtained from the Merrill Lynch’s (2009) database, the Interactive Global Wireless Matrix. The values of revenue per minute (RPM⁹), were available on the Brazilian currency (R$). These values were deflated by a price index (IPCA), so that the RPM data are in values of March of 2004.

The data for the total minutes of calls originating on the networks of operators were computed based on the values of minutes of use (MOU¹⁰).

A binary variable called Incorp was included to test structural changes due to the incorporation of Telemig Celular by Vivo in June 2008.

To test the stationarity of the panel we use the unit root tests proposed by Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003) and Nyblom and Harvey (2000). These tests did not presented conclusive results, however, considering that the unit root is a long-run factor, and that our data covers four years, we consider that the stationarity of the panel is not a critical issue in this case.

The results of the estimates are presented in Tables 3.1 and 3.2. They indicate that demand for mobile services in Brazil is, statistically, elastic.

The statistic of the Hausman test indicates non-rejection of the null hypothesis that the estimates obtained through the random effects model are consistent. Moreover, the reduced amount of cross-sectional data (four operators) and the large number of temporal observations (twenty quarterly data) makes very small the difference between the estimates made by the fixed effects model (Model 3) and the random effects model (Model 6).

Considering that the application of the model developed in Section 2 demands a single value of the price-elasticity, only Models 3, 4, 5 and 6 fit into our needs. However, Models 4 and 5 control for structural break due to the incorporation of Telemig Celular by Vivo in June 2008. Since that the existence of structural break did not presented statistical significance, we discard the estimates of these models.

Considering that Models 3 and 6 are those ones that fit into our needs for the application of the model developed in Section 2, and that the estimate of the price-elasticity in these Models are very similar, we than will use estimate of Model 3 which is a price-elasticity equal to -1.62. We must stress that the use of estimates of Model 6 (-1.64) do not affect significantly the results and the conclusions of the model.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const.</td>
<td>-0.391731</td>
<td>-0.462130**</td>
<td>-0.916435***</td>
<td>-0.875082***</td>
<td>-0.803830***</td>
</tr>
<tr>
<td></td>
<td>(0.1922)</td>
<td>(0.0149)</td>
<td>(2.00E-07)</td>
<td>(0.0003)</td>
<td>(0.0011)</td>
</tr>
<tr>
<td>LnRPMReal</td>
<td>-1.04807***</td>
<td>-1.12255***</td>
<td>-1.61898***</td>
<td>-1.56946***</td>
<td>-1.48665***</td>
</tr>
</tbody>
</table>

⁹ The revenue per minute (RPM) is a proxy for prices widely used by the mobile market. The RPM is calculated by dividing monthly voice-only Average Revenue per User (ARPU) by the Minutes of Use per month per average user (MOU).

¹⁰ “The Minutes of Use per month per average user is calculated by dividing total minutes of use on the operator’s network by the average subscriber base during the quarter.” (Merrill Lynch 2009, p. 200).
## Table 2 – Results of the estimations of models 1 to 5 – Pooled OLS

<table>
<thead>
<tr>
<th></th>
<th>Model 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const.</td>
<td>-0,425429</td>
</tr>
<tr>
<td></td>
<td>(0,1370)</td>
</tr>
<tr>
<td>LnRPMReal</td>
<td>-1,63906***</td>
</tr>
<tr>
<td></td>
<td>(1,23e-015)</td>
</tr>
<tr>
<td>Teste de Hausman</td>
<td>1,02849</td>
</tr>
<tr>
<td></td>
<td>(0,310513)</td>
</tr>
</tbody>
</table>

Obs.: *** Estimates significant at 1%.

Figures in brackets refer to the p-value of the estimates.
3.2 – Model calibration

Given $c$, $C$ and $A$, the parameters $\{a_{\text{min}}, a_{\text{max}}, t, (\beta_j)_{j=1}^4, B_1, B_2\}$ are calibrated as follows:

- Parameters $\beta_1, \ldots, \beta_j$ and $t$ are calibrated in order to reproduce the values of $n_1, \ldots, n_j$ and $\rho$.

- Parameter $a_{\text{min}}$ will be set at $a_{\text{min}} = 0$, and $a_{\text{max}}$ will be adjusted to ensure that the predicted MOU values are similar to those observed in the market.

- Parameters $B_1, B_2$ will be calibrated to ensure that the predicted ARPU$^{11}$ and the share of operators revenue from interconnection are similar to those observed in the Brazilian market.

The Brazilian mobile telephony market data are the following:

- $J = 4$, considering operators Vivo ($j = 1$), Claro ($j = 2$), Tim ($j = 3$) and Oi ($j = 4$).

- $N = 191.2$ million, with 159 million mobile operator’s customers, therefore representing a penetration rate of $\rho = 0.831$.

- 46.8 million subscribers from Vivo (29.4% of market share).

- 40.4 million subscribers from Claro (25.4% of market share).

- 37.8 million subscribers from Tim (23.7% of market share).

- 33.9 million subscribers from Oi (21.3% of market share).

- The values of $c = 0.10$ and $C = 0.05$ are the same used in Wright et al (2007).

- For the interconnection rate will be considered the average of the rates observed in the four operators $A = 0.403$.

- The annual fixed cost $F$ is considered as R$ 84.00 in order of the estimates of fixed monthly cost of $7.00, as shown in Ellery Jr (2006).

Considering the data presented above and the calibration method, we find the following parameter values:

- $a_{\text{min}} = 0$ and $a_{\text{max}} = 0.4$;

- $\beta_1 = 210, \beta_2 = 185, \beta_3 = 165$ and $\beta_4 = 150$;

$^{11}$ ARPU is defined as the Average Revenue per User.
Using the model described in Section 2 with the parameters calibrated and estimated in Section 3 we executed some simulations in order to analyze the impacts of variations in the MTR on some endogenous variables. In all figures below, the horizontal axis represents the values of the MTR.

In Figure 4.1 it is observed that an increase in the MTR provokes a decrease in the rentals of each operator. This effect arises from the fact that by increasing $A$, the operators will compete for this interconnection revenue. To capture this revenue operators reduce the price charged in the form of rentals, in order to get more clients. As a consequence, the mobile penetration rates also increases, as seen in Figure 4.2.

Since we are allowing operators to set differentiated prices for on-net and off-net calls, an increase in the MTR leads to an increase in prices of off-net calls (and therefore a decrease in the M2M off-net traffic) and a decrease in prices of on-net calls (and increase in the M2M on-net traffic). In this way, the waterbed effect can be observed. These effects are shown in Figures 4.3 and 4.4.

![Figure 1 – Rentals](image-url)
Figure 2 - Penetration

Figure 3 - Total M2M off-net traffic
An interesting effect may be found in the relationship between the MTR and the total F2M traffic. If in one hand from the increase of the MTR (A) follows an increase in penetration ($\rho$), which results in an increase in F2M traffic, on the other hand, this increase in MTR is fully passed on to the price of F2M call ($P$), resulting in a reduction of the total traffic of this type of call. Thus, one can find the value of the MTR that maximizes the F2M traffic, as shown in Figure 4.5.
Due to the different effects of the interconnection charge over the different types of calls, we present in Figures 4.6 and 4.7 the total traffic originated on mobile networks and the MOU predicted by the model. Both variables are maximized in $A = 0.20$.

![Figure 6 – Total traffic (minutes)](image)

![Figure 7 – Minutes of Use (minutes)](image)

With respect to the total consumer surplus, we can argue that for small values of $A$, the penetration rate is low, so an increase in $A$ will bring an increase in the consumer surplus. However, for large values of $A$, the variation in the penetration
rate is not significant and the fall of the telephony traffic dominates, provoking a decrease in the consumer surplus. Figure 4.8 shows the maximum for the total consumer surplus.

![Figure 8 – Total consumers' surplus with $A \in [0.35; 0.55]$](image)

On the other hand, due to the significant increase of the telecommunication operators profits, the economic surplus is always an increasing function of the MTR, as depicted in Figure 4.9.

![Figure 9 – Economic surplus](image)
The impact of the MTR on the degree of competition may be analyzed calculating the inverse of the Herfindahl-Hirschman Index (IHHI). It is a measure of the degree of the market competition. Figure 4.10 shows that the market competition is maximized at $A = 0$.

![Figure 10 – Inverse Herfindahl-Hirschman Index (IHHI)](image)

Thus, we can observe that the optimal value of the MTR depends on the objective of the NRA. Table 4.11 shows the optimal values for each possible objective that the regulator may pursue.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Optimal MTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration ($\rho$)</td>
<td>R$\ 0.45$</td>
</tr>
<tr>
<td>Mobile traffic</td>
<td>R$\ 0.30$</td>
</tr>
<tr>
<td>Landline traffic</td>
<td>R$\ 0.20$</td>
</tr>
<tr>
<td>Total traffic</td>
<td>R$\ 0.20$</td>
</tr>
<tr>
<td>MOU</td>
<td>R$\ 0.20$</td>
</tr>
<tr>
<td>Landline consumers’ surplus</td>
<td>R$\ 0.15$</td>
</tr>
<tr>
<td>Mobile consumers’ surplus</td>
<td>R$\ 0.40$</td>
</tr>
<tr>
<td>Total consumers’ surplus</td>
<td>R$\ 0.40$</td>
</tr>
<tr>
<td>Economic surplus</td>
<td>&gt; R$\ 0.55$</td>
</tr>
<tr>
<td>Competition (IHHI)</td>
<td>R$\ 0.00$</td>
</tr>
</tbody>
</table>

Table 4– Optimal MTR

5. CONCLUSION
In the mobile telephony market, the presence of positive externalities coming from the penetration rate in that service must be taken into account when regulatory policies are implemented. The market power in addition to the network effects raise a phenomenon called “the waterbed effect”, where the variation of one variable controlled by the regulator produces changes in other variables and in some cases may reduce the consumer welfare.

In this work we extend the model proposed by Wright et al (2007) in order to adjust it to the Brazilian market. Specifically, we introduce differentiated prices for on-net and off-net calls and consider that mobile operators are also charged with the mobile termination rate. After estimating the price-elasticity of mobile services demand, we calibrate the model with some Brazilian observed data. Finally, we perform a comparative static analysis where it is possible to measure the effect of the MTR over other variables of the model.

In this way, we conclude that the choice of the MTR depends on the objective variable that the regulator aims to maximize.

Despite the natural limitations of the analysis (lack of data for operators costs and strong assumptions on the consumer preferences) the results presented here serve as a direction for the regulatory entities. According to our results, the classical result, where the price that maximizes total economic surplus is equal to marginal cost, does not hold in general, for the interconnection charge for mobile networks.

However, it is essential that regulators know the operators’ cost structures and that they have a clear objective for regulation. So, the ANATEL’s initiative of implementation of the cost model, according to ANATEL (2005a), seems to go in the right direction. However, we note that the optimal MTR, depending on the penetration of mobile telephony and the goal of regulation, is not necessarily equal to the cost of interconnection, in view of the waterbed effect and the positive externalities of the market growth of mobile telephony over the landline telephony market.

ACKNOWLEDGMENTS
The authors are grateful to the financial support of CNPq (Brazil) through grants 305317/2003-2 and 472178/2006-7.

REFERENCES

Brasil (2003b), Decreto n.º 4.769, de 27 de junho de 2003
CRT (2007), Resolución 1.763 de 2007, Comisión de Regulación de Telecomunicaciones, Colombia.


