Enforcing free roaming among UE countries: an economic analysis

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***Abstract*—In October 2015, the European parliament has decided to forbid roaming charges among UE mobile phone users, starting June 2017, as a first step toward the unification of the European digital market.**

In this paper, we aim at investigating the consequences of such a measure from an economic perspective. In particular, we analyze the effect of the willingness-to-pay heterogeneity among users (also due to wealth heterogeneity), and the fact that the roaming behavior is positively correlated with wealth.

Considering a monopolistic operator, we compare the paid-roaming situation (with usage-based pricing) to the envisioned free-roaming from the point of view of the operator and of users. Our analysis suggests that imposing free roaming degrades the revenues of the operator but can also deter some users from subscribing. This is because paid roaming allows some partial market segmentation; hence we conclude that such (apparently beneficial) regulatory decisions must be taken with care.

I. Introduction

Users are more and more dependent on online services (e-mail, geographical mapping, ridesharing, ...), and maintaining access to those services while abroad is increasingly valuable. Hence a strong demand for the possibility of *roaming*, i.e., of having an operator in the visited country provide connectivity services in a seamless manner. This is done through arrangements between operators, that we do not consider in this paper. We rather focus here on the economic aspects of roaming from the user point of view through the prices charged. Since user willingness-to-pay for global connectivity is large, and because of very limited competition on that segment [2], [4], the market ends up with relatively high prices for such services.

While some existing work consider the economic aspects of national roaming, with cooperation/competition issues among operators [7], we concentrate on international roaming. More precisely, we investigate the potential impact of the recent decision of the European parliament[1] to forbid roaming charges in Europe as of June 15, 2017. Already, since April 2016 those roaming charges have been capped, as a period of transition. The aim of those decisions is to create an open European digital market, and foster economic activity by easing travels among EU countries. Also, imposing free-of-charge roaming carries an idea of improved fairness among users, while paid roaming could lead to prohibitive costs for some users. Finally, it is well-known that users have a preference for flat-rate pricing; having no extra charge whatever the data usage (in volume and geography terms) goes in that direction. This was pointed out in [3], but at the time (2009) free roaming seemed like an unrealistic option.

Our claim in this paper is that free roaming being beneficial is not always obvious. To investigate the question, we take a simple model with one monopoly operator implementing usage-based roaming pricing (when allowed), and consider the pricing decisions with and without the free-roaming constraint. Our user-side model assumes that there is a positive correlation between the willingness-to-pay for the domestic connectivity service, and the willingness-to-pay for the roaming connectivity service, since both are linked to user wealth (and in addition, we expect wealthier people to travel more often). Assuming the operator selects revenue-maximizing prices for both cases [5], we show that imposing free-of-charge roaming to the operator can actually worsen the situation for several actors: the operator revenue diminishes, less users subscribe to the (domestic) service, and the least wealthy users would have preferred the paid-roaming situation. This is due to the fact that extra roaming prices allow to discriminate high-income users: the operator can charge less for the basic service and still make substantial revenues through roaming charges that it collects mainly from those wealthy users. Removing that option, all users are charged the same amount: as the unique revenue source, the subscription price is larger, leading to less users subscribing to the service and low-income users being worse off. In summary, enforcing free roaming only benefits to high-income users, to the expense of low-income ones, a phenomenon going against the initial fairness-improvement aim of free roaming. Hence our recommendation is that those aspects be considered with care when making such regulatory decisions or monitoring their implementation.

The remainder of this paper is organized as follows. Section II presents our model for user preferences and operator revenues. The outcomes are computed in Section III, and the paid-roaming and free-roaming situations are compared in Section IV. Conclusions and directions for future work are given in Section V.

[1] https://ec.europa.eu/digital-single-market/en/news/new-rules-roaming-charges-and-open-internet

II. Model

Our mathematical model focuses on a single country, but we keep in mind that different countries will correspond to different markets, hence different distributions among user willingness-to-pay for digital services: this is particularly salient in the UE, where GDP per capita among countries vary by a factor up to 15[2].

Note that the envisioned rules allow operators to limit roaming rights for frequent travelers, hence we assume here that users can only subscribe to providers operating in their country of residence[3], a rule imposed by the EU to prevent (unfair) competition between countries. Therefore, the rule does not exactly create a unified European market, and we can still expect discrepancies among subscription prices in different countries.

A. Pricing plan

In this paper, we assume that a monopolistic provider operates in the considered country: following the most popular data plans, we consider that this provider offers an unlimited data consumption plan when in the residence country, at a price (per month) p. Market segmentation and the choice of other quota-based plans are worth studying but are beyond the scope of this paper, where we focus on the impact of roaming charges.

Again following the current market conditions, we assume that roaming data is charged based on usage, through a simple linear pricing scheme. The price per volume unit for roaming traffic is denoted by c, so that a user consuming a roaming volume v (possibly null) over a month, is charged a total amount $p + cv$.

B. User preferences

For this plan, users have different willingness-to-pay values (in monetary units per month) for the domestic data use. We denote that value for a particular user by θ, and assume that the distribution of θ over the market is known to the operator.

Also, users have different needs and preferences in terms of data consumption while roaming: some just travel less than others, and some are willing to pay more for mobile access than others in roaming situations. Nevertheless, we expect a positive correlation between the willingness-to-pay θ for the (local) data plan, and the willingness-to-pay function (in terms of volume) for roaming data, which we denote by $r_\theta(\cdot)$, a function of the consumed volume over a month.

As a result, for a generic user characterized by θ, the net utility when subscribing to the operator's offer and consuming a volume v_r per month (on average) when roaming is of the form

$$U = \theta - p + r_\theta(v_r) - cv_r. \quad (1)$$

In this paper, to carry out analytical derivations, a specific form for r_θ will be considered, as commonly adopted in [1], [6], but other choices can be studied similarly:

[2]Source: https://en.wikipedia.org/wiki/Economy_of_the_European_Union

[3]http://europa.eu/rapid/press-release_IP-16-3111_en.htm

Assumption A: For any value of θ, the function r_θ is such that

$$r_\theta(x) = \begin{cases} \theta x - \alpha \frac{x^2}{2} & \text{if } x \leq \frac{\theta}{\alpha} \\ \frac{\theta^2}{2\alpha} & \text{otherwise.} \end{cases}$$

with α a fixed parameter. The marginal valuation function r'_θ then has the simple expression

$$r'_\theta(x) = [\theta - \alpha x]^+$$

where $[y]^+ := \max(y, 0)$.

Functions defined by Assumption A are non-negative, null at 0, non-decreasing and concave, and cover some expected effects:

- users with high θ values (i.e., willing to pay more for the plan even without roaming) are also willing to pay more for roaming data usage than users with low θ values;
- and those users are more frequently out of their residence country, so that if roaming was at no extra cost (i.e., $c = 0$) they would consume a larger amount of roaming data, here $\frac{\theta}{\alpha}$.

III. User choices and operator revenue for fixed prices

We assume here that the subscription price p as well as the roaming data per-unit price c are fixed by the operator, and we analyze user choices. Later, we will consider that the operator is able to anticipate those choices, and uses this ability to set p and c so as to maximize revenue.

A type-θ user will consider whether or not to subscribe–and if so, how much roaming data to use–based on p and c. To do so, the user estimates how much roaming data $v_r(\theta)$ she would use, and just applies (1): if the net utility is positive the user subscribes, otherwise she doesn't. More specifically, we can define the optimal net value from roaming usage

$$V(\theta, c) := \max_{x \geq 0} r_\theta(x) - cx,$$

so that the net utility is simply $\theta - p + V(\theta, c)$, and the user subscribes if and only if $\theta + V(\theta, c) > p$.

Under Assumption A we simply have $V(\theta, c) = \frac{(\theta-c)^2}{2\alpha}\mathbb{1}_{\{\theta>c\}}$, obtained at a volume $v_r^*(\theta) = \left[\frac{\theta-c}{\alpha}\right]^+$, so the user subscribes if and only if

$$\theta + \frac{(\theta - c)^2}{2\alpha}\mathbb{1}_{\{\theta>c\}} > p. \quad (2)$$

The left-hand side of (2) is strictly increasing in θ. Consequently, if a user θ subscribes, any other user with $\tilde{\theta} \geq \theta$ also subscribes. Additionally, the left-hand side of (2) is continuous, null at 0 and tending to infinity when $\theta \to \infty$, hence there exists a unique solution $\bar{\theta}$ of

$$\bar{\theta} + \frac{(\bar{\theta} - c)^2}{2\alpha}\mathbb{1}_{\{\bar{\theta}>c\}} = p, \quad (3)$$

and the set of subscribers is the set $D := \{\theta : \theta > \bar{\theta}\}$. We then have the following proposition.

Proposition 1: For any price pair (p, c) the users who subscribe are those with $\theta > \bar{\theta}$, where

$$\bar{\theta} = \min\left(p, c - \alpha + \sqrt{\alpha^2 + 2\alpha[p-c]^+}\right). \quad (4)$$

Proof: If $c \geq p$, we immediately check that the solution to (3) is $\bar{\theta} = p$.

Alternatively, if $c < p$ the solution to (3) is in the open interval (c, p). More precisely, $\bar{\theta}$ is the unique root in (c, p) of the degree-two polynomial

$$\frac{(X-c)^2}{2\alpha} + X - p,$$

that is, $\bar{\theta} = c - \alpha + \sqrt{\alpha^2 + 2\alpha(p-c)}$.

We finally check that (4) summarizes both cases. ∎

A. Payed roaming

We assume without loss of generality a total mass 1 of users.

The ISP has to determine the prices p and c in order to maximize its revenue. The revenue of the ISP can be written

$$R(p,c) = \int_{\theta=\bar{\theta}}^{\infty} (p + c v_r^*(\theta)) \mathrm{d}F(\theta)$$

where F is the distribution of θ over the population of potential subscribers, and $v_r^*(\theta)$ the volume of roaming usage for a type-θ user. Recall that under Assumption A we have $v_r^*(\theta) = \left[\frac{\theta - c}{\alpha}\right]^+$.

We end up with

$$R(p,c) = p(1 - F(\bar{\theta})) + c \int_{\theta=\bar{\theta}}^{\infty} \frac{[\theta - c]^+}{\alpha} \mathrm{d}F(\theta).$$

If F is exponential with rate λ, we have

$$R(p,c) = pe^{-\lambda\bar{\theta}} + \frac{c}{\alpha} e^{-\lambda\bar{\theta}} [\bar{\theta} - c]^+ + \frac{c}{\alpha} \frac{e^{-\lambda c}}{\lambda} e^{-\lambda[\bar{\theta}-c]^+}$$

Determining the optimal revenue seems intractable analytically, but it can easily be done numerically.

B. Free roaming

We now consider the situation where the provider cannot charge for roaming usage, hence $c = 0$. In that case, the subscription price p can be adjusted to maximize revenue.

Proposition 2: For any subscription price p, the set of subscribers is $D = (\bar{\theta}, \infty) = \left(-\alpha + \sqrt{\alpha^2 + 2\alpha p}, \infty\right)$ and the revenue can be written $R(p,c) = p(1 - F(-\alpha + \sqrt{\alpha^2 + 2\alpha p}))$.

If F is exponential with rate λ, the revenue-maximizing p is $p = \frac{1 + \sqrt{1 + \alpha^2\lambda^2}}{\alpha\lambda^2}$.

Proof:

The expression of $\bar{\theta}$ comes directly from $c = 0$ in Proposition 1.

Still with $c = 0$, the expression of the ISP revenue can be simplified to $R(p, 0) = p(1 - F(-\alpha + \sqrt{\alpha^2 + 2\alpha p}))$.

For $F(x) = 1 - e^{-\lambda x}$, by differentiating with respect to p, we get a maximum when $1 - \lambda p \alpha / \sqrt{\alpha^2 + 2\alpha p} = 0$, that is, $p = \frac{1 + \sqrt{1 + \alpha^2\lambda^2}}{\alpha\lambda^2}$. ∎

IV. Comparing free roaming to paid roaming

Our goal in this section is to compare the impact of optimal strategies defined in the previous section. A question we would like to answer is: What is the impact of free roaming with respect to a paid one on the ISP revenue and on users in general. Let us observe a numerical example, with an exponential distribution of rate λ of user parameters.

Figure 1 displays the optimal subscription price p in terms of λ. Without the possibility for the ISP to make extra revenue

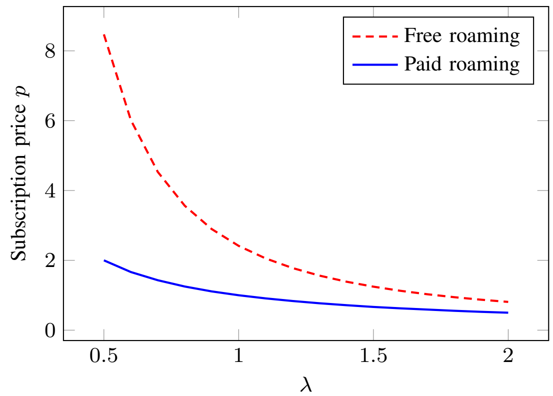

Figure 1. Revenue-maximizing subscription price, in terms of λ with $\alpha = 1$

from roaming usage, the base subscription price with free roaming is larger than the one with paid roaming. As expected, when λ increases (i.e., people are less wealthy) prices decrease in both cases.

Figure 2 displays the ISP revenue for both free and paid roaming in terms of λ when using the optimal prices, for $\alpha = 1$.

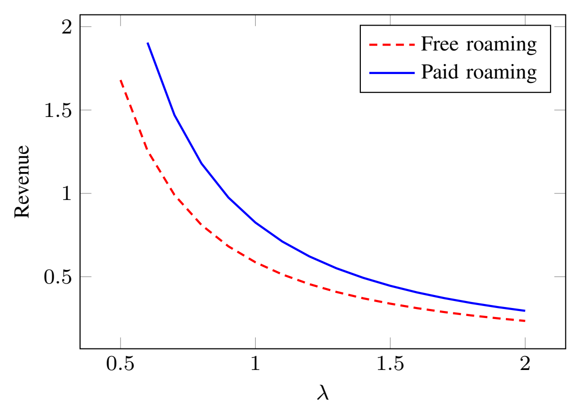

Figure 2. ISP revenue in terms of λ

Paid roaming naturally yields larger revenues since the provider has more degrees of freedom.

Now let us take a look at users, who differ through their type (the value of θ in our model). Figure 3 shows the threshold value $\bar{\theta}$, above which users subscribe and below which they do not. We observe that $\bar{\theta}$ is larger for free roaming than for paid roaming, hence imposing free roaming would lead to a smaller number of subscribers.

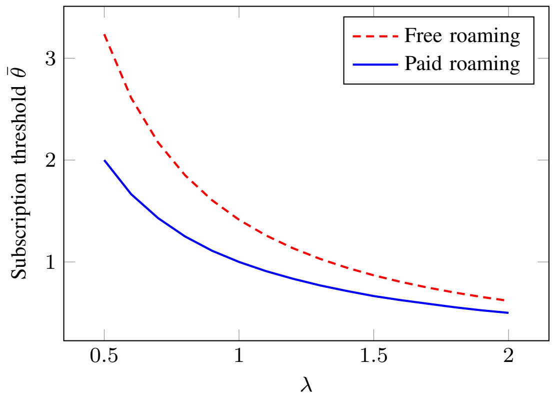

Figure 3. Subscription threshold $\bar{\theta}$, in terms of λ: users with $\theta > \bar{\theta}$ subscribe to the service.

Figures 4 and 5 respectively display the total price paid (subscription plus possible roaming) and the user utility, for each type-θ user. The figures show that with paid roaming,

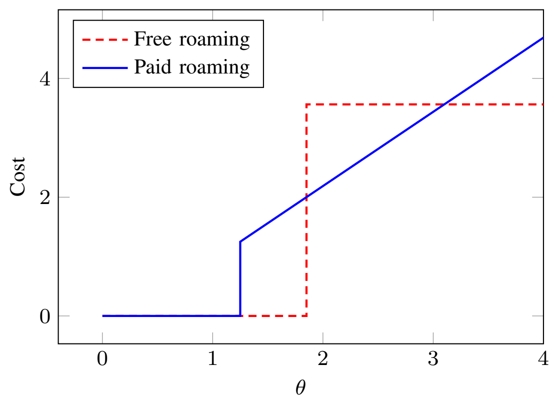

Figure 4. Total amount paid in terms of θ (at the optimal price), when $\lambda = 0.8$

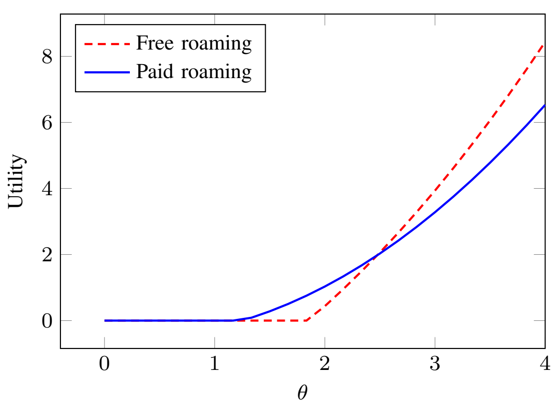

Figure 5. User utility in terms of θ (at the optimal prices), when $\lambda = 0.8$

most of the revenue comes from the most wealthy users, while with free roaming all subscribers contribute at the same level to the revenues. In terms of user utility, we can distinguish three zones for θ:

- users with very low θ values do not subscribe to the service in any scenario (paid or free roaming), and are not affected by the change;
- users with high θ values subscribe in both scenarios, but pay more and consume less in the paid-roaming case than in the free-roaming case, hence those users would prefer the free-roaming scenario;
- between those extremes, users strictly prefer the paid-roaming situation, since they benefit from a lower subscription price (which can allow them to subscribe while they would not in the free-roaming case) and have a limited roaming usage.

In addition to looking at the impact of the ISP policy on each user, we can look at its impact on the population as a whole, by considering consumer surplus. Consumer surplus is defined as the aggregated net utility of users:

$$\mathrm{CS} = \int_D (\theta - p + r_\theta(v_r(\theta)) - cv_r(\theta))\mathrm{d}F(\theta).$$

If p_r is the revenue-maximizing subscription price in case of free roaming, and (p_p, c_p) the revenue-maximizing prices in case of paid roaming, with CS_r and CS_p the corresponding consumers surpluses, we can simplify the formulas:

$$\begin{aligned}
\mathrm{CS}_r &= \int_{-\alpha+\sqrt{\alpha^2+2p_r\alpha}}^{\infty} (\theta - p_r + \theta^2/(2\alpha))\mathrm{d}F(\theta) \\
\mathrm{CS}_p &= \int_D \left(\theta - p_p + \frac{([\theta - c_p]^+)^2}{2\alpha}\right)\mathrm{d}F(\theta) \\
&= \left[\int_{\bar{\theta}}^{c_p} (\theta - p_p)\mathrm{d}F(\theta)\right]^+ \\
&\quad + \int_{\max(c_p,\bar{\theta})}^{\infty} \left(\theta - p_p + \frac{(\theta - c_p)^2}{2\alpha}\right)\mathrm{d}F(\theta)
\end{aligned}$$

For F exponential with rate λ, we end up with

$$\begin{aligned}
\mathrm{CS}_r &= \int_{-\alpha+\sqrt{\alpha^2+2\frac{1+\sqrt{1+\alpha^2\lambda^2}}{\lambda^2}}} \left(\theta - \frac{1+\sqrt{1+\alpha^2\lambda^2}}{\alpha\lambda^2} + \theta^2/(2\alpha)\right)\lambda e^{-\lambda\theta}\mathrm{d}\theta \\
&= e^{(-\lambda(-\alpha+\sqrt{(\alpha^2\lambda^2+2\sqrt{\alpha^2\lambda^2+1}+2)/\lambda^2}} \frac{\sqrt{\alpha^2\lambda^2+2\sqrt{\alpha^2\lambda^2+1}+2}+1}{\alpha\lambda^2} \\
\mathrm{CS}_p &= \left[-\frac{e^{-\lambda\bar{\theta}}\lambda p - e^{-\lambda\bar{\theta}}\lambda\bar{\theta} + e^{-\lambda c}c\lambda - e^{-\lambda c}\lambda p - e^{-\lambda\bar{\theta}} + e^{-\lambda c}}{\lambda}\right]^+ \\
&\quad + e^{-\lambda x}\frac{2\alpha\lambda^2(x-p) + c^2\lambda^2 - 2c\lambda^2 x + \lambda^2 x^2 + 2\lambda(\alpha + x - c) + 2}{2\alpha\lambda^2}
\end{aligned}$$

with $x = \max(c_p, \bar{\theta})$.

Figure 6 displays CS for both free and paid roaming in terms of λ when using the optimal prices, for $\alpha = 1$. The impact on consumer surplus leans towards free roaming: it yields higher CS than paid roaming, but the relative difference is quite small, and we may expect that there exist distributions of θ such that the CS with paid roaming exceeds that with free roaming. Hence it is not obvious that imposing free roaming would benefit users as a whole, illustrating that an analysis such as the present one is of interest.

V. Conclusions and Perspectives

In this paper, we have proposed a model, focusing on the provider and user sides, to investigate the impact of recent UE

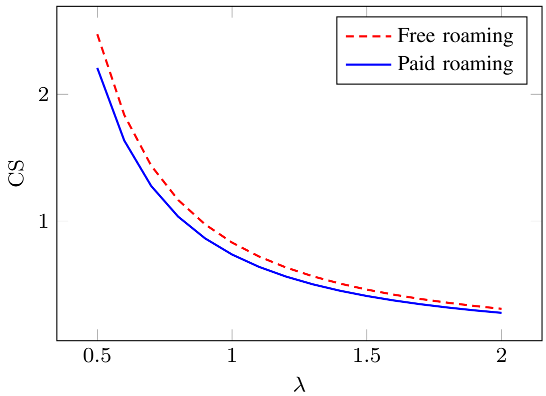

Figure 6. Consumer surplus in terms of λ

decisions forbidding charging for data usage while roaming. Our results suggest that imposing a switch from paid roaming to free roaming would favor the most wealthy users, and that it could be to the detriment of users with intermediate wealth. Also, the revenue extracted by the provider would be significantly lower.

Since this effect on users depending on their wealth was not obvious, we consider that is it worth highlighting and that such decisions, even if intuitively beneficial for the society, should be taken with care and their implementation closely monitored.

Among the limitations of our work, we have considered a monopolistic operator. It would be interesting to investigate to what extent our conclusions remain valid in the case of several competing operators.

In future work, we also intend to study the interactions among providers of countries with significant roaming traffic from one to another.

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