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# Interconnection Charges, Substitutability and Network Externalities: An Empirical Approach\*

By Christos Agiakloglou and Demetrius Yannelis\*\*

## Summary

*Using ARIMA and regression analysis, we examine whether the entry of the mobile telephony in the market for local-trunk and international calls in Greece has affected in any significant way the volume of traffic of the incumbent monopoly, the Hellenic Telecommunications Organization. Even though we cannot draw conclusive results, there is substantial evidence that there is no substitutability between the services offered by the mobile telephony and the Hellenic Telecommunications Organization. Thus, the opportunity cost to the incumbent monopoly after the entry of the mobile telephony must be close to zero. Moreover, there is evidence that the entry of mobile telephony has produced network externalities to the incumbent monopoly.*

## 1. Introduction

The telecommunications industry is based on a network of which certain parts exhibit natural monopoly characteristics. In those parts of the industry where competition exists, rival firms must get access to the "bottleneck" facilities. A typical case is the market for long-distance calls which is considered competitive. Potential entrants seek access to the local loop which is supplied by the incumbent monopoly. A widely-discussed method for the pricing of bottleneck facilities is the "efficient component pricing rule" (ECPR)<sup>1</sup>. The rule states that, for productive efficiency, the interconnection charge paid by the entrant should be equal to the average cost of interconnection plus the opportunity cost of providing the access. Opportunity cost refers to the average profit forgone by the monopoly *after* interconnection is established.

Even though the ECPR rule is based on some unrealistic assumptions<sup>2</sup>, it has gained a relatively wide acceptance due to its "simplicity"<sup>3</sup>. One of its main weaknesses lies in the definition of opportunity costs. If the good sold by the entrant is a perfect substitute for the one offered by the monopoly, then the rule guarantees that the monopoly will provide access if the entrant is more efficient than the monopoly itself and the monopolist's profits are unchanged after interconnection has taken place. Opportunity costs, in this case, may not be too difficult to identify. However, matters are complicated if network externalities are present. In this case, opportunity costs cannot be estimated *a priori*. On the other hand, if the goods are imperfect substitutes or even complements, then opportunity costs may be negative and the monopoly must actually subsidise the

entrant<sup>4</sup>. It is clear that the ECPR rule does not take into account the existence of network externalities and, therefore, the opportunity costs have to be redefined. Baumol and Sidak (1994) address the issue of social marginal opportunity costs, but in their analysis network externalities are clearly not taken into account. If they were, the monopolist could end up with a higher profit after interconnection (provided that the externalities are positive) and would have an incentive to invite entry. However, the ECPR rule gives the monopoly the same profit before and after interconnection and the "pertinent opportunity-cost figure is, of course, the contribution actually forgone by the Local Exchange Carrier..."<sup>5</sup>.

In specifying interconnection charges, one should know the true opportunity costs. Although the issue of interconnection pricing in Greece is still in its infancy compared to other

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<sup>1</sup> See Baumol and Sidak (1994).

<sup>2</sup> See Laffont and Tirole (1994).

<sup>3</sup> See Ambak et al. (1994).

<sup>4</sup> See Armstrong and Doyle (1995) for a critical discussion of the rule. Economides (1995) has shown that a quantity leader may invite entry if the "network effect" is greater than the "competitive effect".

<sup>5</sup> Baumol and Sidak (1994), p.110.

countries like the U.S. and the U.K., interconnection charges are paid by the two GSM carriers to the incumbent monopoly OTE (Hellenic Telecommunications Organisation)<sup>6</sup>. The role of the present paper is to try to show whether the entry of the Mobile Telephony (*MT*) has produced any significant change in the traffic of OTE, i.e., whether network externalities are present<sup>7</sup>. The entry of *MT* certainly has two effects: a competitive effect, as the services of *MT* may be regarded as imperfect substitutes to those of the fixed telephony and a network effect which includes calls made from a fixed telephony to a mobile one. It would be desirable to know which effect dominates the other, so that opportunity costs may be calculated more effectively and the interconnection charges that will follow may be designed to attain productive efficiency.<sup>8</sup> The approach we use is the following. We consider two bi-monthly series of observations of pricing-units provided by OTE: a) the aggregate Local-Trunk pricing units — hereafter *LT* —, a series of 68 observations, from January 1984 to April 1995 and b) the aggregate international pricing units — hereafter *INT* —, a series of 57 observations, from January 1986 to April 1995<sup>8</sup>. Using two different approaches, the ARIMA analysis and a regression analysis, our objective is to analyse both series and to determine if any conclusive remarks can be made as to whether or not the presence of *MT* has affected the generating process of these two series.

## 2. The ARIMA analysis

We consider for each series, in addition to the whole set of observations, a sub-period of observations up to the point where *MT* enters the market, i.e., in July 1993. Using then the traditional ARIMA analysis of Box and Jenkins<sup>9</sup>, our objective is to select the best-fitted model for each sub-period and for the whole period of each series. Thus, in the process of examining whether or not the behaviour of the generating process for these two series has been affected by the presence of *MT*, we take the following two steps based on the best-fitted model chosen for the sub-period of each series. In the first step, we compare actual data with forecasts obtained by the best-fitted model of each sub-period of each series in order to get a picture of how the actual data has behaved relative to what was expected. In the second step, we compare the bestfitted models for both periods in each series to examine whether or not the generating process has changed due to the entry of *MT*.

To avoid the problems that typically arise with the issue of first differentiations, given the fact that the sample auto-correlations of the *LT* series indicate the presence of a unit autoregressive root, ARIMA( $p,0,q$ ) models with a constant and ARIMA( $p,1,q$ ) models with no constant are fitted for all possible combinations of  $p + q \leq 5$ , where the first observation of the undifferentiated series is deleted to allow comparability. The estimation was done through full Maximum Likelihood estimation using SPSS. The best-fitted model according to both AIC and SBC information criteria is the following ARIMA(0,1,1) model:

$$(1-B)X_t = (1-0.43B)\epsilon_t$$

where  $B$  is the backshift operator and  $\epsilon_t$  is white noise. It is interesting to point out that the second best-fitted model chosen by both criteria is the ARIMA(1,0,1) process with an auto-regressive parameter of 0.99 and a moving average parameter of 0.43. Apparently this is a good example of how to detect the presence of a unit autoregressive root by just using the Box and Jenkins (1976) methodology<sup>10</sup>, and without getting involved with testing procedures like the augmented Dickey-Fuller test in which several studies by Schwert (1989), Agiakloglou and Newbold (1992) and Ng and Perron (1995) have indicated the problematic behaviour of the *ADF* test. In fact, in the process of selecting one of these two models for the purpose of making inferences about future behaviour, it will not make any difference which one will be selected, since both will generate very similar forecasts. Looking at the forecasts and comparing them with the actual data, we see that all observations beyond the entry of *MT* are above the forecasts — within the limit of a 95 % confidence interval using the standard errors of forecasting.

Moreover, applying the ARIMA analysis in the same manner as before to the whole set of observations for the *LT* series provides the best-fitted model chosen by both criteria. Not only is the model the same as the one obtained for the sub-period, the ARIMA(0,1,1) process, but also the magnitude of the moving average parameter which is 0.41 is very similar to the one obtained for the sub-period. It is also fascinating to point out that the second best-fitted model chosen by both criteria is also the ARIMA(1,0,1) model with an autoregressive parameter of 0.99 and a moving average parameter of 0.40. Hence, as far as examining the behaviour of the *LT* series through the ARIMA analysis is concerned, we can simply say from the statistical point of view that the total volume of pricing-units was not affected by the presence of *MT*, since both the generating process and the estimates of the moving average parameter remained unchanged after the entry of *MT*. We must also note

<sup>6</sup> For an analysis and critique of the existing method in determining interconnection charges, see Skayannis and Yannelis (1995).

<sup>7</sup> The network or consumption externality is defined as the increase in the value of a network to a user with the number of units sold, or with the addition of a new node or a new network as in our case (see Mitchell and Vogelsang (1991)). Empirical research focuses on providing evidence that access demand is positively related to system size (see Taylor (1994)). However, the present study is concerned with the positive network externalities that may be created to the existing network through the interconnection of another network so that we may call these effects „production externalities“.

<sup>8</sup> There is no separate data for domestic and trunk calls. The traffic is reported in „pricing units“ or impulses, that is, each impulse is a pricing unit.

<sup>9</sup> Box and Jenkins (1976).

<sup>10</sup> See also Newbold et al. (1993).

two factors that tend to lower the volume of pricing-units of OTE. The first is the substantial increase in the local and trunk tariffs (25 % on average) that occurred in February 1993, i.e., one month before the entry of *MT*, and the second is the digitalization of the network and the introduction of local-call tariffs based on duration (according to an impulse rate), which made the tariffs even higher in the same period. So we may conclude that despite the above increases in tariffs, the potential decline in the traffic of OTE may have been compensated by the network effects created by *MT*. Therefore, there is no indication that for the *LT* series the entry of *MT* did harm OTE so that we can conclude that opportunity costs in this case may be regarded as being close to zero.

For the *INT* series we estimate only ARIMA( $p,0,q$ ) models with a constant for all possible combinations of  $p+q \leq 5$ , since we did not find any evidence of first differentiating by just looking at the sample autocorrelations. The estimation was done through full Maximum Likelihood estimation using SPSS. The best-fitted model according to both AIC and SBC information criteria is the following ARIMA(3,0,2) model

$$(1 - 1.62B + 1.60B^2 - 0.63B^3)(X_t - \mu) = (1 - 0.82B + 0.96B^2)\epsilon_t.$$

Here, the second best-fitted model according to the SBC criterion is the ARIMA(1,0,0) model with an autoregressive parameter of 0.72. Comparing now the forecasts generated by the ARIMA(3,0,2) model with the actual observations we see that although the values of most observations are above the forecasts, there are a few observations of the forecasting period (towards the end of the period) whose values are above the limits of a 95% confidence interval based on the forecasts errors. It is actually hard to explain what could have been the cause of such behaviour. One possible explanation could be that the model, since it had many parameters, was not good enough to produce reliable forecasts. However, this is not the case because we got the same results even by using the second best chosen model by SBC the ARIMA(1,0,0). However, we cannot say conclusively that the increased volume of pricing-units for these few periods was due exclusively to the entry of *MT*. If something similar had happened, it would more likely have remained for more periods.

Furthermore, the best-fitted model using the ARIMA analysis for the whole period chosen by both information criteria is still the ARIMA(3,0,2) model but with different estimated coefficients

$$(1 - 1.80B + 1.79B^2 - 0.77B^3)(X_t - \mu) = (1 - 1.01B + 0.99B^2)\epsilon_t$$

where the second best-fitted model by the SBC criterion is the ARIMA(2,0,0) model with values of the autoregressive parameters of  $\phi_1 = -0.94$  and  $\phi_2 = 0.31$ . Therefore, we realize that for the *INT* series although the same ARIMA model is chosen for both periods by both information

criteria, the estimates of the coefficients are not the same, a fact which could very well have been caused by the presence of extreme observations. In fact, that is why SBC is choosing the AR(2) model as the second best-fitted model for the whole period and not the AR(1) model, although AIC chooses for both periods the AR(5) model as the second best-fitted model. Of course, it is known that AIC has the tendency to select over-parameterized models, but for the purpose of this study the issue of the same model for both periods can be supported if AIC is used to select the first or the second best-fitted model.

Moreover, in February 1993 there was an increase in international tariffs by 4.7% (on average) which does not seem to have influenced international traffic. This may imply that the potentially reduced traffic of OTE may have been compensated by the network effects created by *MT*, especially close to the end of the period where the traffic of *MT* has increased considerably compared to the early stages of the entry of *MT*. Hence, as in the case of the *LT* series, the services offered by OTE and *MT* indicate no substitutability whatsoever, at least up to this point, and we can say that the entry of *MT* for international calls did not harm OTE.

### 3. Regression analysis

So far we have tried to approach our analysis by applying the ARIMA analysis to both periods and to determine whether or not any conclusions can be drawn in terms of how the generating processes have been affected by the entry of *MT* in the market. Another way of examining this issue is by investigating whether the presence of *MT* has affected the drift and the slope of the time trend of both processes assuming that the volume of pricing-units increases over time. To illustrate this, consider for each series the following regression model:

$$X_t = C + \beta t + \gamma dc + \delta dt + \sum_{i=1}^5 \varphi_i X_{t-i} + u_t$$

where  $X_t$  stands for either the *LT* or the *INT* series,  $t=1,2, \dots, T$ ,  $dc$  and  $dt$  are dummy variables defined as follows:

$$dc = \begin{cases} 0 & \text{for } t < T_E \\ 1 & \text{for } t \geq T_E \end{cases} \text{ and } dt = \begin{cases} 0 & \text{for } t < T_E \\ t & \text{for } t \geq T_E \end{cases}$$

$T_E$  being the time period in which *MT* enters the market and  $u_t \sim \text{iidN}(0, \sigma^2)$ . The role of the two dummy variables  $dc$  and  $dt$  in the above regression equation is to investigate whether or not the drift and the slope of the time trend variable have changed during the period in which *MT* entered the market. Broadly speaking, if the amount of pricing-units made to and from *MT* is large relative to the total volume of pricing-units made by OTE, then we should expect a positive effect on the constant of the regression and

a positive effect on the slope of the trend indicating that the slope of the generating process becomes steeper due to the entry of *MT*.

For both series, as in the ARIMA analysis, models up to five autoregressive parameters are estimated and the best-fitted model for each series is chosen according to the significance of the coefficients of all lagged dependent variables.

For the *LT* series the best-fitted model is

$$X_t = 1356.9 + 23.70t + 38.51dc + 1.86dt + 0.40X_{t-1}$$

(4.98) (4.76) (0.03) (0.08) (3.37)

$R^2=0.93$   $DW=2.05$

and for the *INT* series it is

$$X_t = 805.9 + 7.30t - 1004.2dc + 17.48dt + 0.87X_{t-1} - 0.59X_{t-2}$$

(5.06) (3.27) (1.33) (1.20) (6.93) (3.86)

$R^2=0.66$   $DW=2.26$

where the figures in parenthesis are the absolute values of the t-statistics for testing the null hypothesis that each coefficient is zero.

For both series the coefficients of the two dummy variables are the only variables that are statistically zero indicating that the entry of *MT* has not affected the constant

and the slope of the time trend of both processes. It is interesting to point out, however, that the sign of these two dummy variables, except for the sign of the dc variable for the *INT* series, is what we should expect if the entry of *MT* had significantly affected both processes. Moreover, if we use the coefficient of determination  $R^2$  as a measurement of fit we see that for the *LT* series the magnitude of  $R^2$  is high, indicating that the explanatory variables explain adequately the behaviour of the series whereas for the *INT* series the magnitude of  $R^2$  is low indicating that more variables may be needed to explain the behaviour of the series.

#### 4. Conclusion

Both approaches have shown that there is no evidence as to whether the presence of *MT* has significantly affected the generating process of the two series examined. This may very well be due to the low traffic volume of *MT* compared to that of OTE up to the present. Meanwhile, this study finds that there is no evidence that there is some degree of substitutability between services offered by OTE and *MT* as this was presented and supported by both approaches (ARIMA and regression analysis). Our concluding remarks seem to suggest that the entry of *MT* not only did not harm OTE, but that it is quite possible that it created benefits through network effects. This is more evident in the local-trunk traffic than the international traffic although for the latter the presence of more observations may have helped the analysis.

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## **Zusammenfassung**

### **Zusammenschaltungsgebühren, Substituierbarkeit und Netzwerkexternalitäten: Ein empirischer Ansatz**

*Unter Verwendung von ARIMA und der Regressionsanalyse wird im vorliegenden Beitrag untersucht, ob der Markteintritt von Mobilfunkanbietern bei Orts- und Auslandsgesprächen in Griechenland das Gesprächsaufkommen beim ehemaligen Monopolisten, der Hellenic Telecommunications Organization, signifikant beeinflusst. Obwohl wir noch keine endgültigen Schlüsse ziehen können, gibt es überzeugende Anhaltspunkte dafür, daß keine Substitutionsbeziehung zwischen den Dienstleistungen der Mobilfunkanbieter und denen der Hellenic Telecommunications Organization bestehen. Die Opportunitätskosten nach der Einführung des Mobilfunks müssen für den ehemaligen Monopolisten nahe bei Null liegen. Darüber hinaus gibt es Anhaltspunkte dafür, daß durch den Markteintritt des Mobilfunkbetreibers Netzwerkexternalitäten für den ehemaligen Monopolisten entstanden sind.*