Annex 7 - A report for Ofcom

WHOLESALE TERMINATION REGIME, TERMINATION CHARGE LEVELS AND MOBILE INDUSTRY PERFORMANCE

A study undertaken for Ofcom

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EXECUTIVE SUMMARY

This report presents the results of an econometric study examining the relationship between wholesale arrangements for mobile termination including the charging regime and level of mobile termination rates (MTRs) and key mobile market outcomes.

The study is intended to contribute to the ongoing debate about the relative performance of the Calling Party Network Pays (CPNP) and Bill and Keep (B&K) charging regimes in delivering better outcomes to consumers particularly with regard to retail prices, usage and the take-up of mobile services.

Critics of the CPNP system argue that higher MTRs raise the cost and hence prices of calls between networks and that this acts to hold down usage. However, there is also a need to consider a potential effect in the opposite direction as higher MTRs can lead operators to compete more strongly for customers and their associated termination revenues by lowering their retail prices. Existing empirical studies have found conflicting evidence on the relationship between overall retail prices and the level of MTRs (or the CPNP regime).

There does appear to be consensus on the prediction that higher MTRs and/or the CPNP regime may enhance mobile take-up, at least in the growth phase of a market. This relationship is based on MTRs strengthening operators' incentives to subsidise access to mobile services (including handsets subsidies) as well as avoiding charges for most incoming calls which may otherwise discourage customer take-up.

A key drawback of many of the existing empirical studies is that they rely on usage and pricing data from Merrill Lynch that are poorly suited to deriving conclusions from comparisons of countries with different charging regimes as measurement differences act to bias such comparisons. We also note that while the level of MTRs is higher on average under CPNP regimes, some nominally B&K countries have relatively high MTRs for some type of traffic. Furthermore, prices and usage may vary as much or even more because of differences in the level of MTRs in different countries as they do between two countries with different charging regimes.

To overcome problems of earlier studies, in this paper we focus as much on the level of MTRs as on the choice of regime and we rely on a new data set prepared by Ofcom that is specifically designed to address some of the data issues that have affected many of the earlier studies.

We estimate the relationship between the level of MTRs and certain market outcomes – i.e. take-up, usage, and prices - using a sample of OECD and European countries in the period from 2002 to 2007. This exercise has been carried out taking into account trends that may have jointly affected all the countries over time, as well as regional and country specificities that are unobserved. These "unobservables" include variables that are not specifically accounted for in our analysis but which might affect the relationships studied. The availability of annual observations for each country across the period enables us to gain information from changes over time as well as from differences between countries. As a consequence, our data set helps to reduce the risk of spurious results that may erroneously attribute differences between countries to differences in regimes or the level of MTRs when those differences, in fact, are driven by other factors.

We have also estimated the relationship between the choice of regime (i.e. CPNP or B&K) and market outcomes. However, because regimes have not changed over time in our core data set and because the vast majority of countries are under the CPNP regime, it has not been possible to fully control for regional or country effects. This is a key limitation in relation to our analysis in which we use the CPNP dummy as a control variable.

Following are our key findings.

First, the results on the **take-up** of mobile services, measured as the number of SIM cards per capita, provide the most consistent set of results of this study. We find that the take-up of SIM cards will tend to be higher, (i) the higher the level of MTRs and (ii) if a country has adopted a CPNP regime rather than a B&K regime. A qualification to our finding is that the number of SIM cards per capita is not a precise measure of the penetration of mobile services as countries may also differ in terms of the extent to which individual mobile customers have more than one SIM card.

Second, we find that CPNP regimes tend to lead to lower **usage**, measured as minutes of use (MOU) per subscription. However, this effect needs to be interpreted cautiously as persistent differences across countries, which are not measured by the data, may instead explain the result. We did not find robust statistical evidence on the relationship between usage and level of MTRs. In initial specifications, which explain little of the data variation, we found a negative effect on usage. This effect disappeared in richer specifications that included time and country effects.

Third, we did not find strong evidence in relation to effects on **prices**. We found some evidence that higher levels of MTRs lead to somewhat higher revenues per minute (RPM) using the original Merrill Lynch data. However, the original data on RPM include revenues from termination fees charged in CPNP countries and hence, when used as a proxy for retail prices, will tend to make retail prices appear relatively high in CPNP countries. Using an adjusted measure that attempts to correct for this and for other problems in the measurement in minutes, we did not find a robust relationship between level of MTRs and prices. Our overall conclusion is that the evidence does not robustly show that the level of MTRs affects the (average) level of retail prices.

We also did not find that the choice of the CPNP regime affects prices as proxied by average revenue per minute (RPM) measure. This finding contrasts with the findings of Littlechild.[1] This difference may reflect: (i) we have used a selection of countries that are considered to be in broadly comparable circumstances while Littlechild has used a much larger sample of countries; (ii) we have used data across several years while Littlechild's sample is for one year only.

We also undertook analysis using price indices produced by Teligen and that are frequently used by the OECD and national regulators. Our results using the Teligen price data are also mixed and difficult to interpret. Generally, the findings provide little confidence that a statistically robust relationship has been uncovered between either the choice of wholesale termination regime and prices or between the level of MTRs and prices. The specifications appear to fit the data poorly and explain little of the

[1] Littlechild, S.C. (2006) "Mobile termination charges: calling party pays versus receiving party pays," *Telecommunications Policy*, 30(5-6): 242-277.

variation observed. The findings show that, as in other recent studies, results are mixed when using a number of alternative proxies for prices.

Our Teligen findings are consistent with the "waterbed" effects found by Genakos and Valletti[2] on low usage–low price mobile services, but not with their findings of a negative correlation between the level of MTRs and high usage-high price mobile service subscriptions. The lack of an effect of the level of MTRs on RPM is consistent with a similar finding by Genakos and Valletti based on average revenue per user.[3] Advancing the program of research that focuses on the relationship between prices and the level of MTRs may require further consideration of what measures of prices and what data sources might be best suited for this exercise.

There are two central concerns in our analysis.

First, there are concerns related to the potential endogeneity of key variables of interest. In particular, MTRs could be endogenous which may bias the estimates. For example, if usage was low, an operator or regulator might set higher MTRs to reflect the lower ability to realise scale economies. If MTRs are endogenous, then it will be important to research what additional variables could be used as a convincing instrument to test for the presence of endogeneity and to correct the analysis for any bias that may result.

A further research direction would be to consider a "structural model" of supply and demand of mobile services to establish statistical **causation** between the level of MTRs and regime choice on the one hand and mobile market outcomes on the other. This is important as our findings of an association between higher MTRs and take-up should not be taken as implying that increasing the MTRs in a country would necessarily **cause** take-up to grow.

A second caveat concerns the limitations of the data set. A larger data sample would be helpful, particularly if more information on MTRs becomes available on a comparable format for more nominally B&K countries. Furthermore, there are a host of problems in using the Merrill Lynch data on revenues and MOU for comparisons between countries with different regimes. A failure to fully adjust for all significant problems can readily bias the result of econometric analysis in favour of one regime over the other.

2 Genakos, C and Valletti, T. (2007) "Testing the "Waterbed" Effect in Mobile Telephony," CEP Discussion Paper No 827.

3 Genakos, C and Valletti, T. (2007) "Testing the "Waterbed" Effect in Mobile Telephony," CEP Discussion Paper No 827.

1 INTRODUCTION

This study investigates the effect of different mobile call termination regimes and the effect of the level of mobile termination rates (MTRs) on consumer outcomes. We compare the Calling Party Network Pays (CPNP) with the Bill & Keep (B&K) regime. The particular consumer outcomes we examine are proxies for take-up, usage of mobile services and retail prices.

The choice of mobile termination regime affects operators' and final users' incentives by changing the payment structure involved to originate and complete a call. With the CPNP regime, the operator initiating the call pays the receiving operator for terminating a call to the called party. Retail charges only apply to customers originating the call under the Calling Party Pays (CPP) retail regime, which is generally associated with CPNP. Under a "pure" B&K regime there are no payments between the operators, however in practice under nominally B&K regimes termination charges may also apply depending on the type of traffic, as in the US. The B&K regime is generally combined with a Receiving Party Pays (RPP) regime at the retail level, whereby both the calling and the receiving retail customers pay for the call.

There is currently a significant debate concerning which charging regime performs better in terms of consumer outcomes. Critics of the CPNP regime point out inefficiencies that can arise from the level of MTRs which are charged to competing MNOs to terminate off-network calls. In particular, there are concerns that CPNP regimes lead to excessive termination charges relative to the cost of termination. The basis for this concern is that while an individual mobile subscriber decides which operator to join, under a CPNP regime that operator is able to set its termination charges that are ultimately borne by customers of other operators who call the subscriber. In this situation, absent price controls, operators may have relatively weak incentives to set termination charges around competitive levels. It is true that MTRs are now generally regulated in CPNP countries and regulation has resulted in an overall reduction of mobile termination charges in Europe over the recent years. Nonetheless, it may still be the case that regulation may not be fully effective in constraining MTRs (in addition, regulation itself can carry significant administrative costs to both regulators and industry players).

Operators will need to set their prices for off-net calls to cover the cost of the termination charges that are levied by other operators and thus excessive termination charges may lead to relatively high off-net call prices. Higher off-net call prices could, in turn, lead customers to limit their number of off-net call minutes. However, there is another effect that needs to be taken into account in considering the general relationship between MTRs and mobile retail prices. Higher MTRs can make customers more valuable to acquire because they bring with them greater termination revenues from calls made to those customers. Operators may thus be prepared to set lower retail prices to attract customers to their networks. Thus, there are potentially effects operating in opposite directions on mobile prices. Uncertainty over the impact of MTRs on mobile retail prices also implies it is difficult to predict the effect of MTR levels on overall call volumes.

Another element of the debate regarding charging regimes is their impact on the take-up of mobile services. Proponents of CPNP regimes argue that a key advantage of a CPNP regime is that it supports higher take-up as even individuals who plan to make relatively few calls may decide to become mobile subscribers where the cost of subscribing including the handset is effectively subsidised through MTR revenues that are ultimately paid by other customers who call them. Higher subscriber numbers can also support higher traffic volumes. On the other hand, questions have been raised as to whether the SIM card or subscription take-up effect is relevant for markets that have already achieved high levels of mobile penetration, in particular, is there a real risk of penetration falling in such countries if the regime were to change?

An additional element for consideration in relation to CPNP regimes is that they reduce the need for customers to be charged directly for receiving calls because the cost of termination is instead recovered from the operator of the customer making the call.[4] Charges for receiving calls may make customers reluctant to receive calls (particularly where the number of the person calling is unknown) and this may lead to lower overall call volumes.

The above arguments suggest that it is difficult to predict the impact of MTRs in the absence of empirical evidence. In comparing different charging regimes, a further difficulty is created by the substantial differences in the level of MTRs across countries. Indeed, operators in some nominally B&K countries do levy termination charges for at least some type of traffic and the level of these termination charges may even be higher than termination charges set in particular CPNP countries. This suggests that examining the impact of different levels of MTRs may provide more robust results than focusing only on the choice of charging regime.

A number of existing studies have focused on examining the effect of either the level of MTRs **or** the choice of regime. "Diffusion studies" which focus on take-up have used the choice of regime as an explanatory variable, while studies testing whether a "waterbed" effect exists have examined the relationship between MTR levels and retail prices (or profitability). In our study, we have sought to examine both the impact of the level of MTRs as well as the choice of regime.

The existing studies have tended to rely on data sets that create a number of biases when comparing market outcomes such as usage and revenues between countries with different charging regimes.[5] These biases cast doubt over the reliability of key conclusions from those studies. The analysis in this paper examines the effects of regime choice and the level of MTRs using a new data set which includes measures of usage and revenues which seek, at least, to reduce the problems of the main data sets that have been used previously.

[4] Generally CPNP is not associated with RPP regimes at the retail level for national calls, however customers usually pay directly for receiving calls while roaming abroad.

[5] Data issues are discussed in detail in the following section.

1.1 Related Literature

There is a growing empirical literature on the impact of mobile termination arrangements on various market or consumer outcomes. Differences in the data used including the time period and sample of countries considered are important to bear in mind in assessing the results of the different studies including our own study.

There are two main (interrelated) strands of empirical studies.

One strand focuses primarily on measuring the impact of CPP or RPP retail regimes on the take-up of mobile services. These studies compare retail regimes but the comparisons extend to wholesale CPNP and B&K regimes. Examples of "diffusion studies" that control for country specific effects using panel data sets include the work by Dewenter and Kruse[6] which uses data from a large number of countries around the world, and a paper by Jang et al, which uses data from OECD countries and Taiwan.[7] These studies have reached different conclusions. Jang et al. find that CPNP is associated with greater diffusion of mobile communication services, while Dewenter and Kruse find the opposite.

A second strand examines the effect of regulatory regime on prices, usage and profitability. Littlechild[8] uses data for a single year for about forty countries and finds higher average revenue per minute of use (RPM) and lower usage in CPNP regimes than in B&K regimes. The specifications do not include geographic control variables. The higher RPM in CPNP regimes is interpreted as an indication of higher retail prices relative to B&K regimes. Littlechild's analysis is based mainly on Merrill Lynch data, which has also been used for cross-country comparisons in policy[9] and academic debates to support the conclusion that usage is higher and prices are lower in countries with B&K regimes. There are concerns regarding the use of Merrill Lynch data for international comparisons because minutes of use (MOU) are biased upward and revenue per subscriber is biased downward in B&K regimes relative to CPNP regimes.

Genakos and Valletti[10] and Andersson and Hansen (on CPNP countries only)[11] estimate the effect of differences in the level of MTRs on price and on profitability. Genakos and Valletti examine the effect of the level of MTRs on a price index of outbound services, as well as average revenues per subscriber, in a rich sample of operators' data. They control for characteristics of operators that do not change over time by including a "country-operator" fixed effect. Their findings show that monthly contract "best offers" prices are higher with lower MTRs. This "waterbed" effect arises because MTRs are a significant source of revenues for mobile operators totalling approximately 15% of total revenues

6 Dewenter, R. and Kruse, J. (2005) "Calling Party Pays or Receiving Party Pays? The diffusion of Mobile Telephony with Endogenous Regulation," mimeo.

7 Jang, S., Dai, S. and Sung, S.(2005) The Pattern and Externality Effect of Diffusion of Mobile Telecommunications, The Case of the OECD and Taiwan, *Information Economics and Policy*, 17, 133 – 148.

8 Littlechild, S.C. (2006) "Mobile termination charges: calling party pays versus receiving party pays," *Telecommunications Policy*, 30(5-6): 242-277.

9 For example, a study by WIK-Consult for the European Commission, "The Future of IP Interconnection: Technical, Economic and Public Policy Aspects," 29 January 2008.

10 Genakos, C and Valletti, T. (2007) "Testing the "Waterbed" Effect in Mobile Telephony," CEP Discussion Paper No 827.

11 Andersson, K. and Hansen, B. (2007) "Network Competition: Empirical Evidence on Mobile Termination Charges and Profitability," mimeo, (version of 15 December 2007), study on CPNP countries only.

in the EU. Their findings also show that the "waterbed" effect is not observed on pre-pay tariffs or when they use as a measure of prices average revenue per user.

Our study makes use of a new panel data set prepared by Ofcom, which also includes measures of usage and RPM which have been adjusted to attempt to correct for the known problems with Merrill Lynch data. A key feature of the data set is that it consists of a broadly comparable sample of 39 countries located in European and other OECD members over the period 2002-2007.

It may be argued that the dynamic effects associated with the early market expansions and/or technological changes have become less important as markets have matured and reached a broadly comparable level of diffusion. This is important because the analysis does not model explicitly the dynamic effects of adoption of mobile services as in "diffusion studies." When comparing countries at different stages on the diffusion curve there could be a risk that differences in mobile termination arrangements could be correlated with take-up of mobile services and this apparent effect could be largely explained by market saturation in more mature markets. This risk is limited in our sample period and sample of countries. Competition between different technologies is also not a central concern.

All countries in our core sample had already adopted either a CPNP or a B&K regime prior to 2002 and have not changed regime over the sample period. The core sample includes selected B&K countries consisting of Canada, Hong Kong, Singapore and the US. Unfortunately, detailed information on relevant interconnection charge levels in these nominally B&K countries is available only for the US and this limits the conclusions that can be drawn on the impact of charging regimes (other than from differences on MTRs). There is more information available on the charging regime variable than on the level of MTRs, however examining the impact of different levels of MTRs in a smaller sample is likely to provide more robust results than focusing only on the choice of regime.

The reminder of this paper is structured as follows. Section 2 discusses the key feature of the data and provides summary statistics. Section 3 describes in some detail the theoretical framework and the models we tested empirically. Possible shortcomings and limitations of this study are highlighted and possible avenues for further research and improvements are described. Section 4 shows our main findings. The annexes contain more detailed information on the data and additional empirical results.

2 THE DATA

The panel data set collected by Ofcom consists of annual information on 39 OECD countries between 2002 and 2007.[12] The data include the following variables: level of MTRs, CPNP dummy, MOU (per subscription, per capita, per subscription "debiased"), PPP exchange rates, RPM per Subscription, RPM per subscription "debiased", Teligen Price Indices, GDP, Mobile Penetration, Fixed Penetration, Population, Population Density.

The data set is unbalanced meaning that variables are missing for selected countries and years. We briefly comment on the key variables. Further discussions and detailed descriptions of the variable sources are given in Annex A.

Central to our study are two output measures: mobile service take-up and usage.

Mobile service take-up is measured by the number of SIM cards per capita. The number of SIM cards per capita tends to be higher in CPNP countries or countries with higher levels of MTRs. The number of unique users of mobile services may be broadly comparable in countries with the same wholesale regime. However, our sample includes CPNP and (nominally) B&K countries; therefore it is unlikely that the findings on the effect of MTR levels on the number of SIM cards provide a reliable proxy for effects of MTR levels on the number of unique mobile users.

Usage is measured with MOU. The variable measures the total MOU per subscription consisting of both outgoing and incoming minutes. This is potentially overstated in B&K countries relative to CPNP countries as mobile-to-mobile minutes may be double-counted. We employ alternative measures of MOU (raw and debiased) to attempt to correct for biases in the original data (see Annex A).

We use alternative indicators of retail prices: average RPM and four Teligen indexes of prices. While average RPM per user is often used as a measure of prices, this measure may be subject to bias for two reasons. Revenues include termination fees and, as a result tend to be biased upward in CPNP countries, and MOU measurement suffer of the possible double counting in B&K countries described in the previous paragraph. A "debiased" data series on RPM, prepared by Ofcom, attempts to correct for the biases.

In addition, RPM may be particularly problematic if one wished to assess the impact of higher prices on usage, as the structure of tariffs and the incentives to make calls for consumers are likely to differ (per minute only, fixed monthly payments only, combinations thereof etc). In fact the study of the effect of RPM can be seen as an indirect assessment of likely effects on usage (from higher prices) and the evidence on effects on prices can be seen as a complement to the direct test of the effects of the level of MTRs (or termination regime) on usage.

[12] Ofcom originally collected data for 40 countries, but errors in the data for Slovenia led to the exclusion of this country.

An alternative to the use of RPM is the use of a direct measure of the total price for reference bundles of products like the Teligen indexes. The Teligen index is a measure of yearly prices given a predefined usage pattern common to all countries that is held constant over time. This direct measure of prices may also be problematic as tariffs generally included more services and the usage profile may have changed over time.

Demo-geographic features such as population density are exogenous and might correlate with cost drivers as the network infrastructure may become more expensive in less dense countries. Therefore increased density may be associated with lower investment costs. Some studies have hypothesised that density is a key driver of mobile use, the "human interaction effects" in Jang et al. Typically we expect population density to vary little over time for the majority of countries relative to other variables, which might have implications for the findings as discussed below.

Some variables of potential relevance are omitted from the models and empirical results presented in this study. For take-up, and retail prices, the level of handset subsidies is likely to be also relevant[13] as there is a likely positive correlation between the level of MTRs and the level of handsets subsidies. However, there are no good proxies for these subsidies. Industry structure is likely to matter in two ways. First, competition may boost take-up and usage, as we expect higher industry concentration to lead to higher prices. Second, there may also be a link between spare capacity and number of networks. In practice, the information on industry concentration was available for a smaller sample only and key results have been estimated excluding this variable. Additional tests - not shown in the report - suggest that the results which are robust in the larger sample also emerge from the specification tested in smaller samples which include a measure of concentration.

The availability and price of substitutes are also relevant to performance and usage; most notably other studies have found substitution effects between mobile and fixed services as markets mature. We do not have information on prices of fixed services. The main specifications include the level of take-up of fixed telephony services. A priori, we would expect lower penetration of fixed telephony services to be positively correlated with take-up of mobile services. Also, for the purpose of the study, fixed penetration is considered as a given exogenous feature of markets studied. However there may be a question mark over whether fixed and mobile are always substitutes and whether fixed penetration can be considered as exogenous.

Some studies have included the percentage of pre-pay subscriptions on the grounds that prices as measured by average revenues would be lower with more pre-pay subscriptions. CPNP countries may be expected to have more customers and traffic generated by pre-pay subscriptions and lower prices. Also, pre-pay retail offers could be a means to expand mobile take-up for lower value users. The data set does not contain information on the percentage of pre-pay subscriptions so this is not included in any specification. In practice countries differ very significantly in the proportion of pre-pay users and therefore on the type of users associated with pre-pay. The customer profile in the pre-pay segment

[13] For example H3G Italy's policy of heavily subsidising handsets is likely to be at least in part responsible for this Hutchinson subsidiary's good performance in Italy and might have contributed to extremely high penetration in this country.

might also vary across countries. Pre-pay might include relatively high spending customers in certain countries and customers with a low willingness to pay in other countries.[14]

Prior cross-country studies have used differences in GDP (as a proxy for average income) per capita to explain part of the difference on mobile penetration.[15] We also include this in our empirical specification.

Next, we describe summary statistics and pairwise correlation measures of the key variables of interest.

2.1 Summary statistics

Table 1 reports basic summary statistics for our key variables of interest. The columns in Table 1 report the mean, standard deviation, and number of observations for each variable. The number of observations varies across variables as a variable may not be available for all the sample periods and countries.

An examination of the first row in Table 1 reveals that the level of MTRs has an average value of 8.6. The level of MTRs variable has a standard deviation of 7.7 and it ranges between 0.03 and 30 in the sample.

The second row shows that CPNP is the regime in 90 per cent of all observations. This percentage increases to 97% for those observations where MTRs data is also available. The 3% B&K observations are accounted for by the United States.

The MOU variable measures the yearly total MOU per subscription. The average of the MOU variable equals 187 minutes. The standard deviation equals 129 and, in relative terms, there is less variability compared to MTRs.

The RPM data is the yearly average revenue per user (ARPU) divided by MOU. ARPU is potentially overstated due to double counting of termination payments in CPNP countries and as noted above MOU is likely overstated in B&K countries. The sum of these two measurement errors means that RPM is likely to be understated in B&K countries relative to CPNP countries. The average RPM is 0.12, with a standard deviation of 0.1. The econometric analysis in the next section uses both the original data and (separately) the data after these biases have been removed.

14 For example, in Italy pre-pay users account for a larger than average proportion of subscriptions, penetration is higher, but average revenue per user (ARPU) does not fall when penetration increases, see http://www.gsmap.org/wp-content/uploads/files/ARPU%20paterns038818.pdf, Wireless intelligence, 2006.

15 GDP is also expected to correlate with labour costs, which are not directly measured. These are costs are expected to differ between countries, but not much over time within period considered. Other costs are probably common across countries.

The Teligen price indices measure the price of representative baskets of mobile services over time. There are four different baskets of mobile services which represent users with low, medium and high post-pay and low usage pre-pay or post-pay profiles. The average of the cheapest bundles of services price index is 193 (or 155 with the inclusion of prepay tariffs), while medium bundles average price is 396 and the most expensive bundle average price is 668. All four Teligen indexes display significant variability (a standard deviation is about half the sample average). Closer inspection of Teligen data reveals that year on year price changes are often significant and of opposite direction.

The number of SIM cards per capita (as a proxy for mobile penetration) has an average of 0.88 and a standard deviation of 0.24, the minimum value is 0.23 and the maximum value is 1.48, showing considerable variation. There is less variability in the number of fixed lines per capita, the average of fixed lines per capita is 0.45 and the standard deviation is 0.14. The variable ranges from 0.15 to 0.74.

Lastly, GDP per capita ranges between 4.2 and 63.4, has an average of 19.9 and a standard deviation of 9.9.

Table 1 Summary statistics for key variables in core sample.

Variable	Mean	Standard deviation	Number of observations
MTRs (logmtr)	8.55	7.73	146
CPNP	0.90	0.30	234
	Dummy =1 if regime is CPNP. Not transformed in logs		
MOU (logmin)	186.87	128.56	171
RPM (logrpm)	0.12	0.10	161
LowPrice (logplow)	193.04	87.54	215
Med Price (logpmed)	395.99	183.56	215
HighPrice (logphi)	667.95	329.60	215
LowPricePrePay (logplow2)	155.15	73.49	215
Mobile SIMs (logmobile)	0.88	0.24	230
Fixed Lines (logfixed)	0.45	0.14	228
GDP per capita (loggdpc)	19.89	9.92	214
Population (logpop)	31.18	52.93	234
Density (logdensity)	465.02	1369.39	234

Source: Ofcom data, CEG analysis.

We examined correlations between the key variables of interest. CPNP regime dummy and MOU are negatively correlated with a correlation coefficient of -0.8. This correlation coefficient is significantly different from zero. The CPNP dummy is negatively and significantly correlated with the price of cheaper bundles of services with a correlation coefficient of -0.3.

MTRs are positively correlated with RPM with a correlation coefficient of 0.5 which is significantly different from zero. MTRs are positively correlated with mobile penetration with a correlation coefficient of 0.3, which is significantly different from zero. MTRs are negatively correlated with MOU with a significant correlation coefficient of -0.3.

RPM are not significantly correlated with the low-usage Teligen price index (post-pay only). RPM show a statistically significant correlation coefficient of 0.1 for the other Teligen price indexes. The Teligen price indices of different bundles are positively correlated, with the correlation coefficients for each pair of price indexes ranging between 0.8 and 1, all statistically significant. RPM are a measure of average prices and therefore provide less information than detailed price indexes. This may explain the much lower correlation coefficient between the RPM variable and the Teligen price indexes.

The number of available observations varies between countries. More information is available on the explanatory variables for certain countries and information on retail prices was not available for all countries in the dataset. Importantly more information is available on the CPNP dummy as the data are available for more countries and for more years than on MTRs. The unbalanced nature of the data set makes comparisons across different specifications including the level of MTRs and/or the CPNP dummy difficult. In principle a balanced sample could be selected, but the number of observations in the balanced sample is too small to make statistically clear predictions.

In principle non-OECD and non-European countries could have been added to the data, but a preliminary study revealed that there are clear differences between OECD and Eastern European on one side and non OECD countries on the other. This suggests that the key underlying relationships might well differ. We therefore considered estimating results for mobile penetration on a sample of non OECD countries separately, breaking down the sample in two groups. However, the sample size for non OECD countries is small and other control variables could not be included in model as no information on these control variables was available.[16] For these reasons we show results exclusively on the core sample of 39 OECD countries for which most information was available.[17]

There are at most 6 years of data for each variable. However, some variables are not available for the entire sample period. For example, MTRs data are on average available for four years only.

Table 2 describes the data availability of key variables by country. Data reported as missing are not available for any year. Data are reported as missing only when information was not available throughout the entire sample period. This availability determines whether a country can be included in the sample for the estimation. Inclusion in the sample requires that information is available for the dependent variable chosen and for all explanatory variables included in the model. For example the effect of the level of MTRs on MOU is estimated with a sample of 26 countries (there is no information on MTRs for 3 countries and no information on minutes for 10 additional countries).

16 In this report we use control variable or explanatory variable interchangeably.

17 The data collected by Ofcom included 40 countries, unfortunately we had to exclude Slovenia because of a data error in GDP PPP adjusted figures.

Table 2 Data availability, by country

Country	CPNP dummy	MTRs	Penetration	Minutes	RPM	Teligen indices
Australia	✓	✓	✓	✓	✓	✓
Austria	✓	✓	✓	✓	✓	✓
Belgium	✓	✓	✓	✓	✓	✓
Bulgaria	✓	✓	✓	missing	missing	✓
Canada	✓	missing	✓	✓	✓	✓
Cyprus	✓	✓	✓	missing	missing	✓
Czech Republic	✓	✓	✓	✓	✓	✓
Denmark	✓	✓	✓	✓	✓	✓
Estonia	✓	✓	✓	missing	missing	✓
Finland	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓
Germany	✓	✓	✓	✓	✓	✓
Greece	✓	✓	✓	✓	✓	✓
Hong Kong	✓	missing	✓	✓	missing	missing
Hungary	✓	✓	✓	✓	✓	✓
Iceland	✓	✓	✓	missing	missing	✓
Ireland	✓	✓	✓	✓	✓	✓
Italy	✓	✓	✓	✓	✓	✓
Japan	✓	✓	✓	✓	✓	✓
Korea	✓	✓	✓	✓	✓	✓
Latvia	✓	✓	✓	missing	missing	✓
Lithuania	✓	✓	✓	missing	missing	✓
Luxembourg	✓	✓	✓	missing	missing	✓
Malta	✓	✓	✓	missing	missing	✓
Mexico	✓	✓	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓	✓	✓
New Zealand	✓	✓	✓	✓	✓	✓
Norway	✓	✓	✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓	✓
Portugal	✓	✓	✓	✓	✓	✓
Romania	✓	✓	✓	missing	missing	✓
Singapore	✓	missing	✓	✓	missing	missing
Slovakia	✓	✓	✓	missing	missing	✓
Spain	✓	✓	✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓
Switzerland	✓	✓	✓	✓	✓	✓
Turkey	✓	✓	✓	✓	✓	✓
United Kingdom	✓	✓	✓	✓	✓	✓
United States	✓	✓	✓	✓	✓	✓

3 EMPIRICAL FRAMEWORK

We first describe the framework used to investigate the empirical relationship between the specific measures of performance and other economic variables. We then comment on possible shortcomings and caveats of the framework.

For each of welfare proxy of interest, the empirical model is the following:

$$y_{it} = \mathbf{x}_{it}\,\beta + u_{it} \qquad (1)$$

where *y* denotes the dependent variable, ***x*** denotes a set of explanatory variables, *u* denotes the residual, *i* indicates countries and *t* denotes time. As for the dependent variable *y*, we considered a range of performance measures, including:

- The level of mobile services take-up,
- MOU per user and minutes per capita (raw and debiased),
- low-usage, medium-usage and high-usage Teligen price indices, and
- average RPM, per user (raw and debiased).

The study focuses on the explanatory variables that measure the level of MTRs and a CPNP dummy variable. Estimating the coefficient on the variable for mobile termination levels and the CPNP dummy provides an answer to the question of the effect of these two variables on the welfare measures.

In the set of explanatory variables we include other variables of interest, including: fixed penetration, GDP per capita, population density, and a set of time dummy variables. Regional dummies are also included in specifications that do not model directly country effects. Regional dummies allow us to assess the effect of characteristics that might be shared by countries in the same world regions, but may vary across regions.

Relationship (1) is estimated using OLS. There are two key underlying assumptions: A zero conditional mean,

$$E[u|\mathbf{x}]=0 \qquad (A1)$$

and that the set of covariates included in **x** is not linearly dependent,

$$\text{rank } E[\mathbf{x}'\mathbf{x}]=K \qquad (A2)$$

where K denotes the number of explanatory variables contained in the vector **x**.

To assess the goodness of fit of relationship (1) we report the R-squared measure. As the number of observations is small, we additionally report the R-squared adjusted for the number of covariates to assess how the goodness of fit varies as we vary the model specification.

To improve or verify the robustness of the findings, we include the estimates of an alternative specification with random country coefficients. In the random coefficient model the goodness of fit measure cannot be the R-squared and we have undertaken other tests of fit and reported the relevant statistics which are explained in more detail below.

3.1 Some Caveats

There are a number of caveats and shortcomings associated with the empirical model and analysis.

Exogeneity. The key assumption in model (1) is that all explanatory variables are exogenous. Roughly speaking this means that they are not affected by unobserved shocks (u) that affect the dependent variable. A concern that this assumption might not be appropriate arises with the variable level of MTRs, and possibly fixed penetration, as it is not entirely obvious that these variables are indeed exogenous to the residual *u*. A plausible justification in favour of exogeneity may be that MTRs are indeed regulated exogenously insofar as the choice of regulation and level of MTRs are not based on indicators of performance in the retail market - that is mobile penetration, MOU, mobile call prices.[18] This would be consistent with the view that regulation of MTRs was introduced to regulate call prices from fixed lines to mobile handsets and not because of events that also affect measure of performance. Only at a later stage was MTRs regulation extended to cover also mobile to mobile calls. Therefore regulation of termination rates stemmed from a consideration that had nothing to do with the performance of the mobile industry.[19]

Using the level of MTRs as one of the explanatory variables in the specification to explain prices, take-up and usage, will only yield consistent results if the latter argument holds and MTRs are set exogenously. We note that with **unregulated** MTRs, operators rather than regulators might jointly determine both MTRs and prices as in a classic two-sided market, taking account of prices on both sides of the market, in which case endogeneity would be a serious concern.

In any event, any doubt about the exogeneity of MTRs, assumption (A1), could be alleviated by testing with econometric procedures whether the variable is statistically exogenous. Unfortunately no variables in the data set appeared suitable for this test and it is not straight forward to come up with a variable that appears suitable as an instrument.[20]

Random effects model. This study focuses on a range of countries that, although more comparable than studies based on larger samples of countries, differ significantly in many respects. Country heterogeneity is of interest to the econometrician as country specific circumstances may affect the key relationships we study and may not be adequately controlled for by the economic variables contained in the data set. These include differences in population density, GDP per capita and fixed penetration, but might not capture sufficiently cross-country differences in supply and demand factors. To capture

18 For example, retail prices do not feed directly into the model used to set the MTRs.

19 Indeed, the European Union regulatory framework examines the degree of competition and market power separately through separate market reviews from mobile termination wholesale and mobile origination retail services. There is no explicit link between the degree of regulation of mobile termination - e.g. the level of cost based MTRs - and the degree of regulation on the retail side. Furthermore, there is no relationship between the number of mobile networks and the decision to regulate and the level of MTRs.

20 A suitable test is the Hausmann endogeneity test which allows the formal examination whether Assumption (A1) holds with respect to MTRs. Unfortunately, to conduct the Hausmann test an additional variable needs to be included that is correlated with MTRs and not contained in *x*, the set of explanatory variables in model (1). This variable should be a driver of MTRs, but have no direct impact other than through the role in setting MTRs on the measures of performance of the industry. A measure of alternative regulatory regimes may come to mind, but it is not clear whether such a variable is indeed a good instrument, if regulation as much as tariffs setting, is an instrument for policy makers and regulators. To the extent that regulatory policy may be decided with the specific aim of affecting mobile penetration rates, or MOU and/or prices of calling plans, the variable may be actually a poor instrument and inappropriate.

these variations without adding variables that directly measure these differences, country fixed or country random effects may be included in the econometric study to capture all differences across countries that are relevant and persistent over time.

However the econometric strategy has been constrained by data limitations. Initial trials with country fixed effects revealed a difficulty, as the set of explanatory variables became almost collinear which violates assumption (A2). A different model, so called "in differences" in econometrics jargon, whereby the difference between year *t* and year *t-1* of each variable for given countries is taken and used on both sides of the model, should produce the same results of a fixed effect model, without increasing the number of parameters that need to be estimated. Because a full year of observations is dropped by differencing, we found that taking within country yearly differences resulted in a data set that has too few observations to allow precise coefficient estimates.

Therefore, the following analysis instead reports estimates using a country random effects specification which accounts for country specific variation, where the fixed components are estimated with a Generalised Least Square (GLS) methodology.

More formally, to explain the estimated empirical relationship, we observe that the residual in relationship (1) may be decomposed into two separate components, a country component *c* and a country-time specific component *ε*.

Model (1) is then augmented with the relationship,

$$u_{it} = c_i + \varepsilon_{it} \qquad (2)$$

and instead of assumption (A1) it is now assumed

$$E[\varepsilon_{it} \mid \mathbf{x}_i, c_i]=0 \text{ for all } t \text{ and } E[c_i \mid \mathbf{x}_i]=0 \qquad (A1')$$

where $\mathbf{x}_i=(\mathbf{x}_{i1},\ldots,\mathbf{x}_{iT})$. This yields the random effects specification.

A Chi-squared test statistic is reported to examine the null hypothesis whether the estimated coefficients are jointly different from zero. We report a Chi-squared statistic as the usual R-squared statistics, or the equivalent F test, is not well defined in a random coefficients model. Additionally, we report the Breusch and Pagan Lagrangian multiplier test (also a Chi squared statistic) which examines the null that there are no country random effects.

Functional form. There is no generally applicable economic model giving clear guidance as to the details of the functional form assumptions. To overcome this difficulty different functional form assumptions were examined and tested. Estimates from alternative model specifications are reported including level and log relationships. In the log regressions all quantitative and positive variables are transformed by taking the log. The coefficients of the independent variables on the right hand side of the equation can be interpreted as elasticities. Statistical significance tests are then conducted to examine whether the relationship between the variables of interest fits better in levels or in logs. In the main report we show results in logs only.

Data limitations from sample size. The size of the data set, though much larger than in some studies, is small which limited the regression analysis in a number of ways:

- the estimates are not very precise in most specifications;
- attempts to include a full set of country fixed effects failed as the resulting set of explanatory variables became almost collinear violating assumption (A2);
- the number of observations varies across specifications as some variables have missing values. Ideally, the sample would be restricted to a balanced panel (consisting of observations with non-missing values for all variables), but this would come at the cost of increasing the imprecision of estimates.

4 MAIN RESULTS

This section reports the main results from our regression analysis. Section 4.1 looks at mobile service take-up, section 4.2 looks at usage and section 4.3 looks at retail prices. As we noted in the earlier sections, the evidence on prices shown in section 4.3 can be interpreted as a measure of indirect impacts on usage which should complement the direct findings of section 4.2 on the effect of regime and level of MTRs on usage.

4.1 Take-up of mobile services

Our central finding is that take-up of mobile services is positively associated with both the level of MTRs and the CPNP dummy. This finding is consistent and robust in our analysis.

Table 3 focuses on the effects of the level of MTRs, while Table 4 is concerned with effects of differences in the wholesale regime for mobile termination on take-up. In both cases, before undertaking the estimation, all non-qualitative variables have been transformed by taking logs. The specification in logs has a better fit than the specification in levels as measured by the R-squared statistic. Results in levels (not reported) reveal a qualitatively similar pattern with same sign coefficient estimates.

The coefficient estimates of non-qualitative variables that have been transformed in logs can be interpreted as elasticities. By multiplying the estimated coefficient estimated by a chosen percentage variation of an explanatory variable we can estimate the associated percentage change of the dependent variable.

The explanatory variables are listed on the first column. Coefficients with stars are statistically significant; more stars indicate increased precision in the estimate of the size of the coefficient. More technically, the level of statistical significance is 1% for three stars, 5% for two stars and 10% for one star. Statistical significance at the 10% level should be interpreted as weak evidence that the coefficient differs from zero, most studies use the 5% level as the default level of significance for robust results. In brackets we report standard errors, two standard errors on each side of the coefficient account for the width of the "confidence interval" at 5% level of confidence. Wide confidence intervals mean that the estimated coefficient is not robust and may not be statistically significantly different from zero.

Measures of goodness of fit report how much of the variability in the welfare proxies is explained by the specifications that are tested and how much remains unexplained and is attributed to unmeasured factors (which are captured in the regression "residuals").

We have created a set of time dummies. These are important as they capture macro-economic trends (other than GDP per capita) that might affect performance which are common across all countries in a given year. The year dummies represent the difference relative to 2007, year for which the dummy has been omitted. For example a positive and significant dummy for 2003, should imply that other things equal, the dependent variable was on average higher in 2003 than in 2007.

Likewise, for regional dummies we had to omit one category, the omitted dummy is for "Western Europe and the EEA".

4.1.1 Take-up and MTRs

Table 3 reports the estimation results for six alternative specifications for log of mobile penetration. Mobile penetration is measured by the number of sold SIM cards over total population and, as discussed, might therefore overestimate the number of individuals with access to mobile services especially in CPNP countries. For this reason results from this study, and all studies that have used this measure, must be interpreted with caution if the focus of the comparison is on individual users of mobile services in countries with different regimes.

Specification (4) and specifications (5) in Table 3 are our statistically preferred specifications. Specification (4) has an adjusted R-squared of 0.66 which exceeds the R-squared in specifications (1)-(3). Specification (2) adds a set of year fixed effects in addition to the variables included in specification (1). The year fixed-effects increase the percentage of explained variation in mobile penetration by more than 20%, from 33% to 55%, and the increase is significant even when taking the adjusted R-squared statistic. Adding additional regional fixed effects in specification (4) increases the percentage of explained variation in mobile penetration by another 14%, from 55% to 69%. Hence, the statistically preferred regressions are specifications (4) and (5). Observe that we cannot compare specifications (4) and (5) as these are non-nested and distinct statistical models. Specification (4) includes regional fixed-effects while specification (5) includes country random-effects. Specification (5) has a better fit than specification (6) according to the Chi-squared statistic. In both specifications the null hypothesis of zero random effects can be rejected, implying that country fixed effects are an important element of the specification.

The level of MTRs coefficient is the main effect of interest. Increasing MTRs by one percent goes hand in hand with a 0.034% increase in mobile penetration rates. The point estimate is sharply estimated and consistent across specifications ranging between 0.031% and 0.045%. The log average mobile termination rate in the sample is 0.86. Increasing the average termination rate to 3.14, which amounts to adding one standard deviation to the average,[21] goes hand in hand with an increase of mobile penetration average of 9%, from 84.4% to 92% using the point estimate in specification (5).

GDP per capita, fixed penetration and the regional dummies have the expected signs. Increasing GDP per capita by one percent goes hand in hand with a 0.12% increase in the mobile penetration rate. The point estimate of GDP per capita is consistent across specifications and ranges between 0.09% and 0.22%. Fixed penetration has a positive coefficient estimate in most specifications but the effect is not sharply estimated. The null hypothesis of a zero effect cannot be rejected. The sign on population density appears counterintuitive, if we see this variable as a proxy for lower costs and therefore prices. Increasing population density by one percent goes hand in hand with a 0.04% decrease in the mobile penetration rate. The point estimate of population density is consistent across specifications and ranges between -0.03% and -0.04%. North America, in this case the US only, has a lower mobile penetration rate than the other regions. The estimates of the time fixed effects suggest a significant

[21] This increases the termination rate from 2.4 on average to 23.1 pence in levels.

increase in mobile penetration over time. Year on year the increase ranges between 0.03 and 0.1 and is consistent across specifications.

Table 3 Dependent variable log Mobile Penetration, 2003-2007

	OLS	OLS	OLS	OLS	R.E.	R.E.
	(1)	(2)	(3)	(4)	(5)	(6)
MTRs (log)	0.0372*** [0.0071]	0.0449*** [0.0061]	0.0308*** [0.0069]	0.0343*** [0.0065]	0.0334*** [0.0123]	0.0347*** [0.0119]
GDP p.c. (log)	0.1521*** [0.0411]	0.0875** [0.0352]		0.1237*** [0.0338]	0.2181*** [0.0622]	
Fixed pen. (log)	-0.0167 [0.0617]	0.1288** [0.0542]		0.0758 [0.0521]	0.0243 [0.0904]	
Pop. density (log)	-0.0385*** [0.0125]	-0.0392*** [0.0103]		-0.0413*** [0.0088]	-0.0315 [0.0227]	
dummy y 2003		-0.3098*** [0.0503]	-0.3204*** [0.0486]	-0.3013*** [0.0433]	-0.2638*** [0.0313]	-0.3034*** [0.0252]
dummy y 2004		-0.2739*** [0.0412]	-0.2780*** [0.0389]	-0.2700*** [0.0350]	-0.2393*** [0.0262]	-0.2744*** [0.0200]
dummy y 2005		-0.1745*** [0.0375]	-0.1746*** [0.0350]	-0.1663*** [0.0318]	-0.1525*** [0.0221]	-0.1806*** [0.0175]
dummy y 2006		-0.0810** [0.0366]	-0.0784** [0.0350]	-0.0774** [0.0311]	-0.0723*** [0.0185]	-0.0842*** [0.0175]
North America			-0.4138*** [0.0599]	-0.3654*** [0.0541]		
South East Asia			-0.0634 [0.0492]	-0.0257 [0.0425]		
Eastern Europe Accession Countries			-0.1367*** [0.0302]	0.0182 [0.0433]		
Constant	-0.3835** [0.1738]	0.0717 [0.1578]	0.1208*** [0.0299]	-0.0493 [0.1399]	-0.4355 [0.2770]	0.0517 [0.0316]
Observations	140	140	143	140	140	143
Explanatory variables	4	8	8	11	8	5
Number of Country Effects					36	36
Adjusted R-squared	0.308	0.527	0.530	0.660		
R-sq	0.328	0.554	0.556	0.687		
Fitness statistic Chi-sq					332.70***	270.51***
Random effects test Chi-sq					96.42***	115.59***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

4.1.2 Take-up, CPNP regime and MTRs

Table 4 reports the estimation results for four alternative specifications considering the effect of the CPNP dummy on log mobile penetration.

We could only estimate specifications excluding regional or country random effects when the CPNP regime dummy is included. The reason is that the CPNP dummy variable does not vary over time and is indistinguishable from the random country effects. Similarly, an attempt to include regional effects in specifications with the CPNP dummy also proved to be unfruitful. It turned out that by grouping countries in four regions (for the core sample) - North America, South East Asia, Western Europe/ EEA, and Eastern Europe/ Accession countries - created similar issues linked to the presence of countries with only one type of regime. As the data are too limited to allow us to account for regional

and/or country random effects we are not able to verify the robustness of the underlying relationship and findings. The following analysis has to take into account this major caveat.

In specifications (3) and (4) we include the level of MTRs as well to verify whether the charging regime as proxied by the CPNP dummy has an effect per se (for example the rejection of paying for unwanted calls under the B&K/RPP regimes) on the consumer outcome of interest, penetration of mobile services in this case, or whether once the level of MTRs is included, the charging regime has no significant effects. We note that MTRs are charged in B&K countries, eg the US, and that there is no issue with collinearity arising from the inclusion of both variables.

Specification (2) and specification (4) are our statistically preferred specifications. Specification (4) has an adjusted R-squared of 0.59 which exceeds the R-squared in specifications (1)-(3). We now briefly comment on the estimation results reported in specification (4) and comment on the consistency of the coefficient estimates across alternative specifications reported in Table 4.

The level of MTRs coefficient and the CPNP dummy are the main effects of interest. Increasing the level of MTRs by one percent goes hand in hand with a 0.043% increase in mobile penetration rates in the favoured specification; also the point estimate is sharply estimated.

The CPNP dummy effect is sharply estimated and positive across all specifications, the effect ranges from 0.33% to 0.59%. There are two B&K countries in specification (1) and (2), the US and Canada, and only the US in specification (3) and (4) where the level of MTR is included. Results in levels for the same specification 4 show that the CPNP dummy appears to go hand in hand with an increased SIM cards per population, which is about 27 percentage points higher under the CPNP regime. [22]

An examination of estimates across specifications in Table 4 reveals that the year fixed-effects increase the percentage of explained variation in mobile penetration by more than 20% comparing specifications (3) and (4).

Specifications (3) and (4) reveal that looking at the regime without taking account of the level of MTRs as in specifications (1) and (2) may conceal some important differences across countries. The CPNP dummy coefficient is lower when the level of MTRs is included in the specification. Comparing countries with the same regime, the higher the level of MTRs, the higher mobile take-up. The change in size of the coefficient of the regime dummy suggests that some of the variation that would be attributed to the regime choice is actually explained by the level of MTRs.[23] In specifications (3) and (4) however it is not possible to distinguish effects that are specific to the US from effects that are specific to the B&K regime as it was not possible to include geographic dummies or fixed country effects.

[22] We also estimated specification (2) excluding GDP per capita, information on this variable in PPP adjusted GBP is missing for Singapore and Hong Kong, on a sample including four B&K countries and found a coefficient of 0.304.

[23] We ran separate regression to verify that this is only partly explained by the different sample used in specifications (3) and (4). Estimating specification (2) on the same sample as specification (4) lowers the coefficient of the CPNP dummy to 0.3835.

The coefficient of GDP per capita has the expected sign. Increasing GDP per capita by one percent goes hand in hand with a 0.11% increase in the mobile penetration rate. The point estimate of GDP per capita varies across specifications and drops from 0.32% and 0.35% to 0.11% and 0.17% when the level of MTRs is included in the specification. Fixed penetration has a positive coefficient estimate in specification (4) where it is sharply estimated, but is otherwise not precisely estimated in specifications (1)-(3) where the null hypothesis of a zero effect cannot be rejected. Counter-intuitively increasing population density by one percent goes hand in hand with a 0.04% decrease in the mobile penetration rate in the preferred specification. The point estimate of population density is consistent across specifications and ranges between -0.01% and -0.04%. The estimates of the time fixed effects suggest a significant increase in mobile penetration over time and are sharply estimated in the preferred specification. Year on year the increase ranges between 0.04 and 0.1 but is not consistent across specifications.

Table 4 Dependent variable log Mobile Penetration, 2002-2007

	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)
CPNP Dummy	0.5876***	0.5840***	0.3251***	0.3366***
	[0.0802]	[0.0643]	[0.0875]	[0.0702]
MTRs (log)			0.0346***	0.0425***
			[0.0068]	[0.0056]
GDP p.c. (log)	0.3538***	0.2283***	0.1713***	0.1076***
	[0.0415]	[0.0354]	[0.0396]	[0.0329]
Fixed pen. (log)	-0.0544	0.1499	-0.0122	0.1346***
	[0.0652]	[0.0557]	[0.0590]	[0.0502]
Pop. density (log)	-0.0116	-0.0101	-0.0422***	-0.0430***
	[0.0130]	[0.0104]	[0.0120]	[0.0096]
dummy y 2002		-0.4546***		
		[0.0508]		
dummy y 2003		-0.3676***		-0.3188***
		[0.0497]		[0.0466]
dummy y 2004		-0.2616***		-0.2725***
		[0.0483]		[0.0381]
dummy y 2005		-0.1605***		-0.1724***
		[0.0477]		[0.0347]
dummy y 2006		-0.0798*		-0.0804**
		[0.0471]		[0.0339]
Constant	-1.7328***	-0.9851***	-0.7340***	-0.2909*
	[0.1758]	[0.1615]	[0.1910]	[0.1644]
Observations	208	208	140	140
Adjusted R-squared	0.411	0.6219	0.368	0.595
R-sq	0.422	0.6384	0.391	0.621
Explanatory variables	4	9	5	9

Standard errors in brackets.* significant at 10%; ** significant at 5%; *** significant at 1%

We have estimated specifications (1) and (2) on a sample of non-OECD countries (just including CPNP and time dummies as explanatory variables), but the results had very low fit. We found no effect of CPNP in the sample of 106 observations. Though results might be difficult to interpret due to the greater differences between OECD and non OECD countries, we also estimated this simple specification on all countries jointly. As in the core sample we found that the CPNP dummy is positive and statistically associated with higher mobile take-up, but the specification had very low fit and the year dummies coefficients were not statistically significant (though an F-test on the joint significance of time dummies and the CPNP variable was rejected). Overall we believe that only results for the core sample of 39 OECD countries are robust.

4.2 Usage

We do not find a statistically significant effect of the level of MTRs on MOU. This finding applies to all the measures of minutes of we use. With the raw Merrill Lynch data a negative coefficient estimate appears in initial specifications without time and country fixed effects, but the negative effect disappears as the specification becomes richer and includes time and country effects. We show the findings for alternative measures of usage, MOU per capita and MOU debiased, in Annex B.

We find a negative relationship between the CPNP dummy variable and MOU. Our specification does not account for geography based effects as we could not estimate regional or fixed effects. Therefore the findings that CPNP regime goes hand in hand with lower usage should be interpreted with great caution as they may capture specific features of the Canadian and US market (US only when the variable level of MTRs is included). Because of the limitations of the specifications that include the CPNP dummy this relationship was tested only with the raw measure of MOU.

4.2.1 MOU and MTRs

Table 5 shows the results for 6 different specifications. Our preferred specifications are (4) and (5). Specification (4) has the highest R-squared (57%) among OLS specifications. Specification (5) has the highest chi-squared statistic among all random effects specifications. In our estimation of the relationship between the variables of interest and usage, we found that alternative functional forms perform similarly in terms of goodness of fit. We therefore show only results in logs in this section and comment on the consistency with results in levels for the same specifications.

The level of MTRs coefficient estimate is not robust, as it changes sign across specifications and becomes insignificant or less statistically significant in specifications (2), (3) and (6). The effect of increasing the level of MTRs by 1% ranges from -0.06% to 0.04%.

The effect of GDP per capita is consistently positive and sharply estimated. An increase in GDP per capita of 1% is associated with an increase in minutes that ranges from 0.49% to 0.75%. The effect of a change in fixed services penetration is not statistically distinguishable from zero in all specifications, while the effect of higher population density is consistently found to be negative (ranging from 0.06% to 0.08%).

Time dummies are only significant in specification (6) where the effect is a steady increase in MOU year on year. This effect is not precisely estimated in the other specifications where variables that may follow a trend are included (e.g. GDP) and there are no country effects.

Regional effects estimates suggest that minutes are highest in the US other things being equal. Usage is also higher in the south East Asia region relative to Western Europe. In the Eastern Europe region MOU are lowest, though the effect is not precisely estimated in specification (4).

Table 5 Dependent variable log MOU, 2003-2007

	OLS	OLS	OLS	OLS	R.E.	R.E.
	(1)	(2)	(3)	(4)	(5)	(6)
MTRs (log)	-0.0418**	-0.0363*	0.0282	0.0430**	-0.0624**	-0.0512
	[0.0185]	[0.0198]	[0.0230]	[0.0211]	[0.0307]	[0.0314]
GDP p.c. (log)	0.5410***	0.4897***		0.5351***	0.7498***	
	[0.1529]	[0.1640]		[0.1398]	[0.1764]	
Fixed pen. (log)	-0.0287	0.0498		0.1628	0.0747	
	[0.2024]	[0.2224]		[0.1889]	[0.1590]	
Pop. density (log)	-0.0804**	-0.0837**		-0.0651**	-0.0646	
	[0.0354]	[0.0361]		[0.0284]	[0.0783]	
dummy y 2003		-0.1500	-0.2521*	-0.1507	-0.0602	-0.2010***
		[0.1628]	[0.1338]	[0.1293]	[0.0530]	[0.0331]
dummy y 2004		-0.0833	-0.1304	-0.0797	-0.0248	-0.1345***
		[0.1372]	[0.1112]	[0.1080]	[0.0430]	[0.0257]
dummy y 2005		-0.0954	-0.1425	-0.1036	-0.0419	-0.1225***
		[0.1274]	[0.1044]	[0.1001]	[0.0343]	[0.0229]
dummy y 2006		-0.0443	-0.0609	-0.0478	-0.0068	-0.0458**
		[0.1248]	[0.1044]	[0.0979]	[0.0254]	[0.0223]
North America			0.8919***	1.1388***		
			[0.1637]	[0.1563]		
South East Asia			0.3405**	0.5558***		
			[0.1468]	[0.1365]		
Eastern Europe Accession Countries			-0.5256***	-0.0204		
			[0.1156]	[0.1439]		
Constant	3.3903***	3.6720***	5.0770***	3.4068***	2.8793***	5.1575***
	[0.5873]	[0.6663]	[0.0863]	[0.5582]	[0.6188]	[0.0957]
Observations	107	107	112	107	107	112
Adjusted R-squared	0.237	0.215	0.353	0.516		
R-sq	0.266	0.274	0.400	0.566		
Explanatory variables	4	8	8	11	8	5
Number of Country Effects					26	26
Fitness statistic Chi-sq					145.29***	100.30***
Random effects test Chi-sq					151.08***	153.39***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

4.2.2 MOU, CPNP regime and MTRs

In this section we show results for the CPNP dummy for the original MLWMD data. We find a negative effect of the CPNP dummy on MOU. However, our specification does not account for geography based effects as we could not estimate regional or fixed effects. Therefore, the findings of a negative effect of the CPNP regime on usage should be interpreted with caution. The fit is best when using a specification in levels rather than in logs.

We show in the following table the specifications in logs. The CPNP dummy coefficient is negative and significant throughout. However, lacking regional and country effects it is possible that the CPNP dummy captures a number of other time invariant differences across countries, separating in specification (1) Canada and the US from the other countries, and in specification (2) and (3), the US from all other countries. This is likely to be the case as we know that the significant and negative coefficient of the level of MTRs variable – see specifications (1) and (2) in the above Table 5 - is not robust to the inclusion of regional dummies or country effects. The estimate of the MTRs coefficient in Table 5 switches between insignificant or significant with opposing sign estimates when the persistent differences across countries are modelled with regional dummies or country effects, but the same coefficient is always negative and significant if country or regional effects are excluded from the specification. The results also show that the coefficient of population density is negative and (weakly) significant across all specifications. The specifications (2) and (3) estimated including both the CPNP dummy and the level of MTRs in Table 6 confirm the findings on the effect of the level of MTRs in Table 5.

We believe the results in Table 6 should be taken with caution as they cannot provide robust evidence that the choice of regime (or the level of MTRs), as opposed to other unmeasured factors, explains differences in usage across countries.

Table 6 Dependent variable log MOU, 2002-2007

	OLS	OLS	OLS
	(1)	(2)	(3)
CPNP Dummy	-1.0494***	-1.3660***	-1.3682***
	[0.1214]	[0.1731]	[0.1758]
MTRs (log)		-0.0102**	-0.0091*
		[0.0044]	[0.0048]
GDP p.c. (log)	0.4262***	0.3584***	0.3236**
	[0.0940]	[0.1184]	[0.1261]
Fixed pen. (log)	-0.0374	-0.0644	-0.0066
	[0.1323]	[0.1580]	[0.1746]
Pop. density (log)	-0.0482**	-0.0512*	-0.0540*
	[0.0226]	[0.0279]	[0.0285]
dummy y 2003			-0.0843
			[0.1302]
dummy y 2004			-0.0725
			[0.1078]
dummy y 2005			-0.0886
			[0.0999]
dummy y 2006			-0.0282
			[0.0979]
Constant	4.6768***	5.2923***	5.4893***
	[0.3743]	[0.5005]	[0.5530]
Observations	155	107	107
Adjusted R-squared	0.540	0.536	0.522
R-sq	0.552	0.558	0.563
Explanatory variables	4	5	9

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

4.3 Prices proxies

Findings on retail prices

The statistical relationship between alternative measures of price and level of MTRs or a CPNP dummy is weak. This weak relationship emerges for all price measures, including Teligen price indices.

However, we find some evidence of small scale effects of MTRs on RPM using the original Merrill Lynch data (results in Table 7). As mentioned in Section 2 the original data on RPM includes revenues from termination fees and tends to overstate RPM in CPNP countries. The "debiased" data provided by Ofcom attempt to correct for the biases that might affect comparisons across countries with different wholesale regimes for termination (see Annex A for more detail on the "debiased" data). Using this "debiased" measure we do not find a robust relationship between the level of MTRs and retail prices (Table 8).

We do not find statistically significant effects from CPNP dummy on RPM.

The finding on the regime dummy is inconsistent with the results obtained by Littlechild that finds that RPM are higher in CPP countries. One could nonetheless interpret the evidence on the association between higher MTRs and higher RPM in this study and the association of CPP and higher RPM in Littlechild's study as a consistent pattern linking the higher level of MTRs (on average) in CPNP countries with higher revenues as measured by the original Merrill Lynch data. However, our findings show that the correlation between the level of MTRs and RPM is not robust to the use of a "debiased" measure, suggesting that there is no strong evidence to argue that the positive correlation between prices, as measured with RPM, and the level of MTRs is supported by the data.

The absence of an effect is consistent with the findings of Genakos and Valletti where they use average revenues per user as an indicator of price.

The price index measures from Teligen should provide a better proxy for retail prices than revenues, however, we noted that there is a lot of variability in the data for the studied sample and that the Teligen measures too may be subject to bias as the construction of the price indices relies on fixed usage profiles throughout the period, while usage might have increased.

Genakos and Valletti find that for high-price mobile services there is a negative correlation between Teligen price measures and the level of MTRs (and no effect on low-price services), while this study does not uncover a robust statistical relationship with all Teligen prices.

The findings using Teligen measures of price are reported in Annex C.

4.3.1 RPM and MTRs

We show the finding on the relationship between MTRs and RPM in logs in Table 7. In the logs specifications we find a small but statistically significant coefficient for the level of MTRs in all specifications we examined. This finding would be consistent with the argument that operators increase prices to recover higher MTRs.

Table 7 reports four OLS specifications and two random effect specifications. Our preferred specifications are (4) and (5). The coefficient of the level of MTRs is smallest in the specification with country effects.[24] It is generally sharply estimated, though the inclusion of regional dummies (which increases the goodness of fit significantly) also halves the coefficient from an elasticity of about 0.5 to an elasticity of 0.25 in specification (4) and 0.19 in specification (5). This finding must be interpreted with caution given the bias in RPM measurement in the Merrill Lynch data.

The coefficients of GDP per capita and fixed penetration are insignificant, while population density has the expected sign and is significant in the OLS specifications. The inclusion of regional dummies improves the fit by 12% from specification (2), adjusted R-squared of 33%, to specification (4), which has an adjusted R-squared of 45%. The coefficient of the South East Asia and Eastern Europe regional dummies are negative and significant suggesting lower prices in these regions.

Table 7 Dependent variable log RPM, 2003-2007

	OLS	OLS	OLS	OLS	R.E	R.E.
	(1)	(2)	(3)	(4)	(5)	(6)
MTRs (log)	0.5029***	0.4922***	0.1936**	0.2546***	0.1938***	0.1974***
	[0.0699]	[0.0746]	[0.0916]	[0.0926]	[0.0655]	[0.0636]
GDP p.c. (log)	0.0824	0.2313		-0.8219	0.2210	
	[0.5770]	[0.6180]		[0.6127]	[0.3511]	
Fixed pen. (log)	1.0057	0.7356		0.5170	0.5546**	
	[0.7639]	[0.8381]		[0.8276]	[0.2712]	
Pop. density (log)	-0.4396***	-0.4293***		-0.4385***	-0.1045	
	[0.1337]	[0.1361]		[0.1246]	[0.2813]	
dummy y 2003		0.2748	0.2888	-0.0351	0.1059	0.1046*
		[0.6136]	[0.5318]	[0.5668]	[0.0968]	[0.0534]
dummy y 2004		0.3638	0.4681	0.2146	0.1788**	0.1871***
		[0.5172]	[0.4420]	[0.4733]	[0.0772]	[0.0397]
dummy y 2005		-0.0160	0.1508	-0.0529	0.1414**	0.1498***
		[0.4802]	[0.4152]	[0.4385]	[0.0604]	[0.0341]
dummy y 2006		-0.1220	0.0212	-0.1177	0.0126	0.0205
		[0.4702]	[0.4150]	[0.4292]	[0.0431]	[0.0326]
North America			-0.9657	-1.3420*		
			[0.6508]	[0.6849]		
South East Asia			-2.3661***	-2.6261***		
			[0.5837]	[0.5983]		
Eastern Europe Accession Countries			-1.6544***	-1.8804***		
			[0.4595]	[0.6304]		
Constant	-2.7009	-3.4285	-2.4960***	0.5767	-3.4192***	-3.1908***
	[2.2163]	[2.5115]	[0.3432]	[2.4460]	[1.2177]	[0.3286]
Observations	107	107	112	107	107	112
Adjusted R-squared	0.353	0.335	0.393	0.446		
R-sq	0.377	0.385	0.437	0.504		
Explanatory variables	4	8	8	11	8	5
Number of Country Effects					26	26
Fitness statistic Chi-sq					101.95***	102.29***
Random effects test Chi-sq					113.70***	113.83***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

[24] Valletti and Genakos, see their Table A7, also fail to find significant effects of the level of MTR on average revenues per user. There may be differences in the countries included in the sample between the two studies.

4.3.2 RPM "debiased" and MTRs

The bias in measurement of RPM in countries with different regimes is of concern. The results shown in Table 8 report the findings using log RPM "debiased" by Ofcom. We find that the bias potentially has a strong impact on the findings, the effect of the level of MTRs on prices with the "debiased" measure of RPM is not robust and the goodness of fit is low especially in specification (1) and (2) where the level of MTRs coefficient is significant. The goodness of fit statistic improves significantly in specifications (3) and (4) where we include regional effects in the OLS models. The North America/ US dummy is negative and significant, as well as the South East Asia dummy. The time dummies suggest higher prices from 2003-2005 relative to recent years.

The MTRs coefficient is insignificant in specifications (3) to (6), that is in all specifications that control for regional effects or random effects. Where the MTRs coefficient is significant - OLS specifications (1) and (2) - the coefficient is positive, precisely estimated and of consistent magnitude 0.013-0.015. We found qualitatively similar results, not shown in the report, in the specifications in levels.

Table 8 Dependent variable log RPM debiased, 2003-2007

	OLS	OLS	OLS	OLS	R.E.	R.E.
	(1)	(2)	(3)	(4)	(5)	(6)
MTRs	0.0150***	0.0134***	0.0026	0.0034	0.0075*	0.0058
	[0.0038]	[0.0039]	[0.0044]	[0.0045]	[0.0045]	[0.0045]
GDP per capita	0.0092*	0.0128**		0.0099*	0.0093	
	[0.0049]	[0.0049]		[0.0050]	[0.0084]	
Fixed Penetration	0.8223***	0.5239		0.3087	0.8468*	
	[0.3063]	[0.3189]		[0.3110]	[0.4595]	
Population Density	0.0004*	0.0005**		0.0004*	0.0005	
	[0.0002]	[0.0002]		[0.0002]	[0.0005]	
dummy y 2003		0.1677	0.1560	0.1785*	0.1846***	0.1846***
		[0.1132]	[0.0988]	[0.1043]	[0.0687]	[0.0469]
dummy y 2004		0.2360**	0.2397***	0.2414***	0.2363***	0.2402***
		[0.0935]	[0.0797]	[0.0849]	[0.0542]	[0.0347]
dummy y 2005		0.1820**	0.1938**	0.1937**	0.1842***	0.1872***
		[0.0873]	[0.0748]	[0.0790]	[0.0440]	[0.0311]
dummy y 2006		0.0320	0.0527	0.0440	0.0414	0.0464
		[0.0859]	[0.0747]	[0.0777]	[0.0363]	[0.0310]
North America			-0.6898***	-0.5732***		
			[0.1134]	[0.1191]		
South East Asia			-0.2533***	-0.1959**		
			[0.0849]	[0.0960]		
Eastern Europe Accession Countries			-0.2150**	-0.0233		
			[0.0852]	[0.1118]		
Constant	-2.3904***	-2.4384***	-1.6444***	-2.1151***	-2.4685***	-1.7897***
	[0.1357]	[0.1393]	[0.0658]	[0.1863]	[0.2318]	[0.0700]
Observations	107	107	112	107	107	112
Adjusted R-squared	0.260	0.299	0.377	0.427		
R-sq	0.288	0.352	0.422	0.486		
Explanatory variables	4	8	8	11	8	5
Number of Country Effects					26	26
Fitness statistic Chi-sq					104.92***	97.94***
Random effects test Chi-sq					115.67***	125.02***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

4.3.3 RPM, CPNP regime and MTRs

Due to the poor fit of specifications with the CPNP dummy we report only the results using the original Merrill Lynch data, which are shown in Table 10.

The CPNP dummy does not have a statistically significant effect on RPM. The goodness of fit is extremely weak when the level of MTRs variable is not included in the specification, suggesting the lack of a robust relationship. The results in levels provide similar findings. The time dummies are insignificant and the GDP per capita becomes insignificant when the level of MTRs is included suggesting that GDP may have picked up the effect of differences across countries in the level of termination charges. Population density is significant and has the expected negative sign in specifications (3) and (4).

With all specifications, the conclusion is that there is no statistical evidence of an effect of the CPNP dummy on prices.

Table 9 Dependent variable log RPM, 2002-2007

	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)
CPNP Dummy	0.7438	0.7302	0.1906	0.1822
	[0.6787]	[0.6871]	[0.8374]	[0.8498]
MTRs (log)			0.5010***	0.4905***
			[0.0708]	[0.0754]
GDP p.c. (log)	1.0898**	1.3639**	0.1034	0.2507
	[0.5257]	[0.5850]	[0.5870]	[0.6276]
Fixed pen. (log)	0.0312	-0.3302	1.0093	0.7401
	[0.7395]	[0.8117]	[0.7676]	[0.8424]
Pop. density (log)	-0.1998	-0.1961	-0.4431***	-0.4326***
	[0.1266]	[0.1281]	[0.1351]	[0.1376]
		0.558		
		[0.6116]		
dummy y 2003		0.5744		0.2703
		[0.5958]		[0.6170]
dummy y 2004		0.5269		0.3644
		[0.5838]		[0.5198]
dummy y 2005		0.4018		-0.0154
		[0.5745]		[0.4826]
dummy y 2006		0.1833		-0.1224
		[0.5674]		[0.4725]
Constant	-6.0008***	-7.4925***	-2.9445	-3.6586
	[2.1091]	[2.5004]	[2.4706]	[2.7424]
Observations	155	155	107	107
Adjusted R-squared	0.046	0.022	0.347	0.329
R-sq	0.070	0.079	0.378	0.386
Explanatory variables	4	9	5	9

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

ANNEX A: DATA APPENDIX

Sample Period and Countries

Ofcom collated a dataset of relevant annual data covering 40 countries covering the period from 2002 to 2007 inclusive. These countries are either members of the EU or OECD or both. Where data was unavailable or unreliable there are missing values. Slovenia was dropped from the main sample due to an error in the data, reducing the core sample to 39 countries.

Output Measures

MOU per Subscription

MOU data is obtained from Merrill Lynch and is the total outgoing and incoming MOU per subscription. This was supplemented with data from the Cypriot NRA.

Merrill Lynch note that minutes billed to both the caller and receiver are double counted in B&K countries meaning that MOU are overstated in B&K countries relative to CPNP countries. Merrill Lynch state that the bias applies to on-net mobile-to-mobile calls and estimate that this means that the MOU figure they report is overstated by roughly 20% in B&K countries.

Source: Merrill Lynch Interactive Global Wireless Matrix 4Q07

MOU per Capita

In order to allow for the fact that the proliferation of multiple SIM cards ownership may result in higher penetration rates in CPNP countries Ofcom also adjusted the MOU data to express it in per capita terms. This was done by multiplying the MOU by the number of subscribers and dividing by the population.

Sources: Merrill Lynch Interactive Global Wireless Matrix 4Q07 and ITU WTI 2007

MOU per Subscription (debiased)

This measure is an attempt at correcting for the bias identified by Merrill Lynch by adjusting the MOU per subscription downwards by 20% in every year of the sample period in B&K countries only.

Source: Merrill Lynch Interactive Global Wireless Matrix 4Q07.

Consumer Price Measures

Ofcom collected price data from two different sources: Merrill Lynch and Teligen. Ofcom derived a number of price variable from these.

RPM per Subscription

The RPM per user data is provided by Merrill Lynch, and is the **voice only** average revenue per subscription (ARPU[25]) divided by the total MOU per subscription.

[25] ARPU means average revenue per user. However as ARPU is calculated by dividing total revenues by the active subscriber base rather than the number of unique users, and some users have multiple subscriptions average revenue per subscription is a more accurate description.

Merrill Lynch note that service revenue is overstated in CPNP countries as wholesale termination revenue from off-net mobile to mobile calls is included in the service revenue. Merrill Lynch estimate that this double counted termination revenue could bias ARPU upwards by 5% in CPNP countries. Based on internal information on UK data Ofcom believe that the bias in ARPU could be significantly larger than 5%.

The MOU is overstated in B&K countries relative to CPNP countries. This implies that measured RPM are too low in B&K countries. ARPU is overstated in CPNP countries relative B&K countries. The effects of these two biases go in the same direction and the RPM are biased upward in CPNP countries relative to B&K countries.

Source: Merrill Lynch Interactive Global Wireless Matrix 4Q07

RPM per Subscription (debiased)

This measure attempts to correct for the biases identified above by adjusting the RPM per subscription upwards by the same amount in every year of the sample period in B&K countries only.

Source: Merrill Lynch Interactive Global Wireless Matrix 4Q07

Teligen Price Indices

Ofcom also made use of price indices provided by Teligen. Teligen routinely collects these data for all the 30 OECD countries on quarterly basis. Ofcom also commissioned Teligen to collate a dataset of mobile services price indices based on the OECD 2002 basket methodology. Ofcom asked Teligen to extend the dataset to cover a further 10 non-OECD countries in the sample over the period 2002 to 2007 inclusive. The overall database covers 40 countries for the period 2002 to 2007 (November data each year).

The Teligen price indices measure the price of a representative basket of mobile services over time[26]. Ofcom have chosen to use the OECD-Teligen 2002 basket definitions because Ofcom were advised by Teligen that this was the most consistent index to capture price changes over the period of interest (2002-07).

They specify four different baskets of mobile services which represent users with low usage, medium usage and high usage post-pay and low usage pre-pay or post-pay profiles. These usage profiles were chosen by Teligen so that they are broadly representative of consumption profiles of mobile services across the OECD. The baskets specify a given number of *outbound* call minutes to be made to on-net mobiles, off-net mobiles and fixed lines as well as some SMS services.

[26] The 2002 basket definitions are specified as “Old definitions” in OECD Basket Definitions p.7 http://teligen.com/publications/oecd.pdf.

Each index is calculated by reporting the price of the basket in local currency units, by selecting the cheapest tariff for that usage profile from the available tariffs of the two largest operators[27] in terms of market share by subscribers.

The level of usage is fixed over time in the Teligen index. Whenever mobile price plans include more minutes for a given tariff over time, the index overestimates prices per minute.

Source: Teligen

Termination Rate Measures

This variable is a measure of MTRs. MTRs may vary between peak and off- peak and in some countries there are some set up charges at the beginning of the call. Ofcom used the data collected for EU countries and the methodology used by the European Commission (DG INFOSOC).

Individual MTRs are calculated by collecting the average termination charge excluding VAT for a three-minute call during peak period, taking into account both any applicable call setup and per-minute charges. The EC reports the weighted average of all the MNOs' MTRs within a country. The average is weighted by subscribers and reflects the situation as of 1st October for each year.

The European Commission collects data on the average level of MTRs in EU member states on an annual basis for the EC Implementation Report[28]. Ofcom obtained data for the 27 member states from 2003 to 2007. Ofcom also asked Analysys Mason to collate a dataset of the average level of MTRs using the EC reporting methodology for the 13 remaining countries[29] from 2004 to 2007, and for any of the data points for the EU-27 where there was missing data over the sample period. Using the same approach used by the European Commission approach Ofcom collated a dataset of MTRs in local currency, covering the 40 countries in the sample from 2004 to 2007 using a consistent methodology. MTRs are expressed in GBP pence.

In the collation process Analysys Mason necessarily made a number of simplifying assumptions. As the actual level of MTRs is confidential Analysys used the regulated rate reported by the country's NRA. In the US, where the interconnection regime is complex, and differs according to geographical location, Analysys used a representative location for which to report the MTRs. In Japan, the MTRs data only covers 2 of the 3 operators.

Source: European Commission and Analysys Mason.

27 Where the two largest operators market shares sum to at least 50%. Otherwise the tariffs of the third largest operator are also included. Where tariff data was only available for one operator the price index finds the lowest price for a given usage profile from that operator's tariffs.

28 13th EC Implementation Report supporting data http://ec.europa.eu/information_society/policy/ecomm/doc/library/annualreports/13th/market_data/2007_data.xls

29 The remaining 13 countries are: Australia, Canada, Hong Kong, Iceland, Japan, Korea, Mexico, New Zealand, Norway, Singapore, Switzerland, Turkey and the US.

CPNP Dummy

Dummy indicator variable taking value 1 if regime is CPNP, 0 if B&K.

Source: ML Interactive Global Wireless Matrix, EC for EU countries, Ofcom.

Other data

GDP

Gross Domestic Product in billions (£).

Sources: World Bank WDI Online 2007 for GDP data and OECD/Teligen for PPP exchange rates.

Mobile Penetration

Mobile penetration per capita. Number of active mobile phone SIMs divided by the population.

Source: ITU WTI 2007

Fixed Penetration

Fixed penetration per capita. Number of active fixed line phone subscriptions divided by the population.

Source: ITU WTI 2007

Population

Population (million) has been used to generate GDP per capita figures.

Source: ITU WTI 2007

Population Density

Average population density per square kilometre. Population density is population divided by the surface area. Surface area for 2007 is assumed to be equal to that in 2006. We have rescaled the variable to 100 in habitants per square kilometre.

Sources: ITU WTI 2007 and World Bank WDI Online 2007

Comparing prices across countries

The RPM, price indices, MTRs and GDP data are all measured in currency terms in their original source. Generally this is the local currency. In order to do be able to compare data across several countries it is necessary to convert all these measures into a common currency measure. Ofcom converted all of the nominal variables from the reporting currency in the raw data to the international pound (£) sterling, using a Purchasing Power Parity (PPP) exchange rate provided by the OECD/Teligen. PPP exchange rates are generally considered to be preferable in international price comparisons as they take account of differences in the standard of living and inflation rates between countries.

Regional dummies grouping

- Western Europe EEA: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom
- North America: Canada, Mexico, United States
- South East Asia : Australia, Hong Kong, Japan, Korea, New Zealand, Singapore
- Eastern Europe/ Accession countries/ New Member States: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Turkey

ANNEX B: ALTERNATIVE MEASURES OF USAGE

The "raw" MOU data compiled by Merrill Lynch are subject to bias which is likely to affect comparisons between countries with different regimes.

In the main report we showed that there is no robust statistical evidence of an association between lower MTRs and higher usage when using the raw data.

Geographic effects account for most of the variability that would be attributed to the level of MTRs in specifications that do not include regional or country effects.

The findings with alternative measures of usage, MOU "debiased" by Ofcom and MOU per capita support the conclusion that there is a lack of robust evidence that higher MTRs go hand in hand with lower usage.

B.1.1 Alternative measures of usage – Ofcom "debiased" MOU

As in the specifications with raw minutes per user, using Ofcom "debiased" MOU we do not find a statistically robust relationship between MTRs and usage.

We show the results in Table 10. The level of the MTRs variable coefficient is significant only in specifications (1) to (3) where there are no geographic variables in the explanatory variable set.

Furthermore for the OLS specifications (1) and (2) have low goodness of fit if the regional effects are not included.

The CPNP dummy coefficient is significant and negative, see specification (3), implying higher MOU in the US even controlling for time and economic factors and the level of MTRs. However, it is not possible to ascertain whether the CPNP dummy captures the effect of the CPNP regime or other features of the US market as there is no country fixed effect in the specification.

The GDP per capita coefficient is significant and has the expected sign. Intuitively higher (average) levels of wealth are associated with increased mobile services usage.

The coefficients of the fixed penetration and population density variables are always insignificant and imprecisely estimated.

In specification (5) the time dummies are precisely estimated and show a trend common to all countries in the sample. Mobile usage has increased year on year across all countries.

Of the specifications that exclude the CPNP dummy, specification (5) has the highest goodness of fit. In this specification the coefficient of the South East Asia variable is positive and significant. This shows that usage may also be higher in South East Asia countries relative to European countries.

Table 10 Dependent variable MOU debiased, 2003-2007

	OLS	OLS	OLS	OLS	OLS	R.E.	R.E.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
MTRs	-3.7343***	-3.6001***	-2.0057**	-0.5848	1.2825	0.3147	0.8032
	[1.2024]	[1.3109]	[0.7719]	[1.3074]	[1.2444]	[0.6195]	[0.6763]
CPNP Dummy			-421.6314***				
			[30.4236]				
GDP per capita	4.5257***	4.3814***	2.0722**		6.2544***	7.1523***	
	[1.5597]	[1.6413]	[0.9701]		[1.3905]	[1.6041]	
Fixed Penetration	-16.1165	-3.6865	-46.3786		126.1996	-118.3316*	
	[97.1071]	[105.9344]	[61.7582]		[85.7922]	[69.8694]	
Population Density	-6.2791	-6.4409	3.7665		-3.2201	-6.0556	
	[7.3710]	[7.5265]	[4.4439]		[5.9283]	[16.6209]	
dummy y 2003		-11.5516	-8.6407	-29.7226	-12.2244	-4.9617	-42.5392***
		[37.6146]	[21.9025]	[29.6213]	[28.7749]	[10.3538]	[6.4995]
dummy y 2004		-6.2694	-11.3591	-15.7213	-7.2842	-1.0638	-30.4738***
		[31.0588]	[18.0880]	[23.8892]	[23.4152]	[8.0606]	[4.7085]
dummy y 2005		-9.0225	-13.0801	-20.4569	-14.6057	-2.4818	-23.3355***
		[28.9865]	[16.8802]	[22.4105]	[21.7840]	[6.2581]	[4.1566]
dummy y 2006		-2.4167	-3.9752	-8.1715	-8.4115	-0.1327	-10.9162***
		[28.5208]	[16.6069]	[22.3956]	[21.4331]	[4.7307]	[4.1351]
North America				233.0426***	286.2980***		
				[34.0000]	[32.8462]		
South East Asia				33.6975	102.5486***		
				[25.4459]	[26.4882]		
Eastern Europe Accession Countries				-64.5898**	37.3742		
				[25.5329]	[30.8477]		
Constant	119.1113***	120.9916**	572.7229***	178.1969***	-64.1932	74.4882	182.5714***
	[43.0126]	[46.2634]	[42.2858]	[19.7290]	[51.3981]	[54.1417]	[21.0553]
Observations	107	107	107	112	107	107	112
Adjusted R-squared	0.175	0.142	0.709	0.377	0.516		
R-sq	0.206	0.207	0.734	0.422	0.566		
Explanatory variables	4	8	9	8	11	8	5
Number of Country Effects						26	26
Fitness statistic Chi-sq						118.11***	84.26***
Random effects test Chi-sq						146.01***	138.90***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

B.1.2 Alternative measures of usage – MOU per capita

Using per capita rather than per user minutes takes account of the **potential** for mobile services take-up as approximated by the size of the population in a given country. This could facilitate international comparisons relative to usage because the regime chosen for wholesale termination might have an impact on penetration of mobile services, thus affecting average usage for a given level of MOU.

We show the results with MOU per capita in Table 11. Compared to the results using the raw MOU data the magnitude of the coefficients differs, but the coefficients have the same sign and level of significance. Therefore, qualitatively we find the same results, that is a lack of evidence demonstrating a robust effect of the level of MTRs on MOU per capita.

In specifications (4) to (7) the coefficient of the level of MTRs variable is insignificant, consistently with the results with raw MOU. When we include regional or country controls these variables explain the variability in usage otherwise attributed to the level of MTRs.

GDP per capita is positive and significant in all specifications where this variable has been included in the explanatory variable set.

Table 11 Dependent variable MOU per capita, 2003-2007

	OLS	OLS	OLS	OLS	OLS	R.E.	R.E.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
MTRs	-2.8025**	-2.2280*	-0.8023	-0.3524	1.6590	0.2880	0.6408
	[1.1451]	[1.2288]	[0.7853]	[1.3882]	[1.2827]	[0.9713]	[1.0198]
CPNP Dummy			-377.0395***				
			[30.9536]				
GDP per capita	6.2300***	5.5372***	3.4722***		6.8862***	8.9147***	
	[1.4853]	[1.5385]	[0.9870]		[1.4333]	[2.1217]	
Fixed Penetration	-57.8388	5.5728	-32.6042		105.5276	-212.7816**	
	[92.4793]	[99.3008]	[62.8339]		[88.4311]	[104.8089]	
Population Density	-9.8889	-10.5964	-1.4685		-7.7620	-7.3033	
	[7.0197]	[7.0552]	[4.5213]		[6.1107]	[15.4836]	
dummy y 2003		-51.3418	-48.7388**	-75.8395**	-53.1354*	-36.6877**	-84.8500***
		[35.2592]	[22.2840]	[31.9479]	[29.6600]	[15.3250]	[10.3095]
dummy y 2004		-42.2661	-46.8175**	-56.0745**	-43.4529*	-29.5022**	-68.2175***
		[29.1139]	[18.4031]	[25.9325]	[24.1354]	[12.0311]	[7.5678]
dummy y 2005		-32.7435	-36.3720**	-46.8851*	-37.3657*	-20.1392**	-47.9075***
		[27.1714]	[17.1743]	[24.3518]	[22.4541]	[9.5400]	[6.7222]
dummy y 2006		-14.7501	-16.1438	-22.0155	-19.5641	-8.4106	-22.9421***
		[26.7349]	[16.8962]	[24.3375]	[22.0923]	[7.5177]	[6.6910]
North America				180.7825***	231.7716***		
				[35.9864]	[33.8565]		
South East Asia				0.7508	77.7809***		
				[27.0082]	[27.3030]		
Eastern Europe Accession Countries				-79.1972***	23.6793		
				[27.0404]	[31.7966]		
Constant	89.9143**	97.7680**	501.7241***	202.1509***	-43.9286	88.2577	196.6542***
	[40.9628]	[43.3665]	[43.0224]	[22.1180]	[52.9790]	[63.0339]	[21.4749]
Observations	107	107	107	109	107	107	109
Adjusted R-squared	0.230	0.225	0.690	0.303	0.471		
R-sq	0.259	0.283	0.717	0.355	0.526		
Explanatory variables	4	8	9	8	11	8	5
Number of Country Effects						26	26
Fitness statistic Chi-sq						188.67***	153.39***
Random effects test Chi-sq						136.93***	134.40***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

ANNEX C: TELIGEN PRICE INDEXES

The results in this Annex are based on a sample that includes at most two B&K countries.

C.1 Teligen price index (1): high usage post-pay prices

The results in logs and in levels do not reveal a statistically significant association between the presence of the CPNP regime or the level of MTRs and prices. Over time there appears to be a strong downward trend in prices across all countries. The specification with regional dummies suggests that prices are lower in Western Europe/ EEA and North America (the US) than elsewhere.

C.1.1 High usage post-pay prices and MTRs

The goodness of fit is low in all specifications, but improves with the inclusion of time dummies. In Table 12 we show the results in logs only (the results in levels are similar). The coefficient of the MTRs variable is insignificant (at the 5% level) in all specifications.

Table 12 Dependent variable log High Usage Prices, 2003-2007

	OLS	OLS	OLS	OLS	R.E.	R.E
	(1)	(2)	(3)	(4)	(5)	(6)
MTRs (log)	0.0121	-0.0026	0.0305*	0.0083	0.0119	0.0256
	[0.0173]	[0.0160]	[0.0180]	[0.0194]	[0.0261]	[0.0292]
GDP p.c. (log)	-0.2015**	-0.0714		0.0733	-0.1547	
	[0.1002]	[0.0929]		[0.1009]	[0.1399]	
Fixed pen. (log)	-0.2888*	-0.5770***		-0.3673**	-0.3811*	
	[0.1507]	[0.1429]		[0.1558]	[0.2095]	
Pop. density (log)	0.0715**	0.0731***		0.0691***	0.0519	
	[0.0305]	[0.0273]		[0.0263]	[0.0465]	
dummy y 2003		0.5900***	0.6338***	0.6638***	0.5022***	0.5066***
		[0.1325]	[0.1256]	[0.1294]	[0.0871]	[0.0674]
dummy y 2004		0.5353***	0.5296***	0.5629***	0.4156***	0.4162***
		[0.1086]	[0.1001]	[0.1046]	[0.0723]	[0.0535]
dummy y 2005		0.3611***	0.3370***	0.3636***	0.3188***	0.3277***
		[0.0987]	[0.0900]	[0.0949]	[0.0624]	[0.0470]
dummy y 2006		0.1289	0.1155	0.1260	0.0987*	0.1060**
		[0.0966]	[0.0900]	[0.0928]	[0.0558]	[0.0469]
North America			0.2576	0.1415		
			[0.1572]	[0.1617]		
South East Asia			0.3805***	0.3056**		
			[0.1288]	[0.1270]		
Eastern Europe Accession Countries			0.5710***	0.4224***		
			[0.0787]	[0.1294]		
Constant	6.6812***	5.7867***	5.8314***	5.3738***	6.2178***	6.0759***
	[0.3917]	[0.3895]	[0.0747]	[0.3938]	[0.5654]	[0.0773]
Observations	140	140	146	140	140	146
Adjusted R-squared	0.170	0.337	0.356	0.389		
R-sq	0.194	0.376	0.392	0.437		
Explanatory variables	4	8	8	11	8	5
Number of Country Effects					36	36
Fitness statistic Chi-sq					104.76***	117.74***
Random effects test Chi-sq					89.86***	116.34***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

C.1.2 High usage post-pay prices, CPNP regime and MTRs

The specifications, in logs and in levels, including the CPNP dummy also show poor fit and insignificant coefficients for the variables of interest. Prices are lowest across all countries in 2006 and 2007, because the dummy variables coefficients for 2003, 2004 and 2005 are positive and significant (the results are not presented in this report).

C.2 Teligen price index (2): medium usage post-pay prices

Findings for medium usage price are as weak as the findings for high usage prices. The specifications in logs have better fit than the results in levels (not shown); still little of data variability is explained.

C.2.1 Medium usage post-pay prices and MTRs

The level of MTRs variable is insignificant in all tested specifications (at the 5 percent level). The results in logs perform better than the results in levels, but the goodness of fit is generally low (therefore we do not show the table of results). The results for the OLS specifications with time dummies suggest that medium usage prices are lowest in Western Europe/EEA. Across all countries prices appear to have been falling over time from 2003 to 2006.

C.2.2 Medium usage post-pay prices, CPNP regime and MTRs

The results for the specifications with the CPNP dummy have very low goodness of fit. We do not present these results.

The results in logs and in levels are similar. The coefficients of the variables that vary little over time are significant, suggesting that they might capture unmeasured differences between countries, given the lack of geographic explanatory variables.

C.3 Teligen price index (3): low usage post-pay prices

There is no robust relationship between the key variables of interest and low usage prices emerging from the study. Little of the price differences are explained by the model. We show results in logs only, as the results in levels have even lower goodness of fit.

C.3.1 Low usage post-pay prices and MTRs

Table 13 reports the results in logs. The coefficient of the level of MTRs is insignificant in all specifications but specification (3), where population density is omitted from the specification. All OLS specifications have low fit; we omit specification (1) where the R-squared is below 10%. Specification (4) is the OLS specification with the best fit.

The regional dummy variables are significant and positive. Prices appear to be highest in the US and lowest in Western Europe.

The coefficients of the variables GDP and fixed penetration, not reported in the table of results but included in specifications (2), (4) and (5), are insignificant.

Table 13 Dependent variable log Low Usage Prices, 2003-2007

	OLS	OLS	OLS	OLS	R.E.	R.E
		(2)	(3)	(4)	(5)	(6)
MTRs (log)		-0.0155	0.0589***	0.0302	0.0022	0.0171
		[0.0192]	[0.0197]	[0.0213]	[0.0329]	[0.0314]
Pop. density (log)		0.1079***		0.1062***	0.0858	
		[0.0328]		[0.0289]	[0.0593]	
dummy y 2003		0.4267***	0.4983***	0.5029***	0.3622***	0.3766***
		[0.1597]	[0.1370]	[0.1420]	[0.0975]	[0.0744]
dummy y 2004		0.4830***	0.5166***	0.5098***	0.3720***	0.3838***
		[0.1308]	[0.1092]	[0.1148]	[0.0812]	[0.0591]
dummy y 2005		0.2031*	0.1917*	0.1859*	0.1706**	0.1863***
		[0.1190]	[0.0982]	[0.1041]	[0.0693]	[0.0520]
dummy y 2006		0.0639	0.0619	0.0513	0.0391	0.0543
		[0.1164]	[0.0981]	[0.1018]	[0.0604]	[0.0518]
North America			0.9958***	1.0751***		
			[0.1714]	[0.1775]		
South East Asia			0.5608***	0.5309***		
			[0.1405]	[0.1394]		
Eastern Europe Accession Countries			0.3730***	0.5132***		
			[0.0858]	[0.1420]		
Constant		4.7625***	4.6317***	4.5252***	5.0184***	4.9037***
		[0.4693]	[0.0815]	[0.4321]	[0.6923]	[0.0831]
Observations		140	146	140	140	146
Adjusted R-squared		0.158	0.308	0.356		
R-sq		0.207	0.346	0.407		
Explanatory variables		8	8	11	8	5
Number of Country Effects					36	36
Fitness statistic Chi-sq					58.33***	64.28***
Random effects test Chi-sq					102.79***	117.36***

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

C.3.2 Low usage post paid prices, CPNP regime and MTRs

All OLS specifications estimated including the CPNP dummy have very low fit and explain little of the difference in prices between countries. We do not report the table of results for these specifications. The results in logs are qualitatively similar to the results estimated using variables in levels.

The results in logs reveal that the R-squared ranges between 20% and 30%. In the specifications in logs the CPNP coefficient is negative and significant, the magnitude varies between -0.95 and -1.18, but in all specifications the coefficient of the population density variable is also strongly significant, and counter-intuitively positive (the point estimate of the coefficient ranges between 0.11 and 0.12). A possible interpretation for these findings is those variables that do vary little over time capture other time invariant differences across countries, and that these differences are correlated with differences in prices. The absence of explanatory variables that control for geographic unobserved market features is a major limitation for the interpretation of these findings.

C.3.3 Low usage post-pay prices, CPNP regime and MTRs

The CPNP dummy coefficient is significant and negative in logs and in levels (these results are not presented in this report). Population density and GDP per capita are also significant in selected

specifications and might be capturing other unobserved time invariant differences across countries. These results do not offer grounds for concluding that there is a robust relationship due to the poor fit.

C.4 Teligen price index **(4)**: low usage post and pre pay prices

All specifications estimated perform poorly and explain little of the observed price differences. The specifications in logs have slightly higher fit than specifications in levels. The results are not shown in this report.

C.4.1 Low usage post and pre pay prices and MTRs

The results in logs show that all OLS specifications have low R-squared, especially when the time dummies are not included in the specification. The level of the MTRs variable is only significant in one OLS specification where it is positive. In this specification fixed penetration, population density and GDP per capita are omitted. This suggests that these variables are likely to account for the observed differences in prices.

The findings suggest that prices fell across countries from 2003 to 2006 and are lowest in Western Europe and the EEA.

C.4.2 Low usage post and pre pay prices, CPNP regime and MTRs

The results in logs show that the CPNP dummy coefficient is insignificant in all specifications estimated. The goodness of fit is low for all specifications, for this reason we omit the table of results. The results obtained in level are similar and explain little of the observed price differences.