Testing the "Waterbed" Effect in Mobile Telephony[1]

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Abstract

This paper examines the impact of regulatory intervention to cut termination rates of calls from fixed lines to mobile phones. Under quite general conditions of competition, theory suggests that lower termination charges will result in higher prices for mobile subscribers, a phenomenon known as the "waterbed" effect. The waterbed effect has long been hypothesized as a feature of many two-sided markets and especially the mobile telephony industry. Using a uniquely constructed panel of mobile operators' prices and profit margins across more than twenty countries over six years, we document empirically the existence and magnitude of this effect. Our results suggest that the waterbed effect is strong, but not full. We also provide evidence that both competition and market saturation, but most importantly their interaction, affect the overall impact of the waterbed effect on prices.

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1. Introduction

Mobile termination charges[4] have become the regulators' focus of concern worldwide in recent years. Regarding the fixed-to-mobile termination rates (MTRs) especially, a large theoretical literature has demonstrated that independently of the intensity of competition for customers, mobile operators have an incentive to set charges that will extract the largest possible surplus from fixed users.[5] Mobile subscribers join just one mobile network, and so callers on the fixed telephone network must route calls through a mobile subscriber's chosen network. A mobile operator, even if competing against other mobile operators, always holds a monopoly over delivering calls to its subscribers and will therefore set high MTRs. This "competitive bottleneck" problem provided justification for regulatory intervention to cut these rates. However, reducing the level of termination charges can potentially increase the level of prices for mobile subscribers, causing what is known as the "waterbed" effect. The main purpose of this paper is to examine the existence and magnitude of the waterbed effect in the mobile telephony industry.

Both regulators and academics have recognized the possibility that this effect might be at work and be strong in practice. The first such debate started in 1997 in the UK with the original investigation by the Monopolies and Mergers Commission (now Competition Commission). The Commission broadly endorsed the analysis of the UK telecommunications regulator, Oftel, that competition in the mobile industry did not constrain fixed-to-mobile termination charges and that a price cap was the only remedy likely to address these detriments effectively. The Commission considered that this would yield significant welfare gains without an increase in average retail mobile prices. In fact, it was during these investigations that the term "waterbed" was first coined by the late Prof. Paul Geroski, chairman of the Competition Commission.

In 2005, the New Zealand Commerce Commission introduced similar regulation and while it was convinced that the waterbed effect is a theoretically general phenomenon, it doubted its empirical importance. Similarly, the most recent termination rate proposals by UK's Ofcom (Oftel's successor organization) acknowledged the importance of the waterbed effect, but questioned whether the

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[4] These are the charges mobile operators levy on either fixed network operators or other mobile operators for terminating calls on their networks.

[5] See, for example, Armstrong (2002), Wright (2002), Valletti and Houpis (2005) and Hausman and Wright (2006). Armstrong and Wright (2007) also provide an excellent overview of the mobile call termination theoretical literature and policy in the UK.

effect is "complete", arguing that this can only be the case if the retail market is sufficiently competitive.[6]

Yet, despite the importance of the waterbed effect for welfare calculations, no systematic evidence exists on its existence or magnitude. Detecting such an effect with casual empiricism is difficult. As an example, Figure 1 plots the evolution of subscription prices and termination rates in Italy. While termination rates have been cut steadily over the years, prices to medium user customers, if anything, have declined slightly. Does this imply there is no waterbed effect? Not necessarily, because the positive waterbed effect on subscription prices might be mediated by a number of countervailing factors, such as tougher industry competition with additional firm entry, or technological reasons, such as economies of scale due to growth in traffic volumes.

[Figure 1]

In this paper we analyze the impact of MTR regulation on prices and profit margins on a newly constructed dataset of mobile operators across more than twenty countries during the last decade. The timing of the introduction of regulated termination rates, but also the severity with which they were imposed across mobile firms, varied widely and has been driven by legal and institutional aspects of each country. Using quarterly frequency data and employing panel data techniques that control for unobserved time-invariant country-operator characteristics and general time trends, we are able to identify and quantify for the first time the waterbed effect. Our estimates suggest that although regulation reduced termination rates by about ten percent, this also led to a ten percent increase in mobile outgoing prices. This waterbed effect is shown to be robust to different variable definitions and datasets.

However, although the waterbed is shown to be high, our analysis also provides evidence that it is not full: accounting measures of profits are positively related to MTR. Mobile firms tend to keep part of termination rents instead of passing them on to their customers, and thus suffer from cuts in termination rates. Finally, our empirical analysis also reveals that both competition and market saturation, but most importantly their interaction, affect the overall impact of the waterbed effect on

[6] See "Mobile call termination – Statement", Ofcom, 2007.

prices: the waterbed effect is stronger the more intense competition is in markets with high levels of market penetration and high termination rates.

Our paper is related to an emerging literature on "two-sided" markets that studies how platforms set the structure of prices across the two sides of the business (see, e.g., Armstrong, 2006, Rochet and Tirole, 2006, and Nocke et al., 2007). Telecommunications networks are examples of two-sided markets: providing communication services to their own customers over the same platform and providing connectivity to their customer base to other networks. Whenever we look at two-sided markets, the structure of prices (i.e., who pays for what) is fundamentally important for the development of the market. In mobile telephony, typically it is only senders that pay (under the Calling Party Pays – CPP – system), while receivers do not. This is why termination rates are not the locus of competition and, if left unregulated, they will be set at the monopoly level.[7] Our work therefore also contributes to the more general understanding of two-sided markets. Recent empirical works on two-sided markets include Rysman (2004, on yellow pages; 2007, on credit cards), Argentesi and Filistrucchi (2007, on newspapers), and Kaiser and Wright (2006, on magazines).

The rest of the paper is organized as follows. In section 2 we present a simple model which demonstrates that the waterbed effect is expected to arise under quite general conditions. Section 3 describes our empirical strategy and section 4 discusses the data used. Section 5 presents the main results on the waterbed effect. Section 6 discusses some dynamic aspects of the regulatory impact on prices. Section 7 analyzes how the level of competition and market penetration interact with the magnitude of the waterbed effect, together with other extensions. Section 8 concludes.

2. A simple model of the waterbed effect

In this section we discuss a simple logit model of demand that gives rise to the waterbed effect. Our intention is not to introduce a model for structural estimation, but rather to reassure that the waterbed effect is a common phenomenon under a wide range of market structures.

[7] The U.S. is a noticeable exception in that there is both a RPP (receiving party pays) system in place and, in addition, termination rates on cellular networks are regulated at the same level as termination rates on fixed networks. The U.S. also has a system of geographic numbers that does not allow to distinguish between calls terminated on fixed or mobile networks. For these reasons, the U.S. is not included in our sample. Most of the mobile world is under a CPP system.

There are N consumers, each of whom potentially subscribes to one of the n mobile operators or else chooses not to subscribe. The utility associate with non-purchase is denoted by V_0. When V_0 is very low, then the market is "covered" or "saturated" and every consumer subscribes to one operator. The utility from buying from firm i which sells a whole bundle of services at a total cost of P_i is:

$$U_i = U - P_i + \mu_i,$$

where U is assumed to be identical across consumers and products, while μ_i is a random taste parameter which reflects the idiosyncrasies of individual tastes. This parameter is known to the consumer but is unobserved by the firms.

The logit demand functions are obtained by assuming that all the μ_i are i.i.d. and follow the double exponential distribution with zero mean. As shown by Anderson et al. (1992), in this case the probability of a consumer choosing firm i is given by:

$$\alpha_i = \frac{\exp[(U - P_i)/\sigma]}{\sum_{j=1}^{n} \exp[(U - P_j)/\sigma] + \exp[V_0/\sigma]},$$

where σ is a positive constant, which is positively related to the degree of product differentiation. It can be shown that when $\sigma \to 0$ the variance of μ_i tends to zero. In this case, the multinomial logit reduces to a deterministic model. By contrast, when $\sigma \to \infty$, the heterogeneity in tastes is also very large and the deterministic part of the utility, U_i, has no predictive power and consumers behave as if they were completely random.

For ease of exposition, we assume that all calls made are to fixed users and all calls received are also from fixed users.[8] Thus the demand for incoming calls to mobile subscribers coincides with the demand for (outgoing) fixed-to-mobile calls. The profit of the operator i is:

$$\pi_i = (\underbrace{P_i}_{\text{bill}} - c)\alpha_i N + \underbrace{TQ_{Ii}}_{\text{termination rents}}.$$

[8] Calls from other mobile users could be easily accommodated in this framework. See Calzada and Valletti (2008).

The expression above shows that each mobile network operator derives revenues from two possible sources:

- Services to own customers: these would include subscription services and outgoing calls. All these services are bundled together and cost P_i to the customer, i.e., P_i is the total customer's bill, and c denotes the total cost per customer, while there are no other costs from receiving and terminating calls.
- Incoming calls: these are calls received by own customers of firm i but made by customers of fixed networks. The total quantity of these calls to firm i is denoted by Q_{Ii} and the corresponding price received by the mobile operator (the MTR) is denoted by T and is regulated.

We further assume that each fixed user calls each mobile user with the same per-customer demand function $q_I(T)$. Therefore the total quantity of incoming calls to network i is $Q_{Ii} = \alpha_i N N_F q_I(T)$, where N_F is the total number of fixed users. Then the profit function simplifies to:

$$\pi_i = (P_i - c + \tau)\alpha_i N ,$$

where $\tau = TQ_{Ii} / (\alpha_i N) = TN_F q_I$ is the termination rent per mobile customer.[9]

Since $\dfrac{\partial \alpha_i}{\partial P_i} = \dfrac{-\alpha_i(1-\alpha_i)}{\sigma}$, it is straightforward to show that there exists a unique Nash equilibrium in prices which is defined implicitly as the solution to:

$$(1) \qquad P^* = c - \tau + \frac{\sigma}{1-\alpha^*}, \text{ where } \alpha^* = \frac{1}{n + \exp[(V_0 - U + P^*)/\sigma]} .$$

The corresponding equilibrium profit of this interior solution is:

$$(2) \qquad \pi^* = \frac{\alpha^*}{(1-\alpha^*)}\sigma .$$

[9] Under regulation, MTRs and the corresponding rent per mobile customer are determined by the National Regulatory Authority in each country. If left unregulated, firms would set T to maximize the rent per customer and τ would reach its maximum possible level, independently from the intensity of competition in the market for mobile customers.

The equilibrium price and profit have all the desired properties. In particular, from totally differentiating (1) we obtain the waterbed prediction:

$$(3) \qquad \frac{\partial P^*}{\partial T} = -\frac{1}{1+\dfrac{\exp[(P^*+U+V)/\sigma]}{\{\exp[(P^*+V)/\sigma]+(n-1)\exp(U/\sigma)\}^2}} < 0,$$

which states that the lower the MTR the higher the customer bill, i.e., the watered effect exists under general conditions of competition and product differentiation.

It is also straightforward to show that other comparative statics properties of the equilibrium are in line with one's intuition (see also Anderson et al., 1992). In particular, the price declines with the number of competing firms, and with the degree of product homogeneity. In equilibrium, profits also decline with the number of competing firms and with the degree of product homogeneity. Importantly, profits increase with MTR, although the magnitude of this effect depends on the intensity of competition and on how important the outside option is.

To make further inroads, we now consider the extreme cases of perfect competition and pure monopoly. Consider perfect competition first, which can be generated either as $n \to \infty$, or $\sigma \to 0$. Each firm does not make any extra rent on any customer and the bill is simply:

$$P^* = c - \tau.$$

In other words, under perfect competition any available termination rent is entirely passed on to the customer via a reduction in its bill. Since the overall profit does not change with the level of MTR (it is always zero), we can differentiate the zero-profit condition for any operator (we drop the subscript i to simplify notation), leading to $\frac{\partial (P-c)\alpha N}{\partial T} = -\frac{\partial T Q_I}{\partial T}$ which can be re-written as an expression for the waterbed effect in elasticity terms as:

$$(4) \qquad \varepsilon_W = \frac{\partial P}{\partial T}\frac{T}{P} = \frac{1+\varepsilon_I}{-c/\tau + 1 + \varepsilon_N}.$$

where $\varepsilon_N = \frac{\partial N}{\partial P}\frac{P}{N}$ and $\varepsilon_I = \frac{\partial Q_I}{\partial T}\frac{T}{Q_I}$ are respectively the elasticity of mobile subscription and the elasticity of fixed-to-mobile calls.

The elasticity of incoming calls ε_I is negative and likely to be less than 1 in absolute value.[10] Also, $\varepsilon_N < 0$ and the termination rent is typically small compared to the overall cost per customer, so $-c/\tau + 1 < 0$ too, and the overall sign of the RHS of equation (4) is negative.

Equation (4) was derived under the assumption of a "full waterbed" since any termination rent is simply passed on to the customer. Hence, if there is a full waterbed, profits should not be affected by the level of *T*. Still, a full waterbed effect does *not* imply a straightforward magnitude of the elasticity ε_W. By inspection of (4), the elasticity of the waterbed effect could be above or below 1, in absolute value, depending on the relative sizes of (a) termination revenues relative to costs (τ vs. *c*); and (b) price elasticities for subscriptions and incoming calls ($|\varepsilon_N|$ vs. $|\varepsilon_I|$).

Let us now turn to the case of pure monopoly. The waterbed effect is also expected to be in operations since the price is determined by a classic inverse elasticity rule modified such that the "perceived" marginal cost per mobile customer also includes the termination rents (with a minus sign). Each time a customer is attracted, it comes with a termination rent: the higher the rent, the lower the perceived marginal cost. If regulation cuts termination rents, this is 'as if' marginal costs increase, and as a consequence retail prices will increase as well. Hence, the waterbed phenomenon is also expected under monopoly, as shown by the general eq. (1).

This result is strictly true when the mobile market is "uncovered", in the sense that there is always some customer who does not buy any mobile service, and buys instead the outside option V_0 (i.e., the elasticity of mobile subscription is not zero). This

[10] In a previous version of this work, using detailed cross country information on fixed-to-mobile quantities data for Vodafone only, we estimated ε_I around -0.22. Recall once more that MTRs are regulated, otherwise a monopolist will set its price to the point where demand becomes elastic. Thus, if left alone, the mobile operator would push up the MTR price and obtain higher termination rents. This elasticity refers to the demand for incoming calls from the point of view of the operator, when *T* is changed. The elasticity of fixed-to-mobile calls with respect to the end user price, P_F, can be written as $\varepsilon_F = \frac{dQ_I}{dP_F}\frac{P_F}{Q_I} = \frac{dQ_I}{dT}\frac{T}{Q_I}\frac{P_F}{T}\frac{dT}{dP_F} = \varepsilon_I\frac{P_F}{T}\frac{dT}{dP_F}$. Therefore, the elasticity with respect to the retail price is equal to the elasticity with respect to the MTR (ε_I), times a "dilution factor" (P_F/T) and a "pass-through rate" (dT/dP_F). In the case of the UK, Ofcom have assessed a dilution factor of approximately 1.5 (see "Mobile call termination, Proposals for consultation", Ofcom, 2006). Ofcom also believe that pass-through of the termination may be less than complete (i.e., $dP_F/dT < 1$, or $dT/dP_F > 1$), since BT's price regulation applies to a whole basket of services. In other European countries the fixed network retention ($P_F - T$) is itself directly regulated (e.g., the case in Belgium, Greece, Holland and Italy).

assumption may be called into question as in many countries penetration rates now exceed 100%. While this does not alter our analysis in the case of perfect competition or oligopolistic situations, the monopoly case requires a further qualification. Instead of relying on the first order condition, a monopolist that wants to cover entirely a "saturated" market would choose a price *P* to satisfy the participation constraint of the customer with the lowest willingness to pay. In this limiting situation, a waterbed effect will not exist. Under monopoly, higher termination rates are instead always associated with higher profits, independently of market coverage.[11]

Mobile markets worldwide are dominated by a small number of firms. Competition among them is expected to be somewhere between the two extreme scenarios of perfect competition and monopoly. Under these more general (oligopolistic) market conditions, the same economic logic applies. Hence, our main predictions that we bring to an empirical test are:

1. A waterbed effect exists under quite general market conditions. Lower termination rates induced by regulation should be associated with higher retail prices to mobile customers. We also warned against a too simplistic interpretation of the waterbed price elasticities, since in general one should not expect a 1:1 effect even in a model with perfect competition, as demand elasticities and cost shares will have an impact too.
2. For low levels of market penetration, the impact on retail prices, via the waterbed effect, exists independently from the level of competition. As far as profits are concerned, when the industry is perfectly competitive, exogenous changes in termination rates have no impact on profits. On the other hand, when the industry is not competitive, profits are negatively affected by regulatory cuts in termination rates.
3. For high levels of market penetration, we expect an increase in competition to make the waterbed effect stronger. The waterbed effect is always expected to be in operation under competition for any level of market penetration. However, in the limiting case when the market is fully covered, a monopolist sets its prices just to ensure that the last customer subscribes to the services, in

[11] These effects can be easily understood from inspecting the interior solution (1). When no one buys the outside option ($V_0 \to -\infty$) and $n = 1$, then $\alpha \to 1$ and *P* would instead be set as high as possible to just ensure participation. In this case, $\partial P / \partial T\big|_{\substack{n=1 \\ V_0 \to -\infty}} = 0$. In this limiting case, profits are still positively related to *T*, since *P* ensures participation, while any termination rent is fully kept by the monopolist.

which case termination rates have no impact on mobile retail prices. Therefore, when relating the magnitude of the waterbed effect to the intensity of competition, we will want to control for market penetration, since this is a good proxy for subscription demand elasticity at different stages of the product life cycle of mobile telephony.

3. Econometric Specification

Our empirical strategy is in two steps. In the first step, the analysis is based on the following regression equations:

(5) $\ln P_{ujct} = \alpha_{ujc} + \alpha_t + \beta_1 Regulation_{jct} + \varepsilon_{ujct}$

(5a) $\ln EBITDA_{jct} = \alpha_{jc} + \alpha_t + \beta_1 Regulation_{jct} + \varepsilon_{jct}$

The dependent variable in (5) is the logarithm of outgoing prices ($\ln P_{ujct}$) for the usage profile u = {low, medium, high} of operator j in country c in quarter t. The dependent variable in (5a) is the logarithm of earnings before interest, taxes, depreciation and amortization ($\ln EBITDA_{jct}$) of operator j in country c in quarter t. EBITDA is defined as the sum of operating income and depreciation and we use it as a proxy for profits. The main variable of interest, $Regulation_{jct}$, is for the moment a binary indicator variable that takes the value one in the quarters when mobile termination rates are regulated.

Both regressions constitute a difference-in-difference model, where countries that introduced the regulation are the "treated" group, while non-reforming countries (always regulated or always unregulated) are the "control" group. Due to the inclusion of (usage-)country-operator and time fixed effects, the impact of regulation on prices (or profits) is identified from countries that introduced this regulation and measures the effect of regulation in reforming countries compared to the general evolution of prices or profits in non-reforming countries. The "waterbed" prediction is that, *ceteris paribus*, the coefficient on regulation should have a positive sign in (5), and a negative or zero effect in (5a) depending on whether the effect is full or not.

This difference-in-difference specification allows us to control for time-invariant country-operator characteristics that may influence both regulation and prices or profits. For example, it allows us to control for cost differences across mobile operators due to differential access to spectrum frequency (e.g., some operators have access to 900 MHz spectrum, other only to 1800 MHz, while other to both). Furthermore, the specification also accounts for common global trends.

One important concern regarding this difference-in-difference specification is that the unbiasedness of the estimator requires strict exogeneity of the regulation variable. For example, our results would be biased if countries and operators, which have witnessed slower decrease in prices (including fixed-to-mobile prices) than comparable countries, were more likely candidates for regulation. The direction of causation here would be reversed: *because* of high retail prices, then fixed-to-mobile termination rates are regulated.

There are two ways we can address this concern. Firstly, according to theory, the intensity of competition should *not* matter as to whether or not to regulate MTRs. Unregulated MTRs are always "too high", independently from the level of competition (though the level of competition might affect the optimal level of regulated MTR). In principle, therefore, we should expect every country to regulate MTRs sooner or later, which is indeed what we observe in the data.[12] Secondly, what we observe empirically is the exact opposite of the above prediction. Figure 2 plots the average (time and usage-country-operator demeaned) prices in countries that have experienced a change in regulation, six quarters before and after the introduction of regulation. As we can see, compared to prices in the rest of the world, average prices in countries that experienced a change in regulation were actually *lower* before the introduction of regulation. Moreover, in line with our predictions, the introduction of regulation has a clear positive impact on prices (the waterbed effect) that becomes stronger as regulation becomes progressively more binding over time. Hence, classical reverse causality seems to be less of a concern in our context.[13]

[Figure 2]

[12] As s predicted by the theory, in our sample countries that were never regulated always show much higher MTRs compared to countries that were regulated, after controlling for country-operator and time fixed effects.

[13] In a related vein, we also checked growth rates of prices (again, time and usage-country-operator demeaned) in various groups of countries. Countries which experienced the introduction of regulation, did not show any significant variation in growth rates compared to countries which have been unregulated throughout the period, *before* regulation was introduced. In contrast, growth rates of prices in countries which experienced the introduction of regulation were significantly different from growth rates of prices in countries unregulated throughout the period, *after* regulation was introduced.

Most importantly for establishing causality, the regulation variable should be "random". This (non-selectivity) assumption is quite restrictive because regulatory intervention does not occur randomly, but is the outcome of a long regulatory and political process. However, this process regarding mobile termination rates has been driven in practice by legal and institutional aspects. The UK has been at the forefront of this debate and started regulating MTRs already back in 1997. Other countries followed suit. Importantly, the European Commission introduced a New Regulatory Framework for electronic communications in 2002. The Commission defined mobile termination as a relevant market. Procedurally, every Member State (EU 15 at the time) was obliged to conduct a market analysis of that market and, to the extent that market failures were found, remedies would have to be introduced. Indeed, all the countries that completed the analysis did find problems with no single exception, and imposed (differential) cuts to MTRs (typically, substantial cuts to incumbents and either no cut or only mild cuts on entrants). Hence, the timing of the introduction of regulated termination rates, but also the severity with which they were imposed across mobile operators has been driven by this regulatory process and varied widely across countries with no systematic pattern.[14] Finally, we also estimate a variant of (5) and (5a) allowing for flexible time-varying effects of regulation on prices (Laporte and Windmeijer, 2005) with the aim of distinguishing among any anticipation, short-run and long-run effects.

Moreover, conditional on (usage-)country-operator and time fixed effects, the regulation variable should be uncorrelated with other time-varying factors. In other words, the main criticism of our framework is that we do not allow for joint country-time fixed effects. A spurious correlation pointing towards a high waterbed would arise if, for example, a country is not regulated but is competitive and has low prices, while another country is regulated with low MTR but is also quite concentrated, so it has high prices: we attribute econometrically higher prices to the waterbed (via regulation), even if - in principle - the waterbed effect did not exist at all. While this seems highly unlikely (typically, countries with low MTRs are also competitive, at least anecdotally, which should give rise to the opposite bias) and runs contrary to the

[14] Table A6 in the Appendix presents the countries and timing of regulation's introduction in chronological order. There is no discernible pattern across countries and their timing of regulation's introduction, with both the earlier group of countries and the one that introduced the regulation last being a mix of more developed and less developed countries. A number of recent papers (Besley and Case, 2000; Duso and Röller, 2003, Duso, 2005) indicate the importance of the endogeneity of regulation for the assessment of market outcomes.

evidence presented in Figure 2, it is important to bear in mind this caveat when interpreting our results. Moreover, to alleviate this data limitation problem as much as possible we split our sample of countries into three macro regions (Western Europe, Eastern Europe, and Rest of the World) and introduce regional-time control variables. Despite this not being the ideal solution, our results become stronger, as we will demonstrate in the next section.

A final consideration with the difference-in-difference estimators is that they exacerbate the downward bias in the standard errors arising from positive residual autocorrelation. Thus, following the solution proposed by Bertrand et al. (2004), all reported standard errors are based on a generalized White-like formula, allowing for (usage-)operator-country level clustered heteroskedasticity and autocorrelation.

Before we discuss the various datasources, it should be stressed that using only a binary indicator for regulation is quite restrictive. It does not allow us to distinguish between countries that have introduced substantial price cuts in MTRs and countries that have regulated MTRs too but only mildly. For this reason, we also experiment with two other measures of the impact of regulation.

In the spirit of Card and Kruger (1994), we construct two additional indices. The first one is:

$$MaxMTR\,\text{index}_{jct} = \begin{cases} 0 \text{ if } MTR_{jct} \text{ is unregulated} \\ \dfrac{MaxMTR_{ct} - MTR_{jct}}{MTR_{jct}} \text{ if } MTR_{jct} \text{ is regulated} \end{cases}$$

In other words, when the country is unregulated, the index takes a value of zero. If instead the country is regulated, we construct an index that takes larger values the more regulated a mobile operator is, compared to the operator that is regulated the least in the same country and period.

This index takes advantage not only of the different timing of the introduction of regulation across countries, but also of the widespread variation on the rates imposed across operators within countries. This variation in regulated MTRs was particularly evident in countries where there was a large asymmetry between the "large" incumbents and the "small" entrants. While from a theoretical point of view the "bottleneck" problem exists independently from the size of an operator, in practice, regulators have been more reluctant in cutting the MTRs of the new entrants. They did this most likely with the idea of helping them secure a stronger position in the market. Thus new entrants have been either unregulated for many periods (while the incumbents were regulated at the same time), or they have been regulated nominally but only mildly, while more substantial price cuts were imposed on the incumbents. Hence, in this index, the highest MTR within a country at every period becomes the benchmark for comparing how tough regulation has been on the rest of the firms.

Our second regulation index is based on the same principle, but restricts the sample to only those countries for which we know with certainty that there is at least one fully unregulated operator. For example, the UK was one of the first countries to introduce termination rates regulation, but throughout this period mobile operator 3 (Hutchison) was left completely unregulated. Thus, for the purposes of this index we use the termination rates that this firm was charging as a benchmark for all the other firms. This exercise severely restricts our sample size, but makes the identification even more transparent and exogenous. Hence, the second index is:

$$UnregulatedMTR\,\text{index}_{jct} = \begin{cases} 0 \text{ if } MTR_{jct} \text{ is unregulated} \\ \dfrac{UnregulatedMTR_{ct} - MTR_{jct}}{MTR_{jct}} \text{ if } MTR_{jct} \text{ is regulated} \end{cases}$$

In other words, the index takes the value of zero when the country is unregulated. If instead the country is regulated, we construct an index comparing the rate each operator is regulated to the one charged by the unregulated firm in the same country and period. Both these indexes allow us to get different measures of the severity of regulation in each country and period.

Finally, in the second step, our analysis is based on the following instrumental variable regression models:

(6) $\ln P_{ujct} = \alpha_{ujc} + \alpha_t + \beta_1 \ln(MTR)_{jct} + \varepsilon_{ujct}$

(6a) $\ln EBITDA_{jct} = \alpha_{jc} + \alpha_t + \beta_1 \ln(MTR)_{jct} + \varepsilon_{jct}$

The idea here is to estimate the waterbed effect on prices directly through the MTRs using regulation as an instrumental variable. Regulation is a valid instrument as it is not expected to influence prices other than the impact it induces via MTRs. This is because regulation acts on prices only indirectly via reducing MTRs, while regulators do not intervene in any other direct manner on customer prices. Moreover, this approach allows us to recover directly the elasticity of the waterbed effect.

4. Data

For the purpose of our analysis we matched three different data sources. Firstly, we use Cullen International to get information on mobile termination rates. Cullen International is considered the most reliable source for MTRs and collects all termination rates for official use of the European Commission. Using this source and various other industry and regulatory publications, we were also in a position to identify the dates in which regulation was introduced across countries and operators.

Secondly, quarterly information on the total bills paid by consumers across operators and countries is obtained from Teligen. Teligen collects and compares all available tariffs of the two largest mobile operators for thirty OECD countries. It constructs three different consumer usage profiles (large, medium and low) based on the number of calls and messages, the average call length and the time and type of call. A distinction between pre-paid (pay-as-you-go) and post-paid (contract) is also accounted for. These consumer profiles are then held fixed when looking across countries and time.

Thirdly, we use quarterly information taken from the Global Wireless Matrix of the investment bank Merrill Lynch (henceforth, ML). ML compiles basic operating metrics for mobile operators in forty-six countries. For our purposes, we use the reported average monthly revenue per user (ARPU) and the earnings margin before interest, taxes, depreciation and amortization (EBITDA). Through this source we also obtain information on penetration and number of mobile operators in each country, together with the number of subscribers and their market shares for each operator.

All consumer prices, termination rates and revenue data were converted to euros using the Purchasing Power Parities (PPP) currency conversions published by the Organization for Economic Cooperation and Development (OECD) to ease comparability. None of our results depends on this transformation. More detailed data description, together with the dates of the introduction of regulation and summary statistics, can be found in the Appendix.

The various datasources have different strengths and weaknesses regarding our empirical question. The Teligen dataset has two main advantages. First, by fixing *a priori* the calling profiles of customers, it provides us with information on the best choices of these customers across countries and time. Second, the prices reported in this dataset include much of the relevant information for this industry, such as inclusive minutes, quantity discounts, etc. (although it does not include handset subsidies). However, this richness of information comes at the cost of having data for only the two biggest operators of every country at each point in time. For instance, if a country, such as the UK, had five mobile operators, possibly regulated differentially over time, only two observations per customer profile would be available. This reduces the variability and makes identification of our variables of interest harder, especially given that the biggest mobile operators are often regulated at the same rate.

On the contrary, the ML dataset provides us with information on actual revenues rather than prices. The dependent variables that we use are primarily EBITDA (a measure of accounting profit and cash flow) and ARPU (which consists of all revenues, including revenues from MTR). These are aggregate measures encompassing all revenues associated with mobile voice services. Therefore, they have to be interpreted as measures of an operator's revenues and profitability rather than the total customer bill. Both these accounting measures clearly suffer from endogeneity problems, which could introduce bias and inconsistency in our results. However, this dataset contains useful information on almost all mobile operators in each country and hence it allows us to exploit more within-country variation. For this reason, we have decided to use also this data, with the purpose of corroborating our main results.

5. Results

Table 1 reports our benchmark results from specification (5) using the price information from Teligen as the dependent variable. The data for this table consists of the best possible deals for each user profile among all possible contracts available, both pre-paid and post-paid.[15] For that reason, we also add a binary variable (Pre-

[15] We will later check the robustness of our results if one constraints customers' choices either to pre-paid or to monthly contracts.

paid_{jct}) indicating whether the best deal was on a pre-paid contract or not.[16] The estimated waterbed is 0.133 and strongly significant in column 1, where we utilize the simplest specification with a binary indicator for regulation. That means that the introduction of regulation of MTRs increased bills to customers by 13% on average. Notice that the coefficient on pre-paid is negative but insignificant, indicating that prices on the best pre-paid deals were no different than those on monthly contracts.

In column 2, using the *MaxMTR* index we obtain again strong evidence of the waterbed effect. Similarly, in column 3 when we restrict our sample to only those countries we know with certainty had at least one unregulated mobile operator, we still get a positive and significant effect.[17] Notice also that the coefficient on pre-paid becomes now negative and significant, indicating that pre-paid customers were getting significantly better deals from the two main mobile operators when they were faced with an unregulated competitor. A potential explanation of this result is that incumbent firms were offering significantly better deals to pre-paid customers only when faced with unregulated rivals as a way of protecting their overall market share, but also putting pressure on the prices charged by them. We explore this further when we analyse the waterbed effect separately for pre- and post-paid customers.

In the last two columns, for reasons already discussed in the previous section, we estimate an even more restrictive version of our model by allowing for regional-time fixed effects. Essentially, our sample of countries can be naturally divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (Australia, New Zealand and Japan). Western European countries have been all subject to the New Regulatory Framework adopted by the European Commission, while other Eastern European countries have only recently been subject to regulation with the accession of new member States. Controlling for these regional effects in columns 4 and 5, results in an even stronger waterbed effect, without reducing its statistical significance.[18]

Next, we look at the impact of regulation on profitability measures using specification (5a). Table 2 reports the effect on EBITDA, while we relegate similar

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[16] It is important to mention that the MTR is applied uniformly and does not distinguish, say, between calls to heavy users on contracts and calls to low users on prepaid. However, the waterbed price reaction of the mobile firm to changes in MTR can in principle differ by type of user or call, since their profile of received calls can differ, or the intensity of competition can differ by type of user too.

[17] The elasticities are not directly comparable as the regulatory variables have different mean values.

[18] We do not report the results of column 3 with the regional-country fixed effects because the Western Europe region binary indicator includes all the countries that had one operator being not regulated.

results on the impact on ARPU to the Appendix. Column 1 shows that regulation had a negative effect on profit margins, although the data is considerably noisier. Using our two indexes, instead of the binary regulation variable (columns 2 and 3), reveal again a negative relationship, though the effect is not statistically significant. In columns 4 and 5, the inclusion of the regional-time fixed effects increases the magnitude of the coefficients without affecting much their statistical significance. If markets were fully competitive there should be no impact on profits. Thus, these results suggest that competitors seem to have some degree of market power.

In our second step, using specifications (6) and (6a) we report the results from the IV regressions in Table 3. The first three columns use the same Teligen data as before, whereas the last three columns examine the effect on EBITDA. First stage results across all columns confirm that regulation has a significantly negative effect on MTR as expected. In addition, regulation does not seem to suffer from any weak-instruments problems as indicated by the first stage F-tests. Column 1 shows that that regulation through MTR has indeed a negative and significant effect on prices. The magnitude of the elasticity of the waterbed effect is above 1.[19] Over the period considered, regulation has cut MTR rates by 11% and, at the same time, has increased bills to mobile customers by 0.11 × 1.207 = 13.3%.

The elasticity of the waterbed effect is lower at 0.938 and 0.334, in columns 2 and 3 respectively, using the more sophisticated indexes of regulation, but still negative and highly significant. The effect on accounting profits is positive and significant in column 4, and positive but not significant with the more nuanced measures of regulation. Table 4 also provides evidence that the results remain unchanged and if anything become stronger when we estimate the more restrictive version of our model that includes region-time fixed effects.

We must remark that the ML dataset is probably less reliable than the Teligen dataset, so we take our conclusion on accounting profits more cautiously. In addition, all these results have to be qualified as termination rents could be also exhausted with non-price strategies, i.e., increasing advertising, or giving handset subsidies that we cannot control for. However, we do not expect handset subsidies effects to be too

[19] Note that all the results in Tables 1 and 2 can be directly obtained from Table 3. The impact of regulation on prices, for instance, can be decomposed as $\partial P / \partial \text{Regulation} = \dfrac{\partial P / \partial MTR}{\partial MTR / \partial \text{Regulation}}$, where the denominator and the numerator and are obtained from the 1st and 2nd stage respectively in the IV regression.

relevant, for instance, for pre-paid customers, and the test on EBITDA should take these additional factors into account. If handset subsidies were linked to inter-temporal subsidies (short-run losses are incurred to get long-run profits from captive customers), our results on profitability are, if anything, biased downwards. This is because a cut in MTR would look more profitable as fewer losses are made in the short run. Therefore our result on profitability would probably look stronger if we could account for handset subsidies.[20]

Taken together these benchmark estimates confirm our theoretical intuition that there exists a strong and significant waterbed effect in mobile telephony. However, this effect is not full, as competing firms seem to enjoy some degree of market power.

[Tables 1, 2, 3, 4]

6. Dynamic Regulation Effects

The effect of regulation on prices might not be just instantaneous. On the one hand, termination rates are typically regulated over some periods using "glide paths", in which charges are allowed to fall gradually towards a target over that period. The temporal adjustment path is known and anticipated by operators, at least before a new market review is conducted. On the other hand, there could also be some inertia. For instance, customers may be locked in with an operator for a certain period, therefore there would be no immediate need for mobile operators to adjust their prices as these customers would not be lost right away. Alternatively, when termination rates change, it may take some time for operators to adjust retail prices because of various "menu" costs. Hence, we would like to investigate whether firms anticipated regulation (possibly by trying to affect the outcomes of the regulatory process) and indeed whether the effect of regulation was short-lived or had any persistent long term effects. To quantify these dynamic effects of the waterbed phenomenon, we define

[20] All our analysis is related to the regulation fixed-to-mobile termination rates and not to mobile-to-mobile termination rates. This should not raise particular concerns in our analysis for two reasons. First, in many jurisdictions mobile-to-mobile rates are not regulated, apart from imposing reciprocity, and therefore cuts in fixed-to-mobile rates do not apply to other types of calls. Second, if for some reasons termination of both types of calls is regulated at the same level, theory says that a change in reciprocal mobile-to-mobile rates should have no obvious impact on profits and tariffs (just a re-balancing in the various components of the customer's bill). If firms compete in two-part uniform tariffs, the impact of reciprocal access charges on profits and bills is neutral (see Armstrong, 1998, and Laffont et al., 1998. See also Armstrong and Wright, 2007, for a model that discusses the different types of termination rates). Thus we really interpret our empirical results as the impact of the regulation of fixed-to-mobile termination rates on prices and profits.

binary indicators for twelve, non-overlapping, quarters around the introduction of regulation and a final binary variable isolating the long-run effect of regulation. Our specification is as follows:

(7) $$\ln P_{ujct} = \alpha_{ujc} + \alpha_t + \beta_1 D^{T-6}{}_{jct} + \beta_2 D^{T-5}{}_{jct} + \ldots + \beta_{12} D^{T+5}{}_{jct} + \beta_{13} D^{T+6}{}_{jct} + \varepsilon_{ujct}$$

where $D^{T-6}{}_{jct} = 1$ in the sixth quarter before regulation, $D^{T-5}{}_{jct} = 1$ in the fifth quarter before regulation, and similarly for all other quarters until $D^{T+6}{}_{jct} = 1$ in the sixth quarter after regulation and in all subsequent quarters. Each binary indicator equals zero in all other quarters than those specified. Hence, the base period is the time before the introduction of regulation, excluding the anticipation period (i.e., seven quarters before regulation backwards). This approach accounts for probable anticipation effects (as captured by D^{T-6} to D^{T-1} binary indicators) as well as short (captured by D^{T} to D^{T+5}) and long run effects (captured by D^{T+6}).[21]

Figure 3 plots the regression coefficients on these binary indicators together with their 95% confidence interval. As expected, regulation has no effect on prices six to four quarters before the actual implementation. However, there is some small but statistically significant anticipation of the regulatory intervention three to one quarters before. As discussed before, for the large majority of countries regulation was preceded by a long consultation period between the regulator and the various mobile operators. Our results reveal that operators started adjusting their price schedules slightly upwards even before the actual implementation of the new termination rates.

However, it is the actual implementation of the regulation that has the biggest impact on prices as revealed by the immediate increase on the coefficients after regulation. In other words, regulation is binding from the beginning and as it tightens up over time, the waterbed effect increases. As we can see in Figure 3, regulation also seems to have a large and very significant long-run waterbed effect. The coefficient estimate on D^{T+6}, which quantifies the effect of regulation on prices post the sixth quarter after its introduction, is strongly significant and implies a long run elasticity of the waterbed effect of 33%. Note that this coefficient is not directly comparable to the previous estimates of the waterbed effect, as it incorporates the effect not only of the introduction of regulation, but also of the progressive tightening of termination rates.

[21] See Laporte and Windmeijer (2005) for a discussion of this approach.

What is crucial is that prices seem to respond continuously with every tightening of the rules giving rise to a waterbed phenomenon that is not a one-off event.

[Figure 3]

7. Interaction with Competition and Further Evidence

7.1 Competition and Market Penetration

Having established that the waterbed effect exists and has a strong long run effect, we now want to investigate in greater detail how competition affects this phenomenon. Competition is obviously expected to have a direct impact on prices: the more competitive the market, the lower the prices to customers. Besides this effect, however, if termination rates are "high" (e.g., unregulated) or a substantial mark-up is allowed, competition is expected to have an *additional* impact via the waterbed effect: the more competitive the industry, the lower the prices will be, on top of the direct effect, as any termination rent will be passed on to the customers. As discussed in Section 2, a waterbed effect is expected to exist also under monopoly, though the effect is milder as some rents will be kept by the monopolist. However, the waterbed effect is not expected to be very relevant under monopoly when the market is very saturated and the monopolist still has an interest in covering it. Hence, in our empirical specification it is crucial to control for subscription penetration levels. Our specification reads:

$$(8) \quad \ln P_{ujct} = \alpha_{ujc} + \alpha_t + \beta_1 \ln(MTR)_{jct} + \beta_2 \ln(Competitors)_{ct} + \beta_3 \ln(Penetration)_{ct} + \gamma_1[\ln(MTR)_{jct} \times \ln(Competitors)_{ct}] + \gamma_2[\ln(MTR)_{jct} \times \ln(Penetration)_{ct}] + \gamma_3[\ln(Penetration)_{ct} \times \ln(Competitors)_{ct}] + \delta[\ln(MTR)_{jct} \times \ln(Competitors)_{ct} \times \ln(Penetration)_{ct}] + \varepsilon_{ujct}$$

Equation (8) is an extension of our previous specification (6) with the aim to specify a particular channel that might affect the intensity of the waterbed effect. Our proxy for the intensity of competition is simply the number of rival firms ($Competitors_{ct}$) in each country and period. The number of mobile operators in a country can be taken as exogenous as the number of licences is determined by spectrum availability. Over the period considered, several countries have witnessed the release of additional licences. The degree of market saturation/maturity is measured as the percentage of the population with a mobile phone (Penetration_{ct}). Our main coefficient of interest is δ, where MTR is interacted both with the intensity of competition and with the degree of market saturation.

Results are reported in Table 5. Column 1 is the baseline waterbed effect, comparable to that of column 1 in Table 3, restricted to the sample of firms and countries for which we have information on all these variables. Column 2 shows that a larger number of competing firms exerts the expected negative impact on prices. In column 3,[22] the coefficient on the interaction between the competition variable and MTR is positive but insignificant, whereas in column 4[23] when we introduce all interaction terms, this coefficient becomes positive but barely significant.

As we discuss in our theoretical section, the effect of competition on termination rates would differ depending on the level of market saturation and for that reason in column 5[24] we introduce our preferred specification which includes this triple interaction term. Our coefficient of interest, δ, is negative and strongly significant indicating that the waterbed effect is stronger the more intense competition is in markets with high levels of market penetration and high termination rates. This result is in line with our theoretical predictions where we pointed out the need to control for penetration levels when comparing competitive markets with concentrated ones.

Notice that the direct waterbed effect still exists in all markets, as β_1 is negative and very significant. The rest of the coefficients are also reassuring. We find that competition has a strong, negative direct impact on prices, besides any waterbed effect (β_2 = -0.344) and that prices are also systematically lower in more mature markets (β_3 = -3.228). When MTR is simply interacted with competition, not controlling for penetration levels, there is no statistically significant relationship.

We also find a positive and significant coefficient on the simple interaction between MTR and saturation (γ_2 = 1.422) and on the interaction between the number of competitors and market saturation (γ_3 = 2.346). Although these coefficients are not our main focus, a couple of comments are in place. A positive coefficient on γ_2

[22] The instruments used for this specification are: regulation, interactions of regulation with the other exogenous variables (namely competitors and penetration), the number of own products for each mobile operator in the market (to capture the intensity of competition in the product space, à la Berry et al., 1995) and interactions of the residuals (from the regression: MTR on competitors, penetration, regulation and the various fixed effects) with competitors and penetration (Wooldridge, 2002).
[23] The instruments used are the same as in the previous column 3.
[24] The instruments used are the same as in the previous column 4 with the addition of the triple interaction of the residuals (from the regression mentioned in fn 20) with competitors and penetration.

indicates that the waterbed effect is lower in higher penetration markets. Intuitively, low penetration markets usually consist of heavy users for whom the waterbed effect is expected to be strong. But as the market becomes more saturated, this typically involves attracting marginal users who make and receive very few calls. Hence, we expect the waterbed effect to decrease as the market becomes more saturated because of the different types of consumers that are drawn into the mobile customer pool. On the contrary, we have no prior expectations on the coefficient γ_3 as there is no strong reason to believe that, controlling for the number of competitors, the impact of competition should be more or less intense as the market saturates. On the one hand, a negative coefficient would arise if operators become less capacity constrained and compete more fiercely. On the other hand, if operators in mature markets tend to collude more easily over time, the result would be a positive coefficient.

Finally, in column 6, where we use as an instrument the *MaxMTR* index instead of the binary variable *Regulation*,[25] we confirm the conclusions previously drawn. Results are unaffected for the majority of the coefficients, with the direct waterbed effect (β_1) and the coefficient on the triple interaction (δ) becoming even stronger.

In line with our theoretical predictions, our empirical analysis reveals that both competition and market saturation, but most importantly their interaction, affects the overall impact of the waterbed effect on prices. We also experimented using the HHI index instead of the simple number of competing operators, as a different measure of competition. While the coefficient on the triple interaction (δ) is still significant and has the expected sign (now the coefficient is positive, as an increase in HHI means a lessening of competition), some other results are less stable (see Table A10 in the Appendix). In our opinion, this reveals the limitations of our dataset (although HHI is potentially an alternative measure of competition, it clearly suffers from a more serious endogeneity problem than the number of competitors as discussed above) and of our reduced-form methodology regarding the effect of market structure on the waterbed phenomenon. Future research using a structural approach and more detailed country-level data is required to further understand these mechanisms.

[Table 5]

[25] The rest of the instruments used are the same as in column 5.

7.2 Waterbed Effect on Different Customer Types

In all our previous specifications using the Teligen data, we assumed that a customer could ideally choose the best available contracts at any given point in time, given her/his usage profile. The results are therefore valid if indeed customers behave in this frictionless way. The introduction of mobile number portability[26] certainly makes this possibility all the more realistic. However, as many market analysts advocate, there are good reasons to believe that distinguishing between pre-paid (pay-as-you-go) and post-paid (long-term contract) customers is still important. Customers on long-term contracts may be looking only at similar long-term deals, and may not be interested in a temporary pre-paid subscription, even if this turned out to be cheaper for a while. Switching among operators takes time and for a business user this might not be a very realistic option, even in the presence of number portability. Conversely, customers on pre-paid cards, may have budget constraints and do not want to commit to long-term contracts where they would have to pay a fixed monthly fee for one or more years. Again, these customers may want to look only at offers among pre-paid contracts.

Using our benchmark specification (5), we investigate whether there is a difference in the waterbed effect between pre-paid and post-paid users, when each type of user is limited in her/his choices within the same type of contracts. Tables A8 and A9 (in the Appendix) report the results. Rather intriguingly, we find that pre-paid customers essentially are unaffected by regulation, whereas monthly subscribers bear the bulk of the price increases. This may arise because firms have a more secure relationship with monthly contract subscribers (who tend to stay with the same operator for several years), and so have a greater expectation of receiving future incoming revenues as a result of competing on price for these customers. Post-pay customers also tend to receive more incoming calls, and so become more (less) profitable as termination rates rise (fall). On the contrary, pre-pay subscribers, who are typically very price sensitive, tend to change their number often, therefore it is less likely that their numbers are known by potential callers. Thus pre-pay users receive relatively few calls and a change in MTR has a much lower expected impact

[26] Mobile number portability is the ability of consumers to switch among mobile operators while keeping the same phone number.

compared to post-pay customers.[27] A further factor may be that network operators have a preference to change fixed fees in non-linear contracts rather than pre-pay call price structures, which are closer to linear prices.

The relationship between regulation and prices might not be monotonic and for that reason we examine as before the dynamic waterbed effects using our specification in (7) separately for pre- and post-paid deals. Figures 4 and 5 plot the regression coefficients on the thirteen binary indicators around the introduction of regulation together with their 95% confidence interval for pre-paid and post-paid contracts respectively. In line with our previous analysis, the anticipation of regulation has very little impact on either pre- or post-paid contracts up to two periods before regulation. Monthly customers (Figure 5) then experience a change similar to that analysed with the general unconstrained results. On the contrary, the pattern for pre-paid contracts is more intriguing. As can be seen in Figure 4, the inaction before the introduction of regulation is followed by a short-lived (for periods T and T+1) non-significant decrease in prices and then a continuous non-significant increase in prices for the next four quarters (periods T+2, T+3, T+4 and T+5). There is, however, an overall positive and strongly significant long-run waterbed effect (coefficient on T+6, around 27%) on these prices too.

Notice also the massive increase in the variance associated with these coefficients after the introduction of regulation. Mobile operators seem to have reacted differentially regarding the pricing of these contracts shortly after the introduction of regulation. At the beginning, they seem on average to reduce the prices charged to these customers, possibly trying to lure customers into their networks (with the hope of them upgrading later to monthly subscribers) or potentially as a loss making, short term strategy against smaller firms that either remained unregulated or were not regulated at the same rates. In either case, the strong and positive long-run coefficient illustrates that mobile operators eventually were forced to abandon any such strategies

[27] Vodafone, for example, reports the following churn rates across its major European markets for the quarter to 30 September 2007 (Source: Vodafone):

Markets	Prepaid	Contract	Total
Germany	29.5%	13.5%	22.1%
Italy	22.4%	13.6%	21.7%
Spain	62.5%	13.4%	37.0%
UK	49.9%	18.8%	37.6%

and raise the prices even for the pre-paid customers, which is another manifestation of the power of the waterbed effect.

[Figures 4, 5]

8. Conclusions

Regulation of fixed-to-mobile termination charges has become increasingly prevalent around the world during the last decade. A large theoretical literature has demonstrated that independently of the intensity of competition for mobile customers, mobile operators have an incentive to set charges that will extract the largest possible surplus from fixed users. This bottleneck problem provided scope for the (possibly) welfare-improving regulatory intervention. However, reducing the level of termination charges can potentially increase the level of prices for mobile subscribers, the so called "waterbed" effect.

In this paper we provide the first econometric evidence that the introduction of regulation resulted in a ten percent waterbed effect on average. However, although the waterbed effect is high, our analysis also provides evidence that it is not full: accounting measures of profits are positively related to MTR, thus mobile firms suffer from cuts in termination rates. Finally, our empirical analysis also reveals that the waterbed effect is stronger the more intense competition is in markets with high levels of market penetration and high termination rates.

Our findings have three important implications. First, mobile telephony exhibits features typical of two-sided markets. The market for subscription and outgoing services is closely interlinked to the market for termination of incoming calls. Therefore, any antitrust or regulatory analysis must take these linkages into account either at the stage of market definition or market analysis.

Second, any welfare analysis of regulation of termination rates cannot ignore the presence of the waterbed effect. Clearly, if the demand for mobile subscription was very inelastic, the socially optimal MTR would be the cost of termination (though the regulation of MTR would impact on the distribution of consumer surplus among fixed and mobile subscribers). If, instead, the mobile market was not saturated and still growing there would be the need to calibrate carefully the optimal MTR. We acknowledge that this calibration exercise is very difficult and must be done with great caution. It is therefore all the more important that further analysis is undertaken to understand the behaviour of marginal users that might give up their handsets when the waterbed effect is at work.[28]

Third, our analysis on the existence and magnitude of the waterbed effect is also relevant in the current debate of regulation of international roaming charges. The European Commission voted in 2007 to cap "roaming charges"[29] of making and receiving phone calls within the EU. The aim is to reduce the cost of making a mobile phone call while abroad and hence encourage more overseas (but within EU) phone use. Hence, a reduction in roaming charges may cause a similar waterbed phenomenon, whereby prices of domestic calls may increase as operators seek to compensate for their lost revenue elsewhere. While the magnitude of the waterbed effect caused by this new legislation is debatable, our results demonstrate that regulators have to acknowledge its existence and carefully account for it in their welfare calculations.

Future research should concentrate on two aspects that we consider to be the limitations of this paper. On the one hand, more detailed information would allow researchers to overcome our data restrictions. Having price data on a larger number of mobile operators within countries, would allow for joint country-time fixed effects to be properly controlled for in the empirical specification. Furthermore, to investigate the marginal consumer's behaviour before and after the introduction of regulation and their elasticity regarding the waterbed effect, more detailed consumer-level information is required. On the other hand, given the non-linear retail price schedules and the complex incentives schemes (handsets, personal vs. business buyers' contracts, etc.) provided by mobile operators, more detailed customer information at a country level would allow us to model more satisfactorily the effect of competition and market penetration on the waterbed effect. Such a structural model would also enable us to quantify the effects of various regulatory interventions and their welfare implications. We intend to pursue both avenues in our future research.

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[28] Very importantly, the European Commission is currently preparing a recommendation on MTRs in the EU, where substantial cuts are envisaged; see Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU, Draft, June 2008, http://ec.europa.eu/information_society/policy/ecomm/doc/library/public_consult/termination_rates/termination.pdf.

[29] These are the charges made to customers when using their phones outside their home country, i.e., an Italian customer making/receiving a phone call in Greece.

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5. Appendix

5. 1 Data description

To test the waterbed effect we use a variety of different sources. Regarding the mobile termination rates, we use the biannual data from Cullen International (1999-2006). Cullen International collects all European mobile termination rates information since April 2003 for official use of the European Commission and for that reason is considered one of the most reliable sources for MTRs. We verified the accuracy of this information against Vodafone's own sources and data published by the European Commission's Independent Regulators Group (IRG), but also other third party sources, especially for the period prior to April 2003.

In order to allow for meaningful comparisons between countries, average rates per minute have been calculated for each country using the following assumptions:

(i) A common distribution of traffic throughout the week. This has allowed us to estimate the average termination rate for each operator, taking into account variations in the weekly charging periods. For example, UK and Ireland have relatively short peak rate charging periods, whilst France has a lengthy peak rate charging period. Note that the IRG use default weights of 50% (weekday daytime), 25% (weekday evening and night) and 25% (weekend). The IRG method fails to capture differences in charging periods between operators. Neither of these weighting patterns will correspond to the actual traffic volumes in any one individual country and so, for example, the MTR will be over-stated in countries that have a lower proportion of weekday daytime calls. However, if traffic distributions were to be varied between countries, cross-country comparisons of average termination rates would not be on a true like-to-like basis.

(ii) For most countries a negative exponential distribution of call lengths has been assumed. This is only relevant in cases where countries have an indivisible unit charging structure (e.g., Portugal and Spain, and France prior to the January 2004 rate changes).

(iii) An average call duration of 2 minutes has been assumed for all countries. Note that the IRG assumes an average call length of 3 minutes, which is likely to be an over-statement for mobile calls. This is likely to have the biggest impact in Portugal, where there are significant differences in cost between the first and subsequent minutes. For this reason we have taken particular care to ensure that the average call length assumption is indeed appropriate for Portugal.

(iv) Rates have been averaged over mobile operators according to national subscriber shares. In theory, traffic volumes should be used, but this information is not published for all operators in all markets. Checking the accuracy of calculations using Vodafone's traffic volumes for a number of countries did not reveal any significant differences.

Because all the other datasets used are in quarterly format, we extrapolate the mobile termination rates where necessary to get the same frequency. None of the results reported change qualitatively, if we restrict the sample to two rather than four quarters. The comparable coefficient on Table 1, column 1, is -0.117 (t-stat 3.37).

We obtained mobile operator's prices from Teligen (2002Q3-2006Q1), which reports quarterly information on the total bills paid by consumers across OECD countries based on three usage profiles (high, medium and low). Teligen essentially calculates these total bills across countries and for each usage profile so that they take into account registration or installation charges, monthly rental charges, a number of SMS messages per month and it also takes into consideration any inclusive minutes (or SMS messages) or call allowance value included in monthly subscriptions. For each of the operators covered, a set of packages is included so that the cheapest package offered by the operator can be calculated for each of the three usage profiles.

Finally, mobile operators' accounting and market information comes from the Global Wireless Matrix of Merrill Lynch, which is also available on a quarterly basis (2000Q1-2005Q3). Merrill Lynch compiles basic operating metrics for mobile operators in 46 countries globally. For our purposes, we use the reported average revenue per user (ARPU) and the earnings before interest, taxes, depreciation and amortization (EBITDA). The ARPU is calculated by dividing service revenues by the average subscriber base during the quarter. Service revenues include monthly service charges and usage fees, roaming, long distance and subscriptions to mobile data services. Some operators also include non-service revenues (e.g., equipment sales) in their ARPU calculation. The EBITDA margin is calculated by dividing total EBITDA by total revenues. Note that although we would ideally like to calculate the margin on only the service revenues (i.e., excluding equipment sales from the denominator) few operators outside the US disclose the margins on service revenues. We use the

EBITDA margin as a proxy for profit and cash flow. All the basic variables are described in Table A1.

Matching these different datasets results in the summary statistics described in Table A2 for Teligen (and the matched MTRs) and Table A4 for Merill Lynch (and the matched MTRs). Tables A3 and A5 correspond to Tables A2 and A4 respectively, but limited to the sample we use when we analyze the effect of competition, and also include the additional variables used in that exercise. Table A6 presents the countries and timing of regulation's introduction in chronological order.

[Tables A1, A2, A3, A4, A5, A6]

5.2 Additional results

Impact on ARPU. In the main text (Section 5) we considered the impact of MTR on EBITDA, taken as a measure of profitability. Alternatively, one can also use ARPU (recall that this measure also includes termination revenues, and therefore cannot be taken as a measure of customers' prices). Results are shown in Table A7. In line with the results on EBITDA, we find that higher MTRs have a somehow positive effect on ARPU, though the results are not significant when we include regional-time dummies. Taken together with the results on EBITDA, we have some evidence that the waterbed effect is not full.

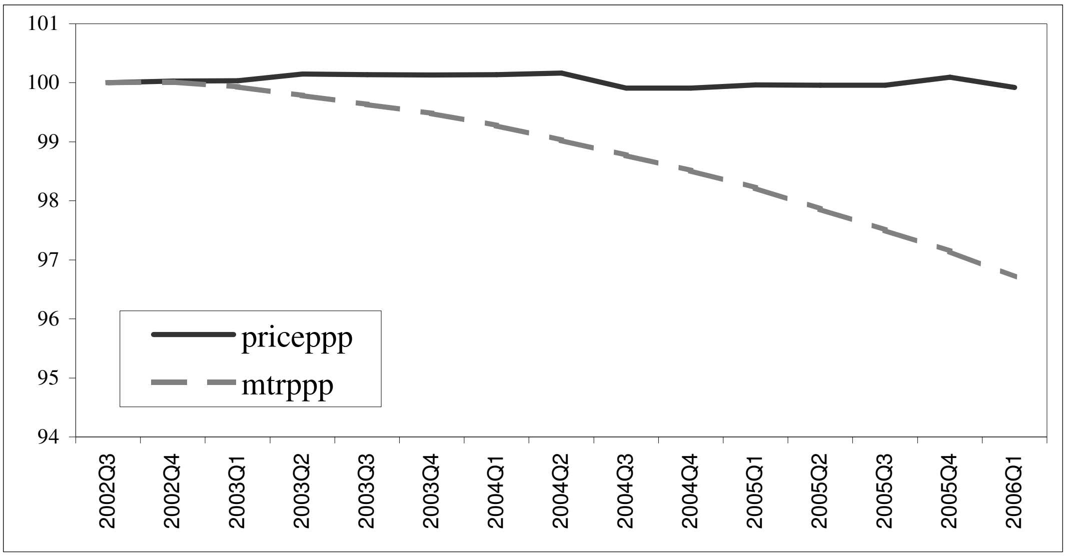
Pre- and post-paid contracts. Table A8 and A9 reports the results discussed in Section 7.2. They are the equivalent to Table 1, split between pre-paid deals (A8) and monthly post-paid contracts (A9). The procedure and interpretation is the same as with Table 1.

Competition. Table A10 reports the results from the first-stage regression of Table 5 (section 7.1). Table A11 reports the full set of results of the impact of competition, using the HHI index of market concentration instead of the number of competitors as a proxy for the intensity of competition in the market.

[Tables A7, A8, A9, A10, A11]

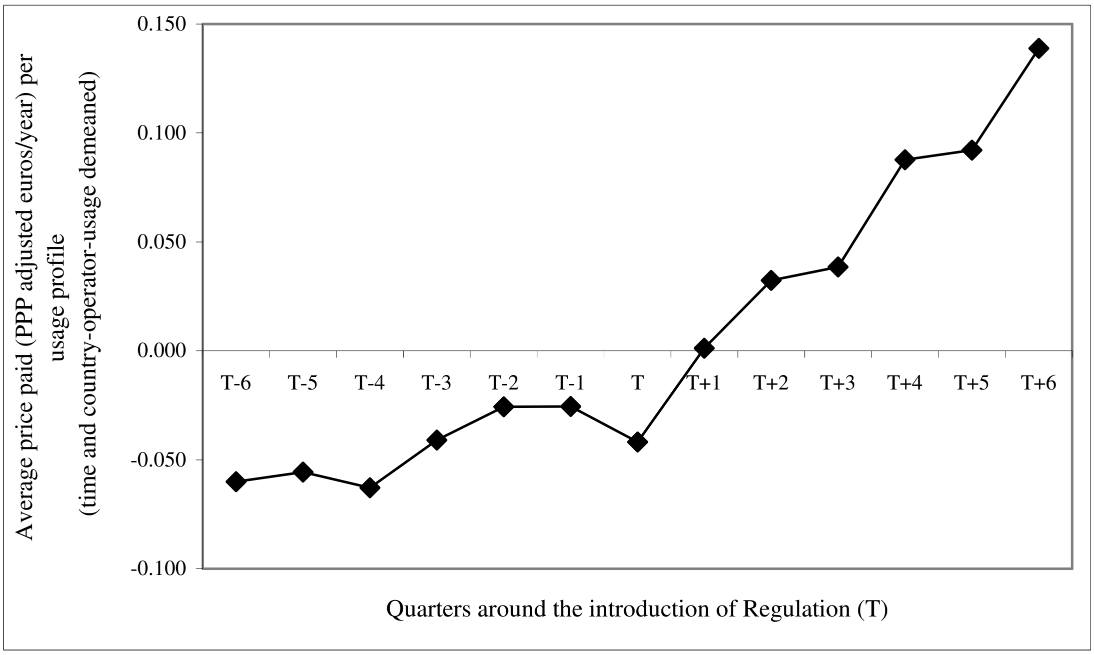
Figure 1

Average price and MTR decline (Italy, Medium User)



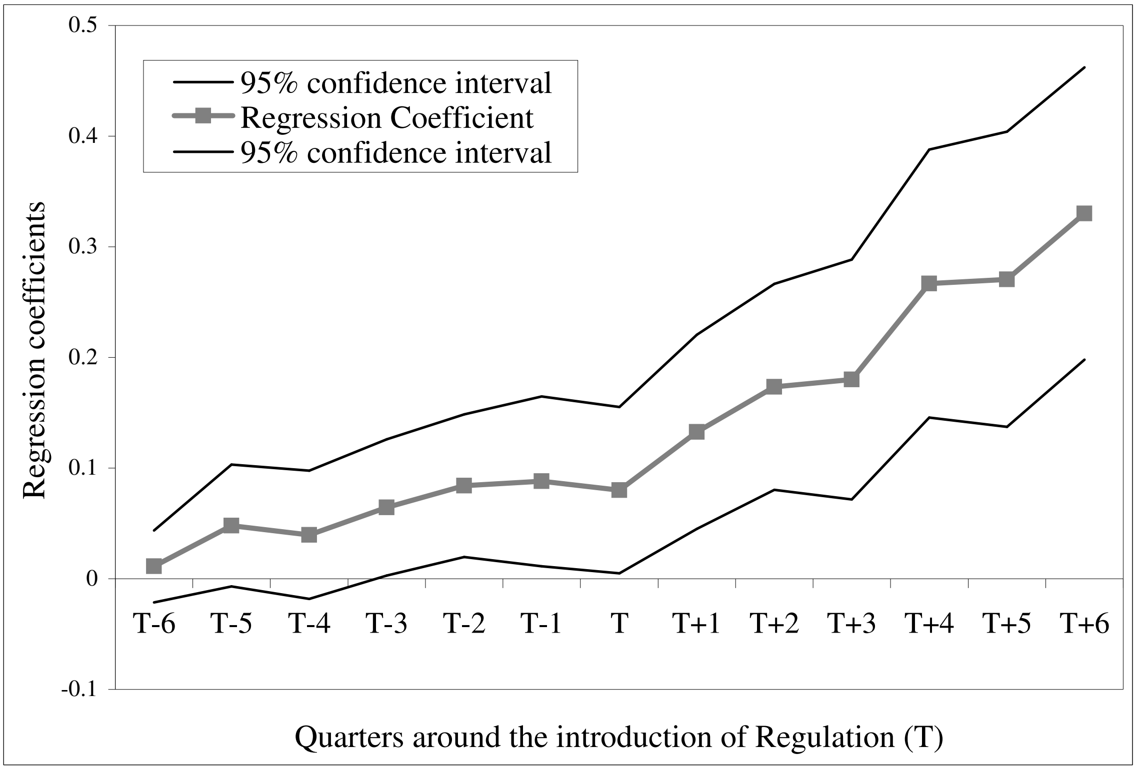
Notes: Figure 1 presents normalized (at the beginning of the period) PPP-adjusted average prices (total bill paid by medium usage consumers) and MTR rates for Italy based on the Teligen and Cullen International dataset.

Figure 2
Average Price around the introduction of Regulation



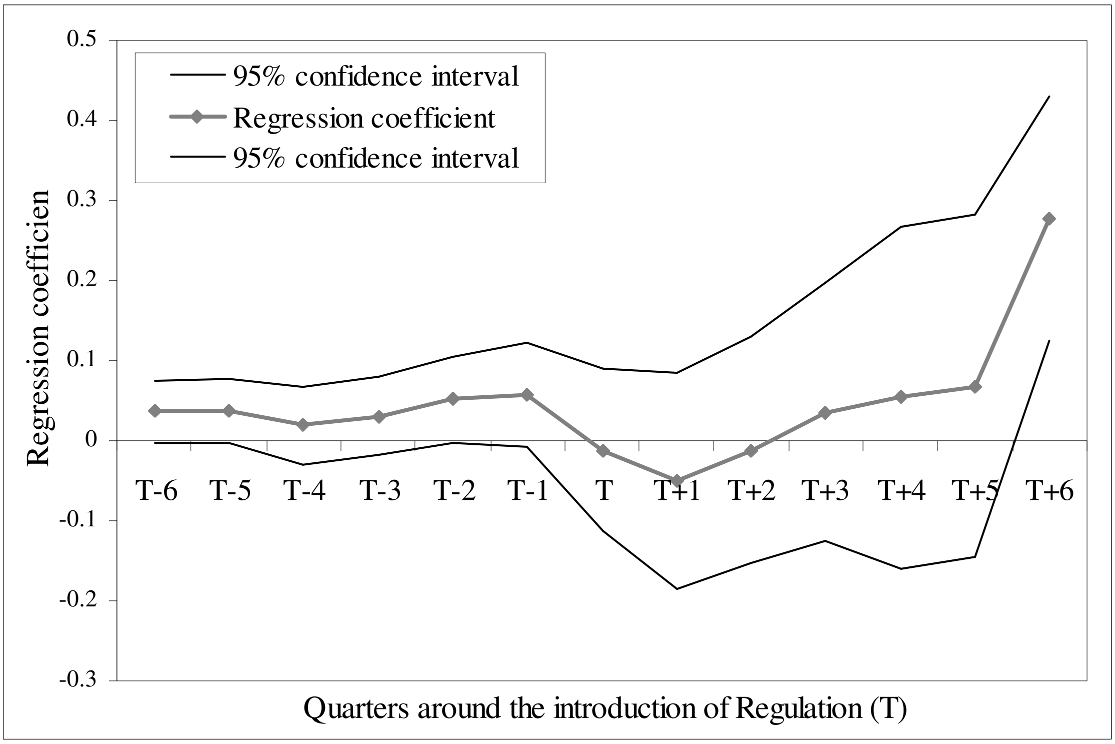
Notes: Figure 2 plots the evolution of time and country-operator-usage demeaned average logarithm of the PPP adjusted price paid per usage profile six quarters before and after the introduction of regulation of fixed-to-mobile termination charges based on the Teligen data corresponding to the best deals available at every period.

Figure 3
The Evolution of the Waterbed Effect



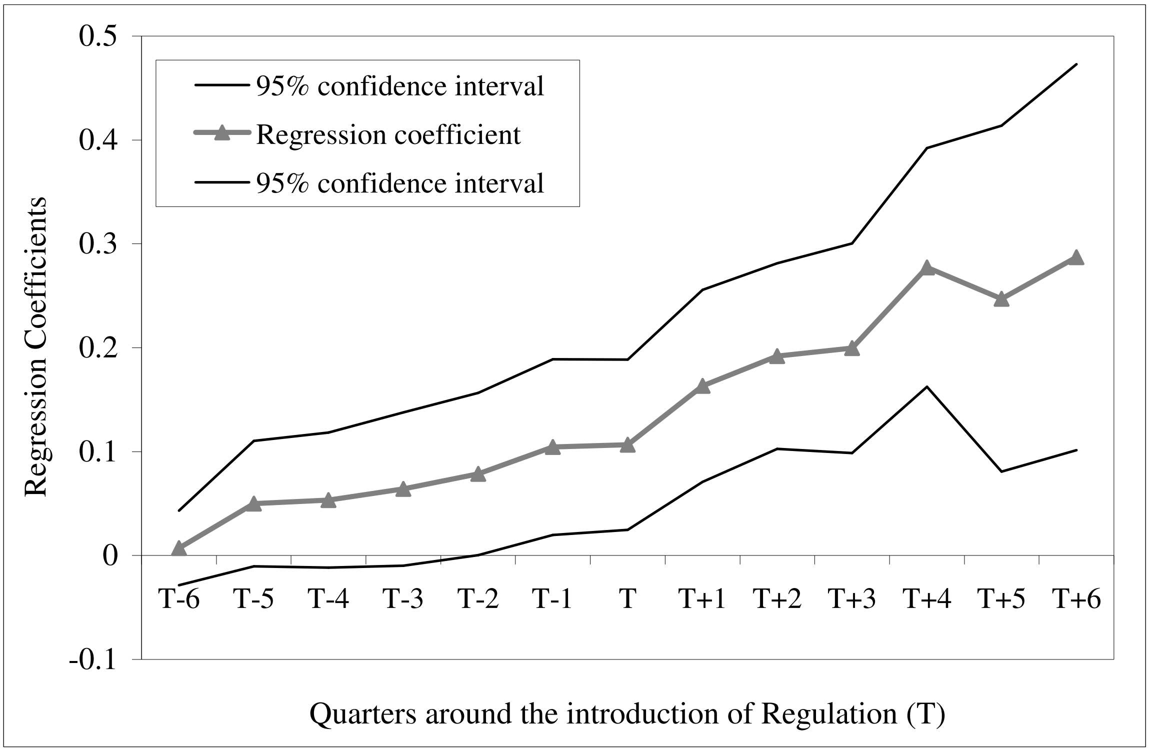
Notes: Figure 3 plots the regression coefficients on binary variables six quarters before and after the introduction of regulation. The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available at every period. All equations include country-operator-usage and a full set of time dummies. Standard errors are adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage.

Figure 4
The Evolution of the Waterbed Effect (Pre-Paid)



Notes: Figure 4 plots the regression coefficients on binary variables six quarters before and after the introduction of regulation. The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available to pre-paid customers at every period. All equations include country-operator-usage and a full set of time dummies. Standard errors are adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage.

Figure 5
The Evolution of the Waterbed Effect (Monthly Subscription)



Notes: Figure 5 plots the regression coefficients on binary variables six quarters before and after the introduction of regulation. The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available to monthly customers at every period. All equations include country-operator-usage and a full set of time dummies. Standard errors are adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage.

TABLE 1 – ESTIMATING THE "WATERBED" EFFECT
(TELIGEN)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}
$Regulation_{jct}$	0.133***			0.152***	
	(0.033)			(0.033)	
MaxMTR $index_{jct}$		0.290***			0.316***
		(0.068)			(0.066)
UnregulatedMTR $index_{jct}$			0.127**		
			(0.051)		
$Pre\text{-}paid_{jct}$	-0.045	-0.051	-0.127***	-0.052	-0.056
	(0.040)	(0.041)	(0.044)	(0.039)	(0.040)
Observations	1734	1734	450	1734	1734
Country-Operator-Usage	150	150	36	150	150
Within-R^2	0.220	0.234	0.367	0.252	0.267

Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available at every period. All equations include country-operator-usage and a full set of time dummies (first three columns) or a full set of region-time dummies (last two columns). All countries in the sample were divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (RoW); see text for more details. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 2 – ESTIMATING THE "WATERBED" EFFECT
(MERRILL LYNCH)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$
$Regulation_{jct}$	-0.125*			-0.138*	
	(0.070)			(0.072)	
MaxMTR $index_{jct}$		-0.024			-0.054
		(0.133)			(0.135)
UnregulatedMTR $index_{jct}$			-0.148		
			(0.236)		
Observations	1135	1135	319	1135	1135
Country-Operator	67	67	16	67	67
Within-R^2	0.209	0.203	0.281	0.215	0.209

Notes: The dependent variable is the logarithm of the EBITDA from the Merrill Lynch dataset. All equations include country-operator and a full set of time dummies (first three columns) or a full set of region-time dummies (last two columns). All countries in the sample were divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (RoW); see text for more details. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 3 – WATERBED EFFECT THROUGH MTR

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	IV	IV	IV	IV	IV	IV
Dependent variable	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$
$ln(MTR)_{jct}$	-1.207***			1.127*		
	(0.411)			(0.603)		
MaxMTR $index_{jct}$		-0.938***			0.070	
		(0.278)			(0.392)	
UnregulatedMTR $index_{jct}$			-0.334**			0.620
			(0.133)			(0.862)
1st Stage Coef.	-0.110***	-0.310***	-0.382***	-0.111***	-0.335***	-0.239**
	(0.024)	(0.035)	(0.028)	(0.037)	(0.051)	(0.098)
1st Stage R^2	0.044	0.127	0.523	0.045	0.112	0.137
1st Stage F-test	21.83***	78.85***	188.24***	8.90***	43.88***	5.90**
	[0.000]	*[0.000]*	*[0.000]*	*[0.004]*	*[0.000]*	*[0.028]*
Observations	1734	1734	450	1135	1135	319
Clusters	150	150	36	67	67	16

Notes: Columns 1, 2 and 3 utilize the Teligen data as in Table 1. The dependent variable for these columns is the logarithm of the PPP adjusted total bill paid by consumers with different usage for the best deals available. Columns 4, 5 and 6 utilize the Merrill Lynch dataset as in Table 2. The dependent variable for these columns is the logarithm of the EBITDA. All regressions use the "Regulation" dummy as the instrumental variable. All equations include either country-operator-usage (Teligen) or country-operator (Merrill Lynch) and a full set of time dummies. P-values for diagnostic tests are in brackets and italics. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by either country-operator-usage (Teligen) or country-operator (Merrill Lynch) are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 4 – WATERBED EFFECT THROUGH MTR (Regional-Time Controls)

	(1)	(2)	(3)	(4)
Estimation method	IV	IV	IV	IV
Dependent variable	lnP_{ujct}	lnP_{ujct}	$lnEBITDA_{jct}$	$lnEBITDA_{jct}$
$ln(MTR)_{jct}$	-1.529***		1.415*	
	(0.496)		(0.757)	
MaxMTR $index_{jct}$		-1.076***		0.187
		(0.283)		(0.473)
1^{st} Stage Coef.	-0.100***	-0.294***	-0.098**	-0.288***
	(0.023)	(0.032)	(0.038)	(0.052)
1^{st} Stage R^2	0.038	0.123	0.040	0.097
1^{st} Stage F-test	18.15***	85.18***	6.47**	30.43***
	[0.000]	*[0.000]*	*[0.013]*	*[0.000]*
Observations	1734	1734	1135	1135
Clusters	150	150	67	67

Notes: Columns 1 and 2 utilize the Teligen data as in Table 1. The dependent variable for these columns is the logarithm of the PPP adjusted total bill paid by consumers with different usage for the best deals available. Columns 3 and 4 utilize the Merrill Lynch dataset as in Table 2. The dependent variable for these columns is the logarithm of the EBITDA. All regressions use the "Regulation" dummy as the instrumental variable. All equations include either country-operator-usage (Teligen) or country-operator (Merrill Lynch) and a full set of region-time dummies. All countries in the sample were divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (RoW); see text for more details. P-values for diagnostic tests are in brackets and italics. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by either country-operator-usage (Teligen) or country-operator (Merrill Lynch) are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 5 – COMPETITION AND WATERBED EFFECT

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	IV	IV	GMM	GMM	GMM	GMM
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
$\ln(MTR)_{jct}$	-1.580***	-1.282**	-0.733**	-0.775***	-0.585***	-1.026***
	(0.587)	(0.525)	(0.285)	(0.235)	(0.223)	(0.220)
$\ln(competitors)_{ct}$		-0.289*	-0.473***	-0.522***	-0.344**	-0.339*
		(0.173)	(0.180)	(0.178)	(0.173)	(0.188)
$\ln(mkt\ penetration)_{ct}$		-0.768	-0.533	-1.785***	-3.228***	-3.707***
		(0.483)	(0.371)	(0.563)	(0.840)	(0.882)
$\ln(MTR)_{jct} \times \ln(competitors)_{ct}$			0.093	0.168*	0.098	0.117
			(0.097)	(0.087)	(0.083)	(0.086)
$\ln(MTR)_{jct} \times \ln(mkt\ penetration)_{ct}$				0.168	1.422***	1.792***
				(0.141)	(0.364)	(0.413)
$\ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$				0.962**	2.346***	2.527***
				(0.441)	(0.557)	(0.587)
$\ln(MTR)_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$					-0.895***	-1.191***
					(0.248)	(0.293)
ΔP/Δcompetitors		-1.282	-0.304	-0.345	-0.263	-0.176
ΔP/ΔMTR		-0.289	-0.614	-0.583	-0.498	-0.914
ΔP/Δmkt penetration		-0.768	-0.533	-0.256	0.269	0.007
Observations	1371	1371	1371	1371	1371	1371
Clusters	141	141	141	141	141	141
Sargan-Hansen test of overidentifying restrictions	-	-	4.244	4.418	6.071	3.654
			[0.374]	*[0.220]*	*[0.108]*	*[0.301]*

Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage for the best deals available from the Teligen data. All equations include country-operator-usage and a full set of time dummies. P-values for diagnostic tests are in brackets and italics. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

APPENDIX

TABLE A1 – VARIABLE DESCRIPTIONS

P_{ujct}	total price paid (PPP adjusted euros/year) per usage profile (usage profiles: high, medium and low)
MTR_{jct}	mobile termination rate (PPP adjusted eurocents/minute)
$ARPU_{jct}$	monthly average revenue per user (PPP adjusted euros/month)
$EBITDA_{jct}$	earnings before interest, taxes, depreciation and amortization margin (%)

Notes: The first variable is constructed using the Teligen dataset, the second variable is taken from the Cullen International dataset and the last two variables are from the Merrill Lynch dataset.

TABLE A2 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
Teligen Table 1 (Best Overall Deals)					
lnP_{ujct}	1734	5.203	1.708	0.107	7.492
$ln(MTR)_{jct}$	1734	1.800	1.656	-3.246	3.573
$Regulation_{jct}$	1734	0.614	0.487	0	1
MaxMTR $index_{jct}$	1734	0.163	0.237	0	1.127
UnregulatedMTR $index_{jct}$	450	0.150	0.291	-0.137	1.127
Pre-$paid_{jct}$	1734	0.324	0.468	0	1
Teligen Table 2 (Pre-Paid Best Deals)					
lnP_{ujct}	1686	5.556	1.680	0.114	7.989
$ln(MTR)_{jct}$	1686	1.883	1.574	-3.246	3.573
$Regulation_{jct}$	1686	0.603	0.489	0	1
MaxMTR $index_{jct}$	1686	0.167	0.239	0	1.127
UnregulatedMTR $index_{jct}$	450	0.150	0.291	-0.137	1.127
Teligen Table 3 (Monthly Subscription Best Deals)					
lnP_{ujct}	1734	5.292	1.695	0.107	7.728
$ln(MTR)_{jct}$	1734	1.800	1.656	-3.246	3.573
$Regulation_{jct}$	1734	0.614	0.487	0	1
MaxMTR $index_{jct}$	1734	0.163	0.237	0	1.127
UnregulatedMTR $index_{jct}$	450	0.150	0.291	-0.137	1.127

TABLE A3 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
Teligen Table 1 (Best Overall Deals)					
lnP_{ujct}	1371	5.239	1.727	0.107	7.492
$ln(MTR)_{jct}$	1371	1.809	1.694	-3.246	3.573
$Regulation_{jct}$	1371	0.626	0.484	0	1
$ln(competitors)_{ct}$	1371	1.273	0.299	0.693	1.946
ln(mkt $penetration)_{ct}$	1371	-0.132	0.153	-0.601	0.167

TABLE A4 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
$lnEBITDA_{jct}$	1135	-1.213	0.530	-4.605	-0.545
$ln(MTR)_{jct}$	1135	1.980	1.830	-3.246	3.934
$Regulation_{jct}$	1135	0.560	0.497	0	1
MaxMTR $index_{jct}$	1135	0.115	0.203	0	1.127
UnregulatedMTR $index_{jct}$	319	0.090	0.236	-0.137	1.127
$lnARPU_{jct}$	1247	3.481	0.242	2.592	4.431
$ln(MTR)_{jct}$	1247	2.046	1.785	-3.246	3.934
$Regulation_{jct}$	1247	0.541	0.498	0	1
MaxMTR $index_{jct}$	1247	0.105	0.197	0	1.127
UnregulatedMTR $index_{jct}$	357	0.080	0.225	-0.137	1.127

TABLE A5 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
$lnEBITDA_{jct}$	1135	-1.213	0.530	-4.605	-0.545
$ln(MTR)_{jct}$	1135	1.980	1.830	-3.246	3.934
$Regulation_{jct}$	1135	0.560	0.497	0	1
$ln(competitors)_{ct}$	1135	1.305	0.298	0.693	1.946
ln(mkt $penetration)_{ct}$	1135	-0.243	0.229	-1.053	0.167

TABLE A6 – REGULATION CHRONOLOGY

Country	Year
Poland	1997
UK	1998
Belgium	1999
Austria	2000
Italy	2000
Japan	2000
Spain	2000
Norway	2001
Sweden	2001
Denmark	2001
Hungary	2002
Portugal	2003
France	2004
Australia	2005
Czech Republic	2005
Germany	2005
Slovak Republic	2005
Switzerland	2005
Ireland	2006
Luxembourg	2006
New Zealand	2006
Turkey	2006
Netherlands	2006
Greece	2006

Notes: Countries in bold are the ones that experienced a change in regulation during our sample. In contrast, countries in italics remain unregulated, whereas the rest of the countries were always regulated during our sample period.

TABLE A7 – ESTIMATING THE "WATERBED" EFFECT
(MERRILL LYNCH)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$lnARPU_{jct}$	$lnARPU_{jct}$	$lnARPU_{jct}$	$lnARPU_{jct}$	$lnARPU_{jct}$
$Regulation_{jct}$	-0.020			-0.027	
	(0.024)			(0.024)	
MaxMTR $index_{jct}$		0.084**			0.067
		(0.041)			(0.046)
UnregulatedMTR $index_{jct}$			0.088**		
			(0.042)		
Observations	1247	1247	357	1247	1247
Country-Operator	74	74	18	74	74
Within-R^2	0.300	0.306	0.408	0.335	0.336

Notes: The dependent variable is the logarithm of the PPP adjusted ARPU from the Merrill Lynch dataset. All equations include country-operator and a full set of time dummies (first three columns) or a full set of region-time dummies (last two columns). All countries in the sample were divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (RoW); see text for more details. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE A8 – ESTIMATING THE "WATERBED" EFFECT
(TELIGEN Pre-Paid)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
$Regulation_{jct}$	0.008			0.014	
	(0.057)			(0.058)	
MaxMTR $index_{jct}$		0.154			0.165
		(0.103)			(0.103)
UnregulatedMTR $index_{jct}$			0.006		
			(0.104)		
Observations	1686	1686	450	1686	1686
Country-Operator-Usage	147	147	36	147	147
Within-R^2	0.131	0.139	0.258	0.141	0.150

Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available to pre-paid customers at every period. All equations include country-operator-usage and a full set of time dummies (first three columns) or a full set of region-time dummies (last two columns). All countries in the sample were divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (RoW); see text for more details. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE A9 – ESTIMATING THE "WATERBED" EFFECT
(TELIGEN Monthly Subscription)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
$Regulation_{jct}$	0.137***			0.158***	
	(0.032)			(0.032)	
MaxMTR $index_{jct}$		0.318***			0.343***
		(0.066)			(0.064)
UnregulatedMTR $index_{jct}$			0.152**		
			(0.056)		
Observations	1734	1734	450	1734	1734
Country-Operator-Usage	150	150	36	150	150
Within-R^2	0.238	0.256	0.393	0.252	0.291

Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available for monthly subscribers at every period. All equations include country-operator-usage and a full set of time dummies (first three columns) or a full set of region-time dummies (last two columns). All countries in the sample were divided into three macro regions: Western Europe, Eastern Europe and Rest of the World (RoW); see text for more details. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE A10 – COMPETITION AND WATERBED EFFECT - First Stage Results

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: $\ln(MTR)_{jct}$						
Instruments						
$Regulation_{jct}$	-0.074***	-0.087***	-1.022***	-1.024***	-1.142***	-0.292***
	(0.017)	(0.020)	(0.112)	(0.116)	(0.103)	(0.048)
$Regulation_{jct} \times \ln(competitors)_{ct}$			0.765***	0.767***	0.860***	-0.005
			(0.081)	(0.085)	(0.075)	(0.021)
$Regulation_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.330***	-0.330***	-0.235***	0.066
			(0.092)	(0.092)	(0.076)	(0.083)
Number of products produced by firm			-0.012	-0.012	-0.027**	-0.031***
			(0.016)	(0.015)	(0.011)	(0.011)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct}$			0.058	0.057	0.001	-0.015
			(0.066)	(0.066)	(0.063)	(0.060)
$MTR\hat{}_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.166**	-0.165*	0.911***	0.986***
			(0.080)	(0.086)	(0.100)	(0.101)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$					-0.784***	-0.780***
					(0.068)	(0.071)
1^{st} Stage R^2	0.025	0.035	0.120	0.120	0.254	0.277
1^{st} Stage F-test	19.92***	19.30***	15.44***	15.08***	48.43***	33.83***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(competitors)_{ct}$						
Instruments						
$Regulation_{jct}$			-1.248***	-1.196***	-1.372***	-0.424***
			(0.153)	(0.158)	(0.141)	(0.077)
$Regulation_{jct} \times \ln(competitors)_{ct}$			1.041***	1.002***	1.142***	0.122***
			(0.113)	(0.117)	(0.104)	(0.027)
$Regulation_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.451***	-0.463***	-0.321***	0.099
			(0.131)	(0.137)	(0.110)	(0.105)
Number of products produced by firm			-0.021	-0.024	-0.046***	-0.051***
			(0.024)	(0.023)	(0.016)	(0.017)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct}$			1.140***	1.173***	1.090***	1.064***
			(0.087)	(0.090)	(0.084)	(0.080)
$MTR\hat{}_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.355***	-0.375***	1.245***	1.373***
			(0.133)	(0.138)	(0.171)	(0.175)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$					-1.179***	-1.184***
					(0.123)	(0.129)
1^{st} Stage R^2			0.375	0.373	0.481	0.516
1^{st} Stage F-test			73.01***	88.95***	132.96***	112.13***
			[0.000]	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(mkt\ penetration)_{ct}$						
Instruments						

$Regulation_{jct}$	0.134***	0.168***	-0.001
	(0.025)	(0.021)	(0.005)
$Regulation_{jct} \times \ln(competitors)_{ct}$	-0.107***	-0.134***	0.005
	(0.018)	(0.015)	(0.003)
$Regulation_{jct} \times \ln(mkt\ penetration)_{ct}$	0.046***	0.019	0.009
	(0.020)	(0.014)	(0.017)
Number of products produced by firm	-0.007***	-0.002	-0.002
	(0.003)	(0.002)	(0.002)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct}$	-0.021***	-0.005	-0.007
	(0.010)	(0.006)	(0.006)
$MTR\hat{}_{jct} \times \ln(mkt\ penetration)_{ct}$	1.037***	0.726***	0.738***
	(0.027)	(0.033)	(0.033)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$		0.227***	0.220***
		(0.025)	(0.025)
1st Stage R^2	0.976	0.984	0.983
1st Stage F-test	1737.00***	11102.54***	13631.34***
	[0.000]	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$			
Instruments			
$Regulation_{jct}$		0.214***	-0.007
		(0.027)	(0.008)
$Regulation_{jct} \times \ln(competitors)_{ct}$		-0.174***	0.004
		(0.020)	(0.004)
$Regulation_{jct} \times \ln(mkt\ penetration)_{ct}$		0.036*	0.028
		(0.019)	(0.022)
Number of products produced by firm		0.000	0.000
		(0.004)	(0.004)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct}$		-0.023**	-0.026***
		(0.009)	(0.009)
$MTR\hat{}_{jct} \times \ln(mkt\ penetration)_{ct}$		-0.397***	-0.379***
		(0.061)	(0.059)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$		1.364***	1.355***
		(0.046)	(0.046)
1st Stage R^2		0.984	0.984
1st Stage F-test		6820.54***	7309.58***
		[0.000]	*[0.000]*

Notes: These are the first stage results from Table 5. The regressions include all the exogenous variables in Table 5. Each column corresponds to the columns in Table 5. Last three instruments are constructed as follows: we first regressed MTR on number of competitors, market penetration and regulation plus the full set of country-operator and time dummies; we then obtained the residuals from this regression and interacted them with the other exogenous variables (Wooldridge, 2002, p.235-237). All equations include country-operator and a full set of time dummies. P-values for diagnostic tests are in brackets and italics. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE A11 – COMPETITION AND WATERBED EFFECT

	(1)	(2)	(3)	(4)	(5)
Estimation method	GMM	GMM	GMM	GMM	GMM
Dependent variable	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}
$ln(MTR)_{jct}$	-1.137***	12.091**	11.535**	23.545***	28.008***
	(0.325)	(5.440)	(5.769)	(5.202)	(7.483)
$ln(HHI)_{ct}$	0.122	3.673**	5.295***	8.038***	7.563***
	(0.609)	(1.620)	(1.743)	(1.745)	(2.059)
$ln(\text{mkt penetration})_{ct}$	-0.760**	-0.466	16.351**	60.167***	81.523***
	(0.301)	(0.366)	(7.188)	(15.656)	(25.825)
$ln(MTR)_{jct} \times ln(HHI)_{ct}$		-1.703**	-1.422**	-2.937***	-3.645***
		(0.692)	(0.709)	(0.644)	(0.963)
$ln(MTR)_{jct} \times ln(\text{mkt penetration})_{ct}$			0.445***	-15.912**	-31.221***
			(0.144)	(6.206)	(11.434)
$ln(HHI)_{ct} \times ln(\text{mkt penetration})_{ct}$			-2.013**	-7.240***	-9.791***
			(0.851)	(1.882)	(3.091)
$ln(MTR)_{jct} \times ln(HHI)_{ct} \times ln(\text{mkt penetration})_{ct}$				1.957***	3.780***
				(0.752)	(1.372)
$\Delta P/\Delta HHI$	0.122	0.593	2.989	3.215	1.360
$\Delta P/\Delta MTR$	-1.137	-1.882	-0.191	-0.570	-1.876
Observations	1371	1371	1371	1371	1371
Clusters	141	141	141	141	141
Sargan-Hansen test of overidentifying restrictions	13.737	8.397	13.904	9.434	10.336
	[0.003]	*[0.015]*	*[0.008]*	*[0.093]*	*[0.066]*

Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage for the best deals available from the Teligen data. All equations include country-operator-usage and a full set of time dummies. P-values for diagnostic tests are in brackets and italics. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator-usage are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE A12 – COMPETITION AND WATERBED EFFECT - First Stage Results

	(1)	(2)	(3)	(4)	(5)
Dependent variable: $\ln(MTR)_{jct}$					
Instruments					
$Regulation_{jct}$	-0.032	-0.032	-0.983***	-0.698***	-0.194***
	(0.024)	(0.024)	(0.105)	(0.075)	(0.028)
$\ln(competitors)_{ct}$	13.841**	13.841**	10.427*	-0.318	3.166
	(6.608)	(6.608)	(5.427)	(4.889)	(4.532)
$Regulation_{jct} \times \ln(competitors)_{ct}$			0.769***	0.542***	0.024
			(0.073)	(0.052)	(0.018)
$Regulation_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.228***	0.009	0.199***
			(0.075)	(0.051)	(0.056)
Number of products produced by firm			-0.004	-0.020*	-0.021**
			(0.016)	(0.011)	(0.011)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct}$	-0.124	-0.124	-0.078	-0.003	-0.033
	(0.090)	(0.090)	(0.072)	(0.075)	(0.073)
$MTR\hat{}_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.045	0.530***	0.586***
			(0.081)	(0.095)	(0.099)
$MTR\hat{}_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$				-0.262***	-0.270***
				(0.084)	(0.089)
$HHI\hat{} \times \ln(competitors)_{ct}$	-1.701**	-1.701**	-1.375**	0.024	-0.348
	(0.817)	(0.817)	(0.676)	(0.606)	(0.566)
$HHI\hat{} \times \ln(mkt\ penetration)_{ct}$	1.825***	1.825***	1.580***	4.801***	4.685***
	(0.441)	(0.441)	(0.276)	(0.624)	(0.578)
$HHI\hat{} \times \ln(mkt\ penetration)_{ct} \times \ln(competitors)_{ct}$				0.494***	0.486***
				(0.042)	(0.047)
1^{st} Stage R^2	0.107	0.107	0.163	0.341	0.355
1^{st} Stage F-test	7.73***	7.73***	18.41***	45.05***	43.17***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: $\ln(HHI)_{ct}$					
Instruments					
$Regulation_{jct}$	0.023***	0.023***	0.219***	0.045	0.020*
	(0.007)	(0.007)	(0.035)	(0.041)	(0.011)
$\ln(competitors)_{ct}$	0.689	0.689	-1.572	-2.182**	-2.434***
	(1.505)	(1.505)	(1.288)	(0.918)	(0.838)
$Regulation_{jct} \times \ln(competitors)_{ct}$			-0.163***	-0.039	-0.007
			(0.025)	(0.029)	(0.005)
$Regulation_{jct} \times \ln(mkt\ penetration)_{ct}$			-0.044	-0.118***	-0.134***
			(0.029)	(0.028)	(0.029)
Number of products produced by firm			-0.007***	-0.010***	-0.009***
			(0.002)	(0.002)	(0.002)

$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct}$	-0.078***	-0.078***	-0.014*	-0.021**	-0.018**
	(0.012)	(0.012)	(0.008)	(0.009)	(0.009)
$MTR\hat{}_{jct} \times \ln(\text{mkt penetration})_{ct}$			-0.126***	0.090**	0.080*
			(0.019)	(0.039)	(0.041)
$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct} \times \ln(\text{mkt penetration})_{ct}$				-0.238***	-0.232***
				(0.035)	(0.037)
$HHI\hat{} \times \ln(\text{competitors})_{ct}$	-0.085	-0.085	0.204	0.255**	0.282***
	(0.187)	(0.187)	(0.160)	(0.112)	(0.104)
$HHI\hat{} \times \ln(\text{mkt penetration})_{ct}$	0.480***	0.480***	0.084	-1.619***	-1.569***
	(0.119)	(0.119)	(0.153)	(0.248)	(0.264)
$HHI\hat{} \times \ln(\text{mkt penetration})_{ct} \times \ln(\text{competitors})_{ct}$				-0.120***	-0.117***
				(0.014)	(0.015)
1st Stage R^2	0.237	0.237	0.391	0.518	0.521
1st Stage F-test	27.21***	27.21***	57.52***	49.11***	52.32***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(HHI)_{ct}$					
Instruments					
$Regulation_{jct}$		-0.205	-7.418***	-5.636***	-1.505***
		(0.188)	(0.919)	(0.691)	(0.223)
$\ln(\text{competitors})_{ct}$		115.601**	82.885*	-5.410	22.492
		(53.689)	(42.284)	(39.028)	(36.503)
$Regulation_{jct} \times \ln(\text{competitors})_{ct}$			5.820***	4.355***	0.159
			(0.649)	(0.483)	(0.142)
$Regulation_{jct} \times \ln(\text{mkt penetration})_{ct}$			-1.960***	-0.270	1.225**
			(0.619)	(0.435)	(0.492)
Number of products produced by firm			-0.029	-0.160*	-0.173**
			(0.127)	(0.083)	(0.083)
$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct}$		-1.297*	-0.771	-0.186	-0.426
		(0.746)	(0.590)	(0.603)	(0.587)
$MTR\hat{}_{jct} \times \ln(\text{mkt penetration})_{ct}$			-0.650	4.618***	5.008***
			(0.651)	(0.775)	(0.834)
$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct} \times \ln(\text{mkt penetration})_{ct}$				-2.805***	-2.828***
				(0.700)	(0.766)
$HHI\hat{} \times \ln(\text{competitors})_{ct}$		-14.175**	-10.888**	0.527	-2.442
		(6.640)	(5.268)	(4.844)	(4.558)
$HHI\hat{} \times \ln(\text{mkt penetration})_{ct}$		15.475***	12.595***	33.532***	32.951***
		(3.636)	(2.295)	(5.210)	(5.135)
$HHI\hat{} \times \ln(\text{mkt penetration})_{ct} \times \ln(\text{competitors})_{ct}$				3.622***	3.581***
				(0.360)	(0.406)
1st Stage R^2		0.109	0.162	0.327	0.337
1st Stage F-test		7.40***	15.21***	37.19***	39.93***
		[0.000]	*[0.000]*	*[0.000]*	*[0.000]*

Dependent variable: $\ln(MTR)_{jct} \times \ln(\text{mkt penetration})_{ct}$			
Instruments			
$Regulation_{jct}$	0.132***	0.142***	-0.013***
	(0.023)	(0.019)	(0.004)
$\ln(\text{competitors})_{ct}$	-2.799**	0.434	-0.086
	(1.345)	(0.431)	(0.425)
$Regulation_{jct} \times \ln(\text{competitors})_{ct}$	-0.114***	-0.114***	0.002
	(0.017)	(0.014)	(0.003)
$Regulation_{jct} \times \ln(\text{mkt penetration})_{ct}$	0.032*	0.004	-0.005
	(0.018)	(0.012)	(0.015)
Number of products produced by firm	-0.008**	-0.003	-0.003
	(0.003)	(0.002)	(0.002)
$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct}$	0.010	-0.007	-0.007
	(0.011)	(0.007)	(0.006)
$MTR\hat{}_{jct} \times \ln(\text{mkt penetration})_{ct}$	1.020***	0.754***	0.790***
	(0.027)	(0.035)	(0.035)
$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct} \times \ln(\text{mkt penetration})_{ct}$		0.191***	0.157***
		(0.029)	(0.030)
$HHI\hat{} \times \ln(\text{competitors})_{ct}$	0.368**	-0.038	0.010
	(0.169)	(0.054)	(0.054)
$HHI\hat{} \times \ln(\text{mkt penetration})_{ct}$	-0.218***	-0.237**	-0.509***
	(0.082)	(0.119)	(0.147)
$HHI\hat{} \times \ln(\text{mkt penetration})_{ct} \times \ln(\text{competitors})_{ct}$		-0.074***	-0.091***
		(0.011)	(0.013)
1st Stage R^2	0.977	0.984	0.983
1st Stage F-test	2134.60***	8885.98***	10569.36***
	[0.000]	*[0.000]*	*[0.000]*
Dependent variable: $\ln(HHI)_{ct} \times \ln(\text{mkt penetration})_{ct}$			
Instrumetns			
$Regulation_{jct}$	-0.024***	-0.001	0.000
	(0.004)	(0.006)	(0.002)
$\ln(\text{competitors})_{ct}$	-0.818***	-0.229	-0.223
	(0.255)	(0.155)	(0.150)
$Regulation_{jct} \times \ln(\text{competitors})_{ct}$	0.018***	0.003	0.001*
	(0.003)	(0.004)	(0.001)
$Regulation_{jct} \times \ln(\text{mkt penetration})_{ct}$	-0.001	0.004	0.004
	(0.004)	(0.005)	(0.005)
Number of products produced by firm	0.001*	0.002***	0.002***
	(0.001)	(0.001)	(0.001)
$MTR\hat{}_{jct} \times \ln(\text{competitors})_{ct}$	0.006*	0.004*	0.004*
	(0.003)	(0.002)	(0.002)

MTR^$_{jct}$ × ln(mkt penetration)$_{ct}$	0.015***	-0.054***	-0.054***
	(0.005)	(0.010)	(0.010)
MTR^$_{jct}$× ln(competitors)$_{ct}$ × ln(mkt penetration)$_{ct}$		0.059***	0.059***
		(0.009)	(0.008)
HHI^ × ln(competitors)$_{ct}$	0.099***	0.028	0.027
	(0.032)	(0.019)	(0.019)
HHI^ × ln(mkt penetration)$_{ct}$	0.892***	1.094***	1.096***
	(0.038)	(0.049)	(0.051)
HHI^ × ln(mkt penetration)$_{ct}$× ln(competitors)$_{ct}$		0.003	0.003
		(0.003)	(0.003)
1st Stage R^2	0.954	0.964	0.964
1st Stage F-test	316.61***	2351.86***	1973.66***
	[0.000]	*[0.000]*	*[0.000]*
Dependent variable: ln(MTR)$_{jct}$× ln(HHI)$_{ct}$ × ln(mkt penetration)$_{ct}$			
Instruments			
Regulation$_{jct}$		1.133***	-0.131***
		(0.172)	(0.035)
ln(competitors)$_{ct}$		1.782	-2.292
		(3.388)	(3.370)
Regulation$_{jct}$× ln(competitors)$_{ct}$		-0.920***	0.016
		(0.127)	(0.026)
Regulation$_{jct}$× ln(mkt penetration)$_{ct}$		0.065	0.000
		(0.111)	(0.129)
Number of products produced by firm		-0.015	-0.018
		(0.020)	(0.020)
MTR^$_{jct}$× ln(competitors)$_{ct}$		-0.105**	-0.105**
		(0.052)	(0.049)
MTR^$_{jct}$ × ln(mkt penetration)$_{ct}$		6.665***	6.970***
		(0.328)	(0.324)
MTR^$_{jct}$× ln(competitors)$_{ct}$ × ln(mkt penetration)$_{ct}$		1.334***	1.046***
		(0.271)	(0.277)
HHI^ × ln(competitors)$_{ct}$		-0.073	0.301
		(0.425)	(0.426)
HHI^ × ln(mkt penetration)$_{ct}$		0.729	-1.578
		(1.102)	(1.327)
HHI^ × ln(mkt penetration)$_{ct}$× ln(competitors)$_{ct}$		-0.477***	-0.623***
		(0.100)	(0.113)
1st Stage R^2		0.982	0.982
1st Stage F-test		6602.23***	7712.37***
		[0.000]	*[0.000]*

Notes: These are the first stage results from Table A11. The regressions include all the exogenous variables in Table A11. Each column corresponds to the columns in Table A11. Last three instruments are constructed as follows: we first regressed HHI on number of competitors, market penetration and regulation plus the full set of country-operator and time dummies; we then obtained the residuals from this regression and interacted them with the other exogenous variables (Wooldridge, 2002, p.235-237). All equations include country-operator and a full set of time dummies. P-values for diagnostic tests are in brackets and italics. Standard errors adjusted for heteroskedasticity and autocorrelation of unknown form and clustered by country-operator are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.