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

Christos Genakos[2] and Tommaso Valletti[3]

June 2007

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 network 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.

[1] We would like to thank Steffen Hoernig, Tobias Kretschmer, Marco Manacorda, Elias Papaioannou, Jonathan Sandbach, Jean Tirole, John Van Reenen, Julian Wright, and seminar audiences in Barcelona, Rome, Paris and the 8th CEPR Empirical IO meeting for helpful comments and discussions. We are also grateful to Bruno Basalisco for research assistance. We acknowledge research funding from Vodafone. The opinions expressed in this paper and all remaining errors are those of the authors alone.
[2] Selwyn College, University of Cambridge & Centre for Economic Performance, London School of Economics, e-mail: cg370@cam.ac.uk, Web: http://www.sel.ac.uk/personal/genakos/
[3] Tanaka Business School, Imperial College London, University of Rome "Tor Vergata" & CEPR, e-mail: t.valletti@imperial.ac.uk, Web: http://www3.imperial.ac.uk/people/t.valletti

1. Introduction

Mobile termination charges[4] have become the regulators' focus of concern worldwide in recent years. Regarding the fixed-to-mobile termination rates especially, 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.[5] 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).[6] Another example is the New Zealand Commerce Commission which, in its 2005 investigation, initially took the position that mobile subscription prices would rise in response to a cut in termination rates only if mobile firms operated in a perfectly competitive environment. The Commission was subsequently convinced that the waterbed effect is a more general phenomenon, but there remained doubts about the importance of such an effect. The most recent termination rate proposals by the UK regulator Ofcom considered the issue of the waterbed in order to analyse the impact of regulation of call termination. Ofcom acknowledged the importance of the waterbed effect, but questioned whether the effect was "complete", arguing that this can only be the case if the retail market is sufficiently competitive.[7]

Yet, despite the importance of the waterbed effect for welfare calculations, no systematic evidence exists on its existence or magnitude. Casual empiricism suggests that mobile subscription prices have been decreasing quite steadily over time in

[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.
[6] The term "waterbed" was first coined by the late Prof. Paul Geroski, chairman of the Competition Commission in the UK, at the time of the first investigation on interconnection charges in the mobile industry.
[7] See "Mobile call termination, Proposals for consultation", Ofcom, September 2006.

virtually every country, despite the regulation of mobile termination rates. At the same time, though, the industry has become more competitive, with additional entry, tougher competition, etc., exerting a countervailing force. As an example, Figure 1 plots the evolution of subscription prices and termination rates in France. While termination rates have been cut steadily over the years, prices to medium user customers have remained more or less constant. Does this imply there is no waterbed effect? Not necessarily as competition in the industry might also have intensified and other trends, such as economies of scale due to growth in traffic volumes, may also mask the impact of the waterbed on subscription prices.

[Figure 1]

In this paper we analyze the impact of fixed-to-mobile termination rate 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 this 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 on average. 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, thus mobile firms 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 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 Armstrong, 2006, and Rochet and Tirole, 2006). 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. The two markets are linked: more subscribers on the network means more opportunities for users of other networks to make calls. 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.[8] This is also a case where the mobile firms sell two goods with interdependent demand: at any given termination rate, the volume of fixed-to-mobile calls that an operator receives depend on the number of mobile subscribers on its network. In a sense, mobile subscribers and fixed-to-mobile calls are complements, as an increase in the number of subscribers will cause an increase in the volume of fixed-to-mobile calls.[9] 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 (2006, on newspapers), and Kaiser and Wright (2006, on magazines).

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

[8] 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.

[9] It is important to be very careful with the use of standard definitions taken from normal "one-sided" markets. In this example, the notion of complementarity between mobile subscribers and fixed-to-mobile calls is more controversial if one starts instead with a price increase of mobile termination.

2. Two simple models of the waterbed effect

In this section we discuss two simple but related models that give rise to the waterbed effect. The first one is a perfect competition model, where the waterbed effect arises from the zero-profit condition. The second model analyzes a monopoly situation, where the waterbed effect arises via an increase in the 'perceived' marginal cost of each customer. The aim of this section is to show how the waterbed effect can emerge under a rather wide range of circumstances.

First, let us make the simplified assumption that the mobile telephony market is characterized by perfect competition Also imagine each mobile network operator derives revenues from two possible sources:

- Services to own customers: these would include subscription services and outgoing calls to customers in the same network, i.e., calls made by own subscribers. All these services are bundled together and cost *P* to the customer, i.e., *P* is the total customer's bill. Let *N* be the total number of customers that an operator gets at a price *P*.
- Incoming calls: these are calls received by own customers but made by customers of other networks. The total quantity of these calls is denoted by Q_I and the corresponding price received by the mobile operator (the MTR) is denoted by *T* and is regulated.

For ease of exposition, we assume that all calls received are from fixed users.[10] Thus the demand for incoming calls to mobile subscribers coincides with the demand for (outgoing) fixed-to-mobile calls. The profit of the operator is:

$$\pi = (\underbrace{P}_{\text{bill}} - c)N + \underbrace{TQ_I}_{\substack{\text{termination} \\ \text{rents}}}$$

where *c* denotes the total cost per customer (this cost includes the handset, and the cost of the bundle of calls and services offered to the customer), while there are no other costs from receiving and terminating calls.

Since the industry is assumed to be perfectly competitive, each firm does not make any extra rent on any customer. The bill therefore is:

[10] Calls from other mobile users could be easily accommodated in this framework.

$$P = c - TQ_I / N = c - \tau,$$

where $\tau = TQ_I / N$ is the termination rent per customer. 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 the operator, leading to $\frac{\partial (P-c)N}{\partial T} = -\frac{\partial TQ_I}{\partial T}$ which can be re-written as

$$N(1+\lambda\varepsilon_N)\frac{\partial P}{\partial T} = -Q_I(1+\varepsilon_I)$$

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, and $\lambda = (P-c)/P = -\tau/(c-\tau)$. We can now obtain an expression for the waterbed effect, expressed in elasticity terms as:

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

The elasticity of incoming calls ε_I is negative and likely to be less than 1 in absolute value.[11] Also, $\varepsilon_N < 0$ and the termination rent is typically small compared to the overall cost per customer, so $1/\lambda = -c/\tau + 1 < 0$ too, and the overall sign of the RHS of equation (1) is negative, i.e., we should indeed expect a waterbed effect

[11] 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. Therefore, 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, September 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. However, in other European countries the fixed network retention ($P_F - T$) is itself directly regulated (e.g., the case in Belgium, Greece, Italy and the Netherlands).

involving a negative relationship between outgoing prices to mobile users and incoming termination prices.

Equation (1) 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 (1), 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, which determines the level of λ); and (b) price elasticities for subscriptions and incoming calls ($|\varepsilon_N|$ vs. $|\varepsilon_I|$).

A similar argument can be made in the case of pure monopoly. Let *N(P)* denote the subscription demand for mobile services, driven as before by the total price *P* of the bundled mobile services. $Q_I(N, N_F, T)$ denotes the total amount of fixed-to-mobile calls, which is assumed to depend on the number of fixed users, number of mobile users, and the call price paid – directly affected by the termination charge.

The monopolist maximises with respect to *P*:

$$\pi = (P - c)N(P) + TQ_I(N(P), N_F, T).$$

The first-order condition gives:

$$\left[P - c + T\frac{\partial Q_I}{\partial N}\right]\frac{\partial N}{\partial P} + N = 0,$$

or in elasticity terms:

$$\text{(2)} \qquad \frac{P - \left(c - T\dfrac{\partial Q_I}{\partial N}\right)}{P} = \frac{P - C}{P} = \frac{1}{|\varepsilon_N|},$$

where ε_N is the elasticity of subscription demand. In other words, the equation above is the classic inverse elasticity rule modified such that the "perceived" marginal cost *C* per 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 below the profit maximising level, 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. This increase in the perceived marginal cost exists with perfect competition as well. The only difference is that the elasticity of the waterbed effect under competition was obtained by differentiating the zero-budget constraint, while now it is derived by totally differentiating the monopolist's first-order condition.

To make some further inroads into the monopoly case, we assume that each fixed user calls each mobile user with the same per-customer demand function $q(T)$, that is $Q_I = NN_F q_I(T)$. Then (2) simplifies into

$$\text{(3)} \qquad \frac{P-(c-\tau)}{P} = \frac{1}{|\varepsilon_N|},$$

where $\tau = TN_F q_I$ is again the termination rent per mobile customer, with $c > \tau$. Assuming a constant-elasticity demand for subscription, from (3) the elasticity of the waterbed effect is negative and given by:

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

which is very similar to the effect derived in (1) under perfect competition (although (1) is obtained from a binding zero-profit condition and not from the first-order condition). Similarly, to see the impact on total profits in equilibrium we can write:

$$\pi = \frac{PN}{|\varepsilon_N|}, \text{ or } \log \pi = \log P + \log N - \log|\varepsilon_N|.$$

We can decompose the elasticity of profits with respect to T (assuming a constant elasticity of subscription demand) into a "waterbed" effect and a "subscription" effect. Since the last effect is $\frac{\partial N}{\partial T}\frac{T}{N} = \frac{\partial N}{\partial T}\frac{P}{N}\frac{\partial P}{\partial T}\frac{T}{P} = -|\varepsilon_N|\varepsilon_W$, we obtain overall:

$$\varepsilon_{\pi} = \frac{\partial \pi}{\partial T}\frac{T}{\pi} = \varepsilon_{W}(1-|\varepsilon_{N}|),$$

which is positive as the monopolist will always set the price in the elastic portion of demand. Higher termination rates should be associated with higher profits to the extent that the firm enjoys substantial market power.

Notice that our analysis so far focused on an "uncovered" market, in the sense that there is always some customer who does not buy any mobile service. This 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, the monopoly example 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.

In summary, we discussed how the waterbed effect would arise under the two extreme cases of perfect competition and monopoly. These simplified models are admittedly unrealistic to describe the complex world of mobile telephony, but appealing as they generate the waterbed effect under very different assumptions. 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. We therefore expect the waterbed effect to be a robust phenomenon even after introducing complexities into the theoretical model that would make it a better and more realistic description of the industry. 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, since 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 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 the market penetration in a given market, since this is a good proxy for subscription demand elasticity at different stages of the product life cycle of mobile telephony.

3. Econometric Specification and Data

3.1 Estimation Strategy

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 market is competitive 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. 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. 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.[12]

[12] 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

[Figure 2]

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. 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

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.

may not be very plausible (typically, countries with low MTRs are also competitive, at least anecdotally, which should give rise to the opposite bias), it is important to bear in mind this caveat when interpreting our results. In addition, we tried to alleviate this data limitation problem as much as possible by splitting our sample of countries into three macro regions (Western Europe, Eastern Europe, and Rest of the World) and introducing 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 indexes. 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 "monopoly 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 entrants 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 very mildly, while much 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.

3.2 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 market 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 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 measures suffer from endogeneity problems which could introduce bias and inconsistency in our results. However, this dataset contains information on almost all mobile operators in each country and hence it allows us to exploit more within-country variation.

4. Benchmark 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.[13] For that reason, we also add a binary variable (Pre-

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

paid$_{jct}$) indicating whether the best deal was on a pre-paid contract or not.[14] 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 severely 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.[15] 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. It seems likely that incumbents were offering significantly better deals to (the more elastic) pre-paid customers as a way of attracting consumers and putting pressure on the prices charged by their unregulated competitors.

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.[16]

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 results on the impact on ARPU to the Appendix. Column 1 shows that regulation had

[14] 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.

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

[16] 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.

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.[17] 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 relevant, for instance, for pre-paid customers, and the test on EBITDA should take

[17] 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 $\partial P / \partial \text{Regulation} = \frac{\partial P / \partial MTR}{\partial MTR / \partial \text{Regulation}}$, where the denominator and the numerator and are obtained from the 1st and 2nd stage respectively in the IV regression.

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.[18]

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]

5. 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 revision 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 binary indicators for twelve, non-overlapping, quarters around the introduction of

[18] 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 are 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 tariffs, the impact of reciprocal access charges on profits and bills is neutral (see Armstrong, 1998, and Laffont et al., 1998). Thus we really interpret our empirical results as the impact of the regulation of fixed-to-mobile termination rates on prices and profits.

regulation and a final binary variable isolating the long-run effect of regulation. Our specification is as follows:

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

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}).[19]

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.

[19] 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]

6. Interaction with Competition and Further Evidence

6.1 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,[20] the coefficient on the interaction between the competition variable and MTR is positive but insignificant, whereas in column 4[21] 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[22] 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

[20] 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, a la Berry et al. 1995) and interactions of the residuals (from the regression: MTR on competitors, penetration, regulation and all the fixed effects) with competitors and penetration (Wooldridge, 2002).

[21] The instruments used are the same as in the previous column 3.

[22] 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*,[23] we confirm the conclusions previously drawn. Results are virtually 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.

Therefore, 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 δ coefficient 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]

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

6.2 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[24] 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.[25] Thus pre-pay users receive

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

[25] Vodafone, for example, reports the following churn rates across its major European markets for the quarter to 30 September 2006 (Source: Vodafone):

relatively few calls and a change in MTR has a much lower expected impact compared to post-pay customers. 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

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]

7. 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 competitive 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 a great 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 fully at work.

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 has voted in 2007 to cap “roaming charges”[26] 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 limitations. 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.

[26] 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.

References

Argentesi, E. and L. Filistrucchi, 2006, "Estimating Market Power in a Two-Sided Market: The Case of Newspapers," *Journal of Applied Econometrics*, forthcoming.

Armstrong, M., 1998, "Network Interconnection in Telecommunications," *Economic Journal*, 108: 545-564.

Armstrong, M., 2002, "The Theory of Access Pricing and Interconnection," in M. Cave, S. Majumdar and I. Vogelsang (eds.) *Handbook of Telecommunications Economics*, North-Holland, Amsterdam.

Armstrong, M., 2006, "Competition in Two-Sided Markets," *RAND Journal of Economics*, forthcoming.

Berry, S., J. Levinsohn and A. Pakes, 1995, "Automobile Prices in Market Equilibrium," *Econometrica*, 63: 841-90.

Bertrand, M., E. Duflo and S. Mullainathan, 2004, "How Much Should We Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics*, 119: 249-75.

Card, D. and A.D. Krueger, 1994, "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania," *American Economic Review*, 84: 772-793.

Hausman, J. and J. Wright, 2006, "Two-sided markets with substitution: mobile termination revisited," *mimeo*, MIT.

Kaiser, U. and J. Wright, 2006, "Price Structure in Two-Sided Markets: Evidence from the Magazine Industry," *International Journal of Industrial Organization*, 24: 1-28.

Laffont, J.-J., Rey, P. and Tirole, J., 1998, "Network competition I: Overview and non-discriminatory pricing," *RAND Journal of Economics*, 29: 1-37.

Laporte, A. and F. Windmeijer, 2005, "Estimation of panel data models with binary indicators when treatment effects are not constant over time," *Economics Letters*, 88: 389-396.

Rochet, J.-C. and J. Tirole, 2006, "Two-Sided Markets: A Progress Report," *RAND Journal of Economics*, forthcoming.

Rysman, M., 2004, "Competition Between Networks: A Study of the Market for Yellow Pages," *Review of Economic Studies*, 71: 483-512.

Rysman, M., 2007, "An Empirical Analysis of Payment Card Usage," *Journal of Industrial Economics*, 55: 1-36.

Valletti, T. and G. Houpis, 2005, "Mobile termination: What is the "right" charge?" *Journal of Regulatory Economics*, 28: 235-258.

Wooldridge, J., 2002, *Econometric Analysis of Cross Section and Panel Data*, MIT Press.

Wright, J., 2002, "Access Pricing under Competition: an Application to Cellular Networks," *Journal of Industrial Economics*, 50: 289-316.

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 provided by Vodafone using Cullen International and its own internal sources. The variable identifies those periods in which the MTRs of network operators were constrained by a formal decision taken by a national regulatory authority. Because all the other datasets used are in quarterly format, we extrapolate the mobile termination rates where necessary to get the same frequency.

For firms' prices we use two data sources. Teligen (2002Q3-2006Q1) reports quarterly information on the total bills paid by consumers across countries. The second dataset is the Global Wireless Matrix of Merrill Lynch. This data is available also on a quarterly basis (2000Q1-2005Q3). For our purposes, we use the reported average revenue per user (ARPU) and the earnings before interest, taxes, depreciation and amortization (EBITDA). ARPU is calculated by dividing total revenues by subscribers. EBITDA is defined as the sum of operating income and depreciation and is used to proxy for profit and cash flow.

Variables are described in Table A1. Table A2 gives summary statistics for the Teligen dataset (and the matched MTRs), while Table A4 gives summary statistics 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 reports all the starting dates of regulation in countries which adopted MTR regulation.

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

5.2 Additional results

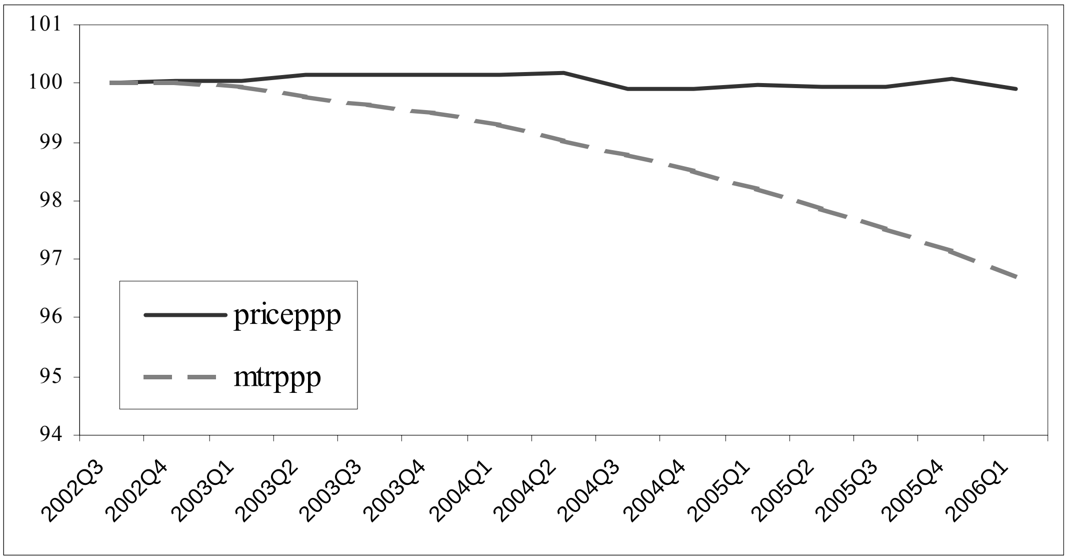
Impact on ARPU. In the main text (Section 3.1) we considered the impact of MTR on EBITDA, taken as a measure of profitability. Alternatively, one can also use ARPU (we recall that this measure also includes termination revenues, and therefore cannot be taken as a measure of customers' prices). Results 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 6.2. 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 6.1). 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.

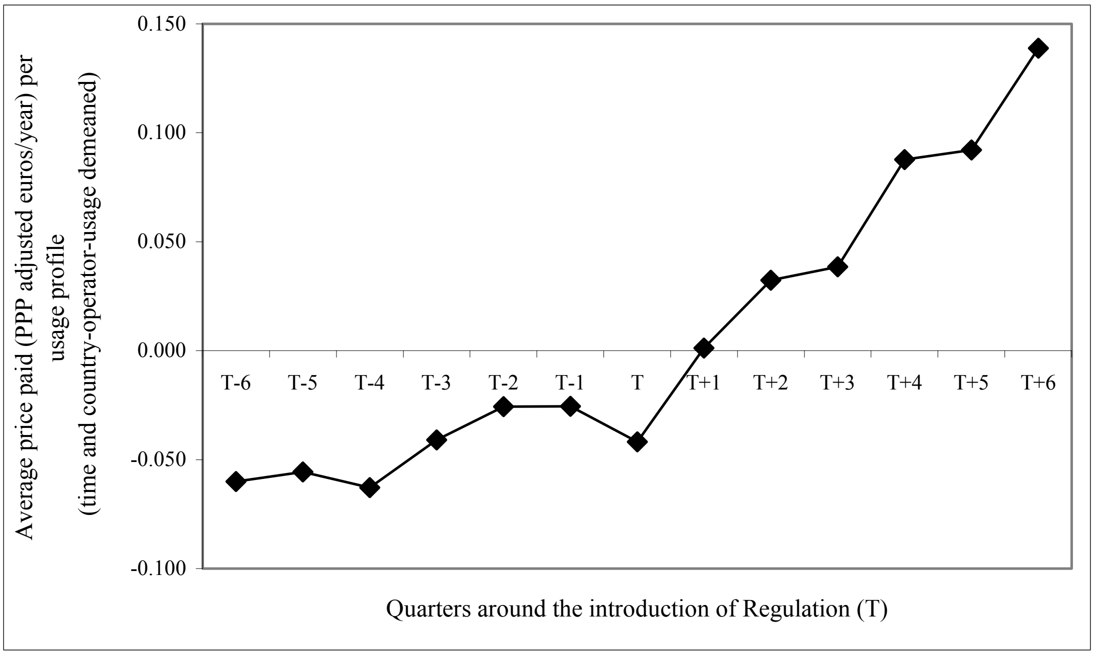
[Tables A7, A8, A9, A10, A11]

Figure 1
Average price and MTR decline (France, Medium User)



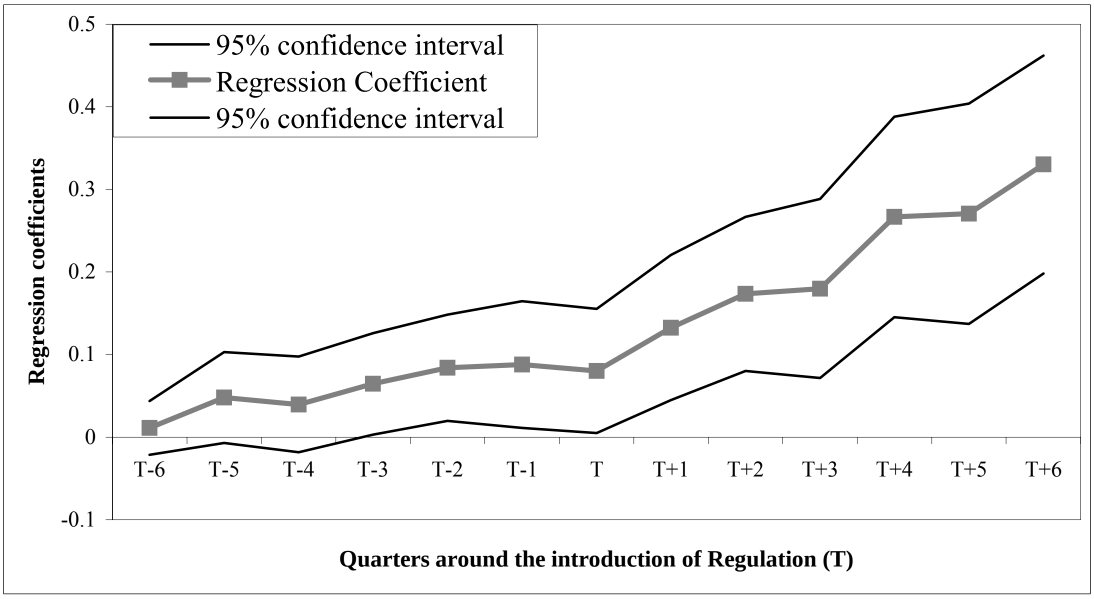
Notes: Figure 1 presents normalized (at the beginning of the period) PPP-adjusted average prices (total bill paid by medium usage consumers) and MTR rates for France based on the Teligen and Cullen International dataset.

Figure 2
Average Price around the introduction of Regulation



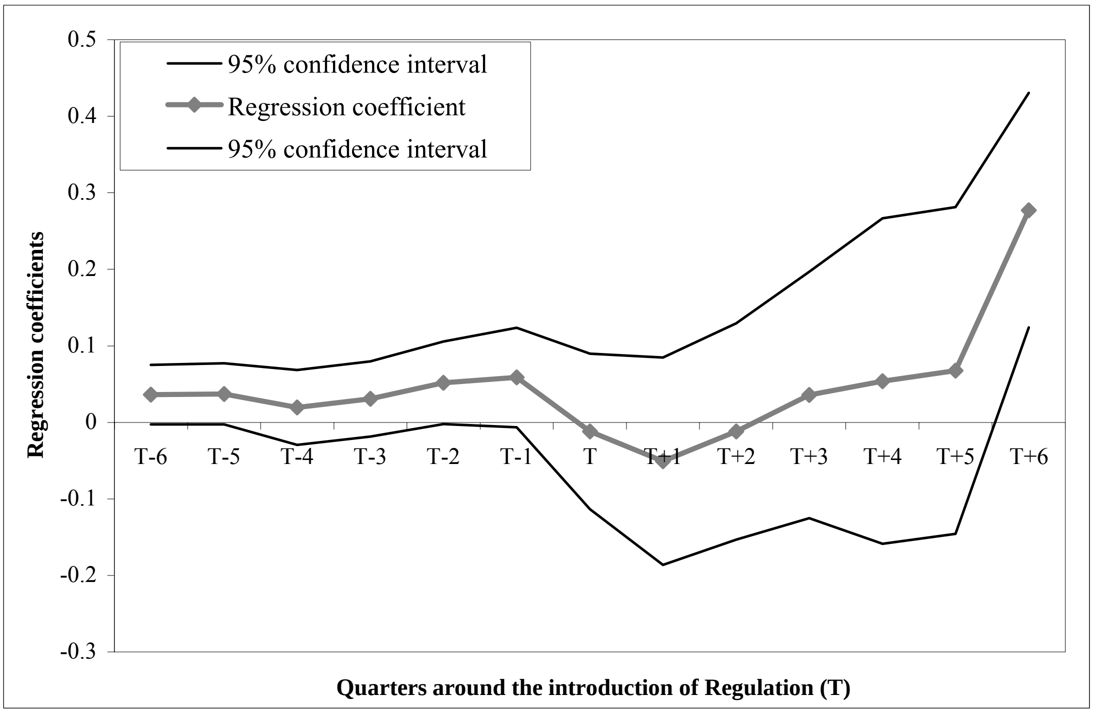
Notes: Figure 2 plots the evolution of time and country-operator-usage demeaned average logarithm of the PPP adjusted price paid per usage profile six quarters before and after the introduction of regulation of fixed-to-mobile termination charges based on the Teligen data corresponding to the best deals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

Figure 3
The Evolution of the Waterbed Effect



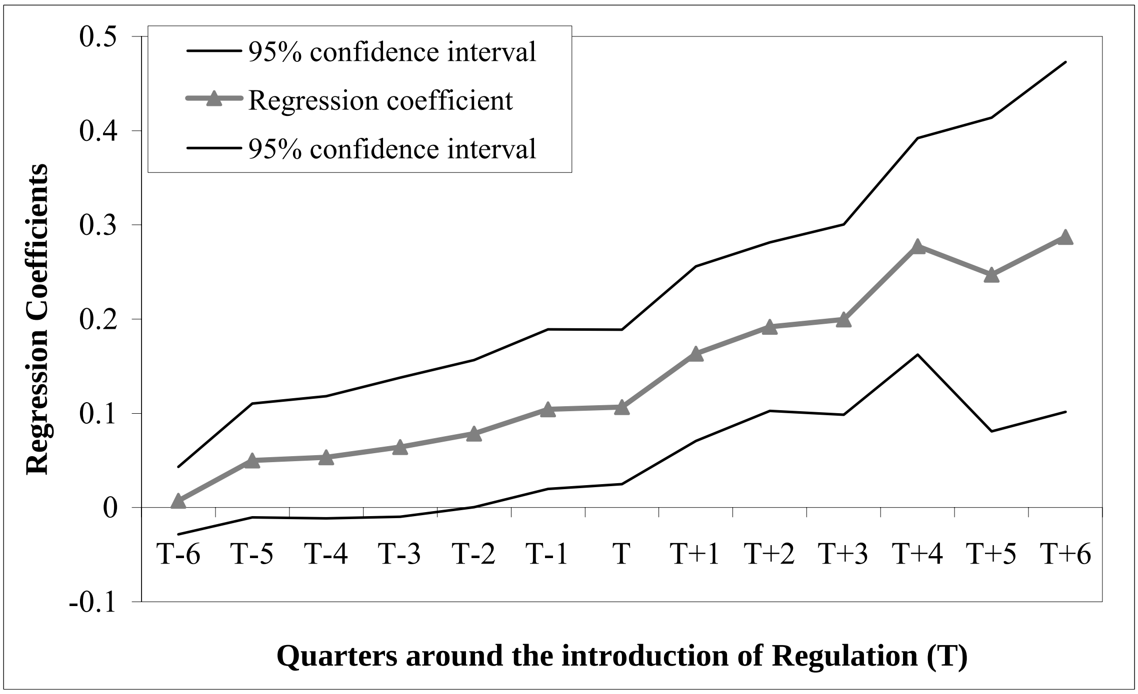
Notes: Figure 3 plots the regression coefficients on binary variables six quarters before and after the introduction of regulation. The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage based on the Teligen data corresponding to the best deals available 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: As Figure 4, but based on the best deals available for monthly subscribers at every period.

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

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
$Regulation_{jct}$	0.133***			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)			(0.076)	
MaxMTR $index_{jct}$		-0.024			-0.054
		(0.133)			(0.139)
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	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln EBITDA_{jct}$	$\ln EBITDA_{jct}$	$\ln EBITDA_{jct}$
$\ln(MTR)_{jct}$	-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	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{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)					
$\ln P_{ujct}$	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
$Pre\text{-}paid_{jct}$	1734	0.324	0.468	0	1
Teligen Table 2 (Pre-Paid Best Deals)					
$\ln P_{ujct}$	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)					
$\ln P_{ujct}$	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)					
$\ln P_{ujct}$	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
Australia	2005
Austria	2000
Belgium	1999
Czech Republic	2005
Denmark	2001
France	2004
Germany	2005
Greece	2006
Hungary	2002
Ireland	2006
Italy	2000
Japan	2000
Luxembourg	2006
Netherlands	2006
New Zealand	2006
Norway	2001
Poland	1997
Portugal	2003
Slovak Republic	2005
Spain	2000
Sweden	2001
Switzerland	2005
Turkey	2006
UK	1998

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
		(0.045)			(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

$\ln(MTR)_{jct}$						
1st Stage R^2	0.025	0.035	0.120	0.120	0.254	0.277
1st Stage F-test	19.92***	19.30***	15.44***	15.09***	48.47***	33.85***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
$\ln(MTR)_{jct} \times \ln(competitors)_{ct}$						
1st Stage R^2			0.375	0.373	0.984	0.516
1st Stage F-test			73.06***	89.02***	6825.55***	112.21***
			[0.000]	*[0.000]*	*[0.000]*	*[0.000]*
$\ln(MTR)_{jct} \times \ln(mkt\ penetration)_{ct}$						
1st Stage R^2				0.976	0.481	0.983
1st Stage F-test				1738.28***	133.06***	13641.36***
				[0.000]	*[0.000]*	*[0.000]*
$\ln(MTR)_{jct} \times \ln(competitors)_{ct} \times \ln(mkt\ penetration)_{ct}$						
1st Stage R^2					0.984	0.984
1st Stage F-test					11110.71***	7314.96***
					[0.000]	*[0.000]*

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 A11 – COMPETITION AND WATERBED EFFECT - First Stage Results

$\ln(MTR)_{jct}$					
1st Stage R^2	0.107	0.107	0.163	0.341	0.355
1st Stage F-test	7.73***	7.73***	18.43***	45.08***	43.20***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
$\ln(HHI)_{ct}$					
1st Stage R^2	0.237	0.237	0.391	0.518	0.521
1st Stage F-test	27.23***	27.23***	57.57***	49.15***	52.36***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
$\ln(MTR)_{jct} \times \ln(HHI)_{ct}$					
1st Stage R^2		0.109	0.162	0.327	0.337
1st Stage F-test		7.40***	15.22***	37.22***	39.96***
		[0.000]	*[0.000]*	*[0.000]*	*[0.000]*
$\ln(MTR)_{jct} \times \ln(\text{mkt penetration})_{ct}$					
1st Stage R^2			0.977	0.984	0.983
1st Stage F-test			2136.18***	8892.52***	10577.14***
			[0.000]	*[0.000]*	*[0.000]*
$\ln(HHI)_{ct} \times \ln(\text{mkt penetration})_{ct}$					
1st Stage R^2			0.954	0.964	0.964
1st Stage F-test			316.84***	2353.59***	1975.01***
			[0.000]	*[0.000]*	*[0.000]*
$\ln(MTR)_{jct} \times \ln(HHI)_{ct} \times \ln(\text{mkt penetration})_{ct}$					
1st Stage R^2				0.982	0.982
1st Stage F-test				6607.09***	7718.04***
				[0.000]	*[0.000]*