APPENDIX A – DATA DESCRIPTION AND MATCHING INFORMATION

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

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

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

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

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

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

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

Finally, mobile operators' accounting and market information comes from the Global Wireless Matrix of Merrill Lynch, which is also available on a quarterly basis (2000Q1-2005Q3). Merrill Lynch compiles basic operating metrics for mobile operators in 46 countries globally. For our purposes, we use the reported average revenue per user (ARPU) and the earnings before interest, taxes, depreciation and amortization (EBITDA). The ARPU is calculated by dividing service revenues by the average subscriber base during the quarter. Service revenues include monthly service charges and usage fees, roaming, long distance and subscriptions to mobile data services. Some operators also include non-service revenues (e.g., equipment sales) in their ARPU calculation. The EBITDA margin is calculated by dividing total EBITDA by total revenues. Note that although we would ideally like to calculate the margin on only the service revenues (i.e., excluding equipment sales from the denominator) few operators disclose the margins on service revenues. We use the EBITDA margin as a proxy for profit and cash flow. All the basic variables are described in Table A1.

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 based on the Teligen dataset, the second variable is taken from the Cullen International dataset and the last two variables are from the Merrill Lynch dataset. See section 4 in the text and Appendix A for more details.

Matching these different datasets results in the summary statistics described in Table A2 for Teligen (and the matched MTRs) and Table A4 for Merill Lynch (and the matched MTRs). Table A3 corresponds to Table A2, but limited to the sample we use when we analyze the effects of competition, and also include the additional variables used in that exercise. Table A5 also provides similar information for the key variables used in Table 4. Table A6 presents the countries and timing of regulation's introduction in chronological order.

TABLE A2 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
Teligen (Best 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

Notes: The above table provides summary statistics on the key variables used in Table 1 (columns 1-3) based on the Teligen data corresponding to the best deals available at every quarter.

TABLE A3 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
Teligen (Best Deals) and Merill Lynch					
$\ln P_{ujct}$	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

Notes: The above table provides summary statistics on the key variables used in Table 3 based on the Teligen data corresponding to the best deals available at every quarter and the Merrill Lynch dataset.

TABLE A4 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
		Merill Lynch			
$lnEBITDA_{jct}$	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

Notes: The upper panel of the above table provides summary statistics on the key variables used in Table 1 (columns 4-6), whereas the lower panel provides similar information for the variables used in Table B1 in Appendix B based on the Merrill Lynch dataset.

TABLE A5 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
		Teligen (Best Deals)			
lnP_{ujct}	504	5.202	1.544	1.067	7.365
$lnFixed_{ujct}$	504	3.454	1.808	-1.538	6.496
$lnVoice_{ujct}$	504	4.877	1.569	0.621	7.357
$ln(MTR)_{jct}$	504	1.485	1.477	-3.246	3.405
$Regulation_{jct}$	504	0.679	0.467	0	1
lnP_{ujct}	545	4.944	1.440	0.114	7.492
$ln(MTR)_{jct}$	545	2.089	1.323	-2.978	3.573
$Regulation_{jct}$	545	0.563	0.496	0	1
		Teligen (Monthly subscriptions)			
lnP_{ujct}	792	5.142	1.540	0.888	7.551
$lnFixed_{ujct}$	792	3.487	1.735	-1.538	6.496
$lnVoice_{ujct}$	792	4.802	1.579	0.258	7.357
$ln(MTR)_{jct}$	792	1.618	1.440	-3.246	3.537
$Regulation_{jct}$	792	0.654	0.476	0	1
		Teligen (Pre-Paid)			
lnP_{ujct}	1670	5.554	1.688	0.114	7.989
$ln(MTR)_{jct}$	1670	1.877	1.580	-3.246	3.573
$Regulation_{jct}$	1670	0.599	0.490	0	1

Source: Author's calculations based on the Teligen data corresponding to the best deals available at every quarter (first panel), deals available to monthly subscribers only (second panel) and deals available to pre-paid customers only (third panel).

Notes: The first panel (Best Deals) provides summary statistics on the key variables used in Table 4 (columns 1-4), the second panel (Monthly subscriptions) provides similar information for the variables used in columns 5-7 and the third panel provides summary statistics on the variables used in column 8.

TABLE A6 – REGULATION CHRONOLOGY

Country	Year
Poland	1997Q1
UK	1998Q1
Belgium	1999Q2
Austria	2000Q2
Italy	2000Q2
Japan	2000Q2
Spain	2000Q2
Norway	2001Q2
Sweden	2001Q2
Denmark	2001Q4
Hungary	2002Q1
Portugal	2003Q4
France	2004Q2
Australia	2005Q2
Czech Republic	2005Q2
Germany	2005Q2
Slovak Republic	2005Q2
Switzerland	2005Q4
Ireland	2006Q2
Luxembourg	2006Q2
New Zealand	2006Q2
Turkey	2006Q2
Netherlands	2006Q3
Greece	2006Q4

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

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APPENDIX B – ADDITIONAL EMPIRICAL RESULTS

Impact on ARPU. In the main text (Section 5) we considered the impact of MTR on EBITDA, taken as a measure of profitability. Alternatively, one can also use ARPU (recall that this measure also includes termination revenues, and therefore cannot be taken as a measure of customers' prices). Results are shown in Table B1. In line with the results on EBITDA, we find that higher MTRs have a small positive effect on ARPU, though the results are not significant when we include regional-time binary indicators. Taken together with the results on EBITDA, we have some evidence that the waterbed effect is not full.

TABLE B1 – WATERBED EFFECT THROUGH MTR (ARPU)

	(1)	(2)	(3)	(4)	(5)
Estimation method	IV	IV	IV	IV	IV
Dependent variable	$lnARPU_{jct}$	$lnARPU_{jct}$	$lnARPU_{jct}$	$lnARPU_{jct}$	$lnARPU_{jct}$
Waterbed Effect	*-2.0%*	*0.9%*	*0.7%*	*-2.7%*	*0.7%*
$\ln(MTR)_{jct}$	0.161 (0.210)	-0.245* (0.143)	-0.315* (0.183)	0.240 (0.231)	-0.222 (0.164)
Region-Time FE	no	no	no	yes	yes
Time FE	yes	yes	yes	yes	yes
County-Operator FE	yes	yes	yes	yes	yes
Instrument	$Regulation_{jct}$	*MaxMTR* $index_{jct}$	*UnregulatedMTR* $index_{jct}$	$Regulation_{jct}$	*MaxMTR* $index_{jct}$
1st Stage Coef.	-0.121*** (0.036)	-0.341*** (0.050)	-0.281*** (0.095)	-0.122*** (0.038)	-0.301*** (0.051)
1st Stage R^2	0.053	0.110	0.166	0.051	0.098
1st Stage F-test	11.14*** *[0.001]*	47.42*** *[0.000]*	8.69** *[0.009]*	8.67** *[0.004]*	35.02** *[0.000]*
Observations	1247	1247	357	1247	1247
Clusters	74	74	18	74	74

Source: Author's calculations based on the Merrill Lynch dataset.

Notes: The dependent variable is the logarithm of the PPP adjusted ARPU. All equations include country-operator and a full set of time binary indicators (first three columns) or a full set of region-time binary indicators (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. The instrumental variable "Regulation" is a binary indicator that takes the value one in the quarters when mobile termination rates are regulated. The instrumental variable "MaxMTR" is an index that takes larger values the more regulated a mobile operator is compare to the operator that is regulated the least in the same country and quarter. The instrumental variable "UnregulatedMTR" is an index that takes larger values the more regulated a mobile operator is compare to the operator that is unregulated in the same country and quarter. The waterbed effect in row four is calculated as: 1st stage coeff. × coeff. ln(MTR), when "Regulation" is used as an instrument or alternatively as: 1st stage coeff. × coeff. ln(MTR)× mean value of instrumental variable. P-values for diagnostic tests are in brackets and italics. Standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) either at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

Pre- and post-paid contracts. In Tables 1-3 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[30] 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.

Using our benchmark IV specification (4), we now 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. Table B2 provides some summary statistics of the key variables. Tables B3 and B4 report the results for pre-paid and monthly (post-paid) contracts respectively. The procedure and interpretation is equivalent to that of Table 1 (columns 1-3) and Table 2 (columns 3 and 4). We find that pre-paid customers essentially are unaffected by regulation, whereas monthly subscribers bear the bulk of the price increases. As explained in the main text, the reason for this may come from the 'countervailing' collusive effect of M2M rates. As an additional explanation, the difference between pre-paid and post-paid may also arise because firms have a more secure relationship with monthly contract subscribers (who tend to stay with the same operator for several years), and so have a greater expectation of receiving future incoming revenues as a result of competing on price for these customers. Post-pay customers also tend to receive more incoming calls, and so become more (less) profitable as termination rates rise (fall). On the contrary, pre-pay subscribers, who are typically very price sensitive, tend to change their number often, therefore it is less likely that their numbers are known by potential callers. Thus pre-pay users receive relatively few calls and a change in MTR has a much lower expected impact compared to post-pay customers.[31]

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

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

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

TABLE B2 – SUMMARY STATISTICS

Variable	Observations	Mean	Standard Deviation	Min	Max
Teligen (Pre-Paid)					
$\ln P_{ujct}$	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 (Monthly subscriptions)					
$\ln P_{ujct}$	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

Source: Author's calculations based on the Teligen data corresponding to deals available to monthly subscribers only (first panel) and deals available to pre-paid customers only (second panel).
Notes: The above table provides summary statistics on the key variables used in Table B3 and B4.

TABLE B3 – WATERBED EFFECT THROUGH MTR (TELIGEN Pre-Paid)

	(1)	(2)	(3)	(4)	(5)
Estimation method	IV	IV	IV	IV	IV
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
Waterbed Effect	*0.8%*	*2.6%*	*0.1%*	*1.4%*	*2.8%*
$\ln(MTR)_{jct}$	-0.069 (0.501)	-0.489 (0.352)	-0.017 (0.260)	-0.137 (0.559)	-0.548 (0.365)
Region-Time FE	no	no	no	yes	yes
Time FE	yes	yes	yes	yes	yes
County-Operator-Usage FE	yes	yes	yes	yes	yes
Instrument	$Regulation_{jct}$	*MaxMTR* $index_{jct}$	*UnregulatedMTR* $index_{jct}$	$Regulation_{jct}$	*MaxMTR* $index_{jct}$
1st Stage Coef.	-0.113*** (0.025)	-0.316*** (0.039)	-0.389*** (0.029)	-0.104*** (0.025)	-0.302*** (0.036)
1st Stage R^2	0.049	0.138	0.532	0.043	0.133
1st Stage F-test	20.37*** *[0.000]*	66.33*** *[0.000]*	175.40*** *[0.000]*	16.82*** *[0.000]*	69.71*** *[0.000]*
Observations	1686	1686	450	1686	1686
Clusters	147	147	36	147	147

Source: Author's calculations based on the Teligen data corresponding to the deals available to pre-paid customers only.
Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage at every quarter. All equations include country-operator-usage and a full set of time binary indicators (first three columns) or a full set of region-time binary indicators (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. The instrumental variable "Regulation" is a binary indicator that takes the value one in the quarters when mobile termination rates are regulated. The instrumental variable "MaxMTR" is an index that takes larger values the more regulated a mobile operator is compare to the operator that is regulated the least in the same country and quarter. The instrumental variable "UnregulatedMTR" is an index that takes larger values the more regulated a mobile operator is compare to the operator that is unregulated in the same country and quarter. The waterbed effect in row four is calculated as: 1st stage coeff. × coeff. ln(MTR), when "Regulation" is used as an instrument or alternatively as: 1st stage coeff. × coeff. ln(MTR)× mean value of instrumental variable. P-values for diagnostic tests are in brackets and italics. Standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) either at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE B4 – WATERBED EFFECT THROUGH MTR (TELIGEN Monthly Subscription)

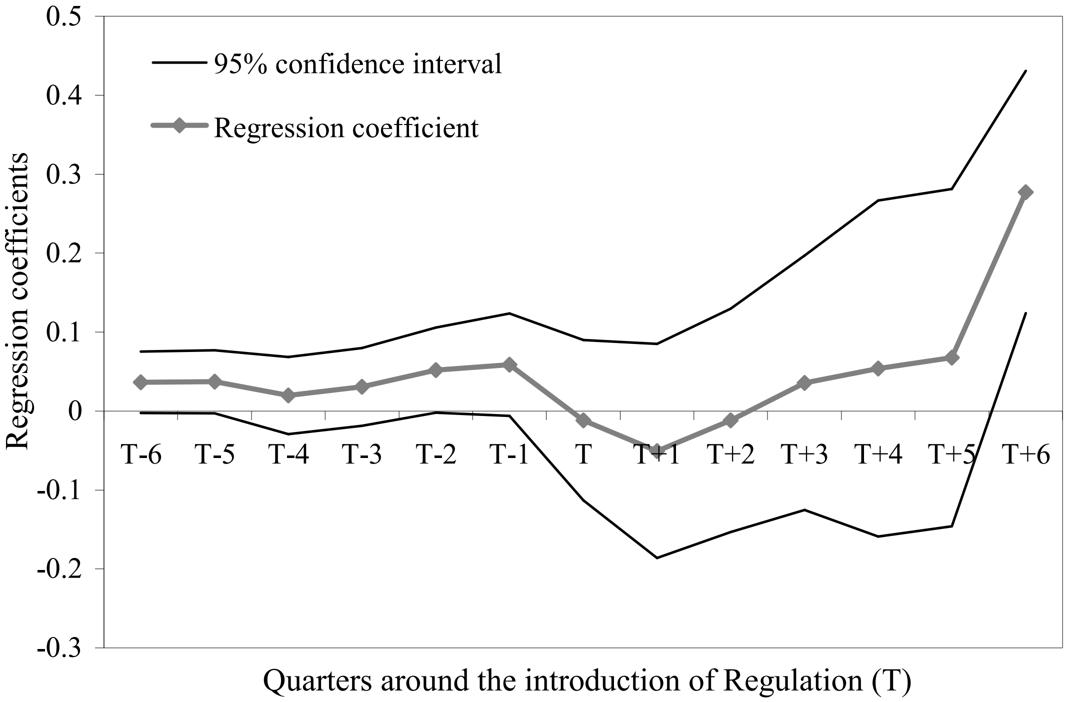
	(1)	(2)	(3)	(4)	(5)
Estimation method	IV	IV	IV	IV	IV
Dependent variable	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}	lnP_{ujct}
Waterbed Effect	*13.7%*	*5.2%*	*2.3%*	*15.8%*	*5.6%*
$ln(MTR)_{jct}$	-1.226*** (0.393)	-1.014*** (0.269)	-0.390*** (0.144)	-1.540*** (0.477)	-1.149*** (0.272)
Region-Time FE	no	no	no	yes	yes
Time FE	yes	yes	yes	yes	yes
County-Operator FE	yes	yes	yes	yes	yes
Instrument	$Regulation_{jct}$	*MaxMTR* $index_{jct}$	*UnregulatedMTR* $index_{jct}$	$Regulation_{jct}$	*MaxMTR* $index_{jct}$
1st Stage Coef.	-0.112*** (0.025)	-0.313*** (0.037)	-0.389*** (0.029)	-0.102*** (0.025)	-0.298*** (0.034)
1st Stage R^2	0.046	0.130	0.532	0.040	0.127
1st Stage F-test	19.63*** *[0.000]*	72.24*** *[0.000]*	175.40*** *[0.000]*	16.110*** *[0.000]*	76.54*** *[0.000]*
Observations	1734	1734	450	1734	1734
Clusters	150	150	36	150	150

Source: Author's calculations based on the Teligen data corresponding to the deals available to monthly subscribers only.
Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage at every quarter. All equations include country-operator-usage and a full set of time binary indicators (first three columns) or a full set of region-time binary indicators (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. The instrumental variable "Regulation" is a binary indicator that takes the value one in the quarters when mobile termination rates are regulated. The instrumental variable "MaxMTR" is an index that takes larger values the more regulated a mobile operator is compare to the operator that is regulated the least in the same country and quarter. The instrumental variable "UnregulatedMTR" is an index that takes larger values the more regulated a mobile operator is compare to the operator that is unregulated in the same country and quarter. The waterbed effect in row four is calculated as: 1st stage coeff. × coeff. ln(MTR), when "Regulation" is used as an instrument or alternatively as: 1st stage coeff. × coeff. ln(MTR)× mean value of instrumental variable. P-values for diagnostic tests are in brackets and italics. Standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) either at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

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 (5) separately for pre- and post-paid deals. Figures B1 and B2 plot the regression coefficients on the thirteen binary indicators around the introduction of regulation together with their 95% confidence interval for pre- 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 B2) then experience a change similar to that analysed with the general unconstrained results (contrast it with Figure 2 in the main text). On the contrary, the pattern for pre-paid contracts is more intriguing. As can be seen in Figure B1, the inaction before the introduction of regulation is followed by a shortlived (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.

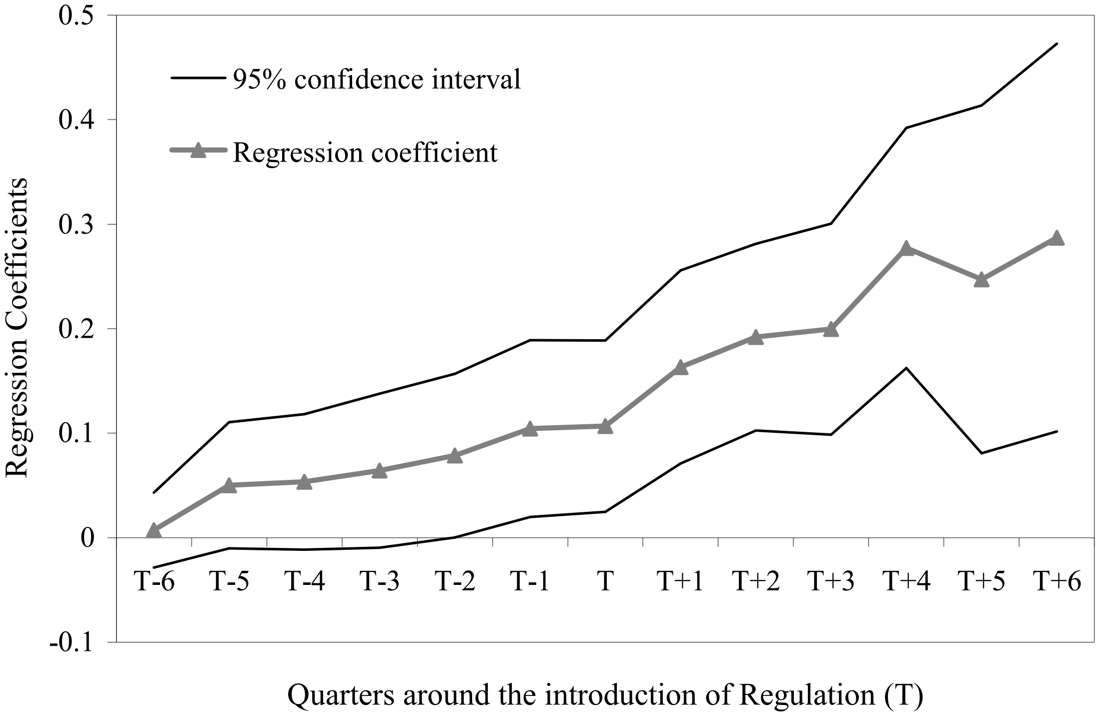
Notice also the massive increase in the variance associated with these coefficients after the introduction of regulation. Mobile operators seem to have reacted differentially regarding the pricing of these contracts shortly after the introduction of regulation. At the beginning, they seem on average 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 and raise the prices even for the pre-paid customers, which is another manifestation of the power of the waterbed effect.

Figure B1: The Evolution of the Waterbed Effect (Pre-Paid)



Notes: Data from Teligen corresponding to the deals available at every quarter to pre-paid customers only. Figure B1 plots the regression coefficients from model (5) 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 at every quarter. All equations include country-operator-usage and a full set of time dummies. Confidence interval is based on standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) at the country-operator-usage level.

Figure B2: The Evolution of the Waterbed Effect (Monthly Subscription)



Notes: Data from Teligen corresponding to the deals available at every quarter to monthly customers only. Figure B2 plots the regression coefficients from model (5) 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 at every quarter. All equations include country-operator-usage and a full set of time dummies. Confidence interval is based on standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) at the country-operator-usage level.

Competition. Table B5 reports the results from the first-stage regression of Table 3 (section 6.1). Table B6 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. Table B7 reports the results from the first-stage regression of Table B6.

TABLE B5 – COMPETITION AND WATERBED EFFECT - First Stage Results

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

1st Stage R^2	0.375	0.373	0.481	0.516
1st Stage F-test	73.01***	88.95***	132.96***	112.13***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(penetration)_{ct}$				
Instruments				
$Regulation_{jct}$		0.134***	0.168***	-0.001
		(0.025)	(0.021)	(0.005)
$Regulation_{jct} \times \ln(competitors)_{ct}$		-0.107***	-0.134***	0.005
		(0.018)	(0.015)	(0.003)
$Regulation_{jct} \times \ln(penetration)_{ct}$		0.046***	0.019	0.009
		(0.020)	(0.014)	(0.017)
Number of products produced by firm		-0.007***	-0.002	-0.002
		(0.003)	(0.002)	(0.002)
$MTRhat_{jct} \times \ln(competitors)_{ct}$		-0.021***	-0.005	-0.007
		(0.010)	(0.006)	(0.006)
$MTRhat_{jct} \times \ln(penetration)_{ct}$		1.037***	0.726***	0.738***
		(0.027)	(0.033)	(0.033)
$MTRhat_{jct} \times \ln(competitors)_{ct} \times \ln(penetration)_{ct}$			0.227***	0.220***
			(0.025)	(0.025)
1st Stage R^2		0.976	0.984	0.983
1st Stage F-test		1737.00***	11102.54***	13631.34***
		[0.000]	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(competitors)_{ct} \times \ln(penetration)_{ct}$				
Instruments				
$Regulation_{jct}$			0.214***	-0.007
			(0.027)	(0.008)
$Regulation_{jct} \times \ln(competitors)_{ct}$			-0.174***	0.004
			(0.020)	(0.004)
$Regulation_{jct} \times \ln(penetration)_{ct}$			0.036*	0.028
			(0.019)	(0.022)
Number of products produced by firm			0.000	0.000
			(0.004)	(0.004)
$MTRhat_{jct} \times \ln(competitors)_{ct}$			-0.023**	-0.026***
			(0.009)	(0.009)
$MTRhat_{jct} \times \ln(penetration)_{ct}$			-0.397***	-0.379***
			(0.061)	(0.059)

$MTRhat_{jct} \times \ln(competitors)_{ct} \times \ln(penetration)_{ct}$	1.364*** (0.046)	1.355*** (0.046)
1st Stage R^2	0.984	0.984
1st Stage F-test	6820.54*** *[0.000]*	7309.58*** *[0.000]*

Source: Author's calculations based on the combination of variables from the Merrill Lynch dataset and the Teligen data corresponding to the best deals available at every quarter.

Notes: These are the first stage results from Table 3, where each column corresponds to the same column in Table 3. The regressions include all the exogenous variables in Table 3. Last three instruments in each panel are constructed as follows: we first regressed MTR on number of competitors, market penetration and regulation plus the full set of country-operator and time binary indicators; we then obtained the residuals from this regression and interacted them with the other exogenous variables (Wooldridge, 2002, p.235-237). All equations include country-operator and a full set of time binary indicators. P-values for diagnostic tests are in brackets and italics. Standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE B6 – COMPETITION AND WATERBED EFFECT

	(1)	(2)	(3)	(4)	(5)
Estimation method	GMM	GMM	GMM	GMM	GMM
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
$\ln(MTR)_{jct}$	-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)
$\ln(penetration)_{ct}$	-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)
$\ln(MTR)_{jct}\times \ln(penetration)_{ct}$			0.445***	-15.912**	-31.221***
			(0.144)	(6.206)	(11.434)
$\ln(HHI)_{ct} \times \ln(penetration)_{ct}$			-2.013**	-7.240***	-9.791***
			(0.851)	(1.882)	(3.091)
$\ln(MTR)_{jct}\times \ln(HHI)_{ct} \times \ln(penetration)_{ct}$				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
$\Delta P/\Delta penetration$	-0.760	-0.466	0.642	1.021	0.813
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]*

Source: Author's calculations based on the combination of variables from the Merrill Lynch dataset and the Teligen data corresponding to the best deals available at every quarter.
Notes: The dependent variable in all regressions is the logarithm of the PPP adjusted total bill paid by consumers with different usage at every quarter. All equations include country-operator-usage and a full set of year binary indicators. The full list of instruments used together with the first stage estimates can be found in Table B7. P-values for diagnostic tests are in brackets and italics. Standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE B7 – COMPETITION AND WATERBED EFFECT-First Stage Results

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

Regulation$_{jct}$× ln(penetration)$_{ct}$			-0.044	-0.118***	-0.134***
			(0.029)	(0.028)	(0.029)
Number of products produced by firm			-0.007***	-0.010***	-0.009***
			(0.002)	(0.002)	(0.002)
MTRhat$_{jct}$× ln(competitors)$_{ct}$	-0.078***	-0.078***	-0.014*	-0.021**	-0.018**
	(0.012)	(0.012)	(0.008)	(0.009)	(0.009)
MTRhat$_{jct}$ × ln(penetration)$_{ct}$			-0.126***	0.090**	0.080*
			(0.019)	(0.039)	(0.041)
MTRhat$_{jct}$× ln(competitors)$_{ct}$ × ln(penetration)$_{ct}$				-0.238***	-0.232***
				(0.035)	(0.037)
HHIhat × ln(competitors)$_{ct}$	-0.085	-0.085	0.204	0.255**	0.282***
	(0.187)	(0.187)	(0.160)	(0.112)	(0.104)
HHIhat × ln(penetration)$_{ct}$	0.480***	0.480***	0.084	-1.619***	-1.569***
	(0.119)	(0.119)	(0.153)	(0.248)	(0.264)
HHIhat × ln(penetration)$_{ct}$× ln(competitors)$_{ct}$				-0.120***	-0.117***
				(0.014)	(0.015)
1st Stage R^2	0.237	0.237	0.391	0.518	0.521
1st Stage F-test	27.21***	27.21***	57.52***	49.11***	52.32***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: ln(MTR)$_{jct}$× ln(HHI)$_{ct}$					
Instruments					
Regulation$_{jct}$		-0.205	-7.418***	-5.636***	-1.505***
		(0.188)	(0.919)	(0.691)	(0.223)
ln(competitors)$_{ct}$		115.601**	82.885*	-5.410	22.492
		(53.689)	(42.284)	(39.028)	(36.503)
Regulation$_{jct}$× ln(competitors)$_{ct}$			5.820***	4.355***	0.159
			(0.649)	(0.483)	(0.142)
Regulation$_{jct}$× ln(penetration)$_{ct}$			-1.960***	-0.270	1.225**
			(0.619)	(0.435)	(0.492)
Number of products produced by firm			-0.029	-0.160*	-0.173**
			(0.127)	(0.083)	(0.083)
MTRhat$_{jct}$× ln(competitors)$_{ct}$		-1.297*	-0.771	-0.186	-0.426
		(0.746)	(0.590)	(0.603)	(0.587)
MTRhat$_{jct}$ × ln(penetration)$_{ct}$			-0.650	4.618***	5.008***
			(0.651)	(0.775)	(0.834)
MTRhat$_{jct}$× ln(competitors)$_{ct}$ × ln(penetration)$_{ct}$				-2.805***	-2.828***
				(0.700)	(0.766)

HHIhat × $\ln(\text{competitors})_{ct}$	-14.175**	-10.888**	0.527	-2.442
	(6.640)	(5.268)	(4.844)	(4.558)
HHIhat × $\ln(\text{penetration})_{ct}$	15.475***	12.595***	33.532***	32.951***
	(3.636)	(2.295)	(5.210)	(5.135)
HHIhat × $\ln(\text{penetration})_{ct}$× $\ln(\text{competitors})_{ct}$			3.622***	3.581***
			(0.360)	(0.406)
1st Stage R^2	0.109	0.162	0.327	0.337
1st Stage F-test	7.40***	15.21***	37.19***	39.93***
	[0.000]	*[0.000]*	*[0.000]*	*[0.000]*
Dependent variable: $\ln(\text{MTR})_{jct}$× $\ln(\text{penetration})_{ct}$				
Instruments				
Regulation_{jct}		0.132***	0.142***	-0.013***
		(0.023)	(0.019)	(0.004)
$\ln(\text{competitors})_{ct}$		-2.799**	0.434	-0.086
		(1.345)	(0.431)	(0.425)
Regulation_{jct}× $\ln(\text{competitors})_{ct}$		-0.114***	-0.114***	0.002
		(0.017)	(0.014)	(0.003)
Regulation_{jct}× $\ln(\text{penetration})_{ct}$		0.032*	0.004	-0.005
		(0.018)	(0.012)	(0.015)
Number of products produced by firm		-0.008**	-0.003	-0.003
		(0.003)	(0.002)	(0.002)
MTRhat_{jct}× $\ln(\text{competitors})_{ct}$		0.010	-0.007	-0.007
		(0.011)	(0.007)	(0.006)
MTRhat_{jct} × $\ln(\text{penetration})_{ct}$		1.020***	0.754***	0.790***
		(0.027)	(0.035)	(0.035)
MTRhat_{jct}× $\ln(\text{competitors})_{ct}$ × $\ln(\text{penetration})_{ct}$			0.191***	0.157***
			(0.029)	(0.030)
HHIhat × $\ln(\text{competitors})_{ct}$		0.368**	-0.038	0.010
		(0.169)	(0.054)	(0.054)
HHIhat × $\ln(\text{penetration})_{ct}$		-0.218***	-0.237**	-0.509***
		(0.082)	(0.119)	(0.147)
HHIhat × $\ln(\text{penetration})_{ct}$× $\ln(\text{competitors})_{ct}$			-0.074***	-0.091***
			(0.011)	(0.013)
1st Stage R^2		0.977	0.984	0.983
1st Stage F-test		2134.60***	8885.98***	10569.36***
		[0.000]	*[0.000]*	*[0.000]*
Dependent variable: $\ln(\text{HHI})_{ct}$ × $\ln(\text{penetration})_{ct}$				

Instruments			
$Regulation_{jct}$	-0.024***	-0.001	0.000
	(0.004)	(0.006)	(0.002)
$\ln(competitors)_{ct}$	-0.818***	-0.229	-0.223
	(0.255)	(0.155)	(0.150)
$Regulation_{jct} \times \ln(competitors)_{ct}$	0.018***	0.003	0.001*
	(0.003)	(0.004)	(0.001)
$Regulation_{jct} \times \ln(penetration)_{ct}$	-0.001	0.004	0.004
	(0.004)	(0.005)	(0.005)
Number of products produced by firm	0.001*	0.002***	0.002***
	(0.001)	(0.001)	(0.001)
$MTRhat_{jct} \times \ln(competitors)_{ct}$	0.006*	0.004*	0.004*
	(0.003)	(0.002)	(0.002)
$MTRhat_{jct} \times \ln(penetration)_{ct}$	0.015***	-0.054***	-0.054***
	(0.005)	(0.010)	(0.010)
$MTRhat_{jct} \times \ln(competitors)_{ct} \times \ln(penetration)_{ct}$		0.059***	0.059***
		(0.009)	(0.008)
$HHIhat \times \ln(competitors)_{ct}$	0.099***	0.028	0.027
	(0.032)	(0.019)	(0.019)
$HHIhat \times \ln(penetration)_{ct}$	0.892***	1.094***	1.096***
	(0.038)	(0.049)	(0.051)
$HHIhat \times \ln(penetration)_{ct} \times \ln(competitors)_{ct}$		0.003	0.003
		(0.003)	(0.003)
1st Stage R^2	0.954	0.964	0.964
1st Stage F-test	316.61***	2351.86***	1973.66***
	[0.000]	*[0.000]*	*[0.000]*
Dependent variable: $\ln(MTR)_{jct} \times \ln(HHI)_{ct} \times \ln(penetration)_{ct}$			
Instruments			
$Regulation_{jct}$		1.133***	-0.131***
		(0.172)	(0.035)
$\ln(competitors)_{ct}$		1.782	-2.292
		(3.388)	(3.370)
$Regulation_{jct} \times \ln(competitors)_{ct}$		-0.920***	0.016
		(0.127)	(0.026)
$Regulation_{jct} \times \ln(penetration)_{ct}$		0.065	0.000
		(0.111)	(0.129)

Number of products produced by firm	-0.015 (0.020)	-0.018 (0.020)
MTRhat$_{jct}$× ln(competitors)$_{ct}$	-0.105** (0.052)	-0.105** (0.049)
MTRhat$_{jct}$ × ln(penetration)$_{ct}$	6.665*** (0.328)	6.970*** (0.324)
MTRhat$_{jct}$× ln(competitors)$_{ct}$ × ln(penetration)$_{ct}$	1.334*** (0.271)	1.046*** (0.277)
HHIhat × ln(competitors)$_{ct}$	-0.073 (0.425)	0.301 (0.426)
HHIhat × ln(penetration)$_{ct}$	0.729 (1.102)	-1.578 (1.327)
HHIhat × ln(penetration)$_{ct}$× ln(competitors)$_{ct}$	-0.477*** (0.100)	-0.623*** (0.113)
1st Stage R^2	0.982	0.982
1st Stage F-test	6602.23*** *[0.000]*	7712.37*** *[0.000]*

Source: Author's calculations based on the combination of variables from the Merrill Lynch dataset and the Teligen data corresponding to the best deals available at every quarter.

Notes: These are the first stage results from Table B6, where each column corresponds to the same column in Table B6. The regressions include all the exogenous variables in Table B6. Last three instruments in each panel are constructed as follows: we first regressed HHI on number of competitors, market penetration and regulation plus the full set of country-operator and time binary indicators; we then obtained the residuals from this regression and interacted them with the other exogenous variables (Wooldridge, 2002, p.235-237). All equations include country-operator and a full set of time binary indicators. P-values for diagnostic tests are in brackets and italics. Standard errors clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

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APPENDIX C – A SIMPLE MODEL OF THE WATERBED EFFECT

In this section we discuss a simple logit model of demand that gives rise to the waterbed effect. Our intention is not to introduce a model for structural estimation, but rather to reassure that the waterbed effect is a common phenomenon under a wide range of market structures. The main purpose of this section is to show the waterbed effect at work, and relate it to the intensity of competition and to market saturation.

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

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

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

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

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

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

For ease of exposition, we assume that all calls made are to fixed users and all calls received are also from fixed users.[32] Thus the demand for incoming calls to mobile subscribers coincides with the demand for (outgoing) fixed-to-mobile calls. The profit of the operator *i* is:

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

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

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

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

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

where $\tau = TQ_{Ii}/(\alpha_i N) = TN_F q_I$ is the termination rent per mobile customer.[33]

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

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[32] Calls to/from other mobile users could be easily accommodated in this framework, see Calzada and Valletti (2008).

[33] Under regulation, MTRs and the corresponding rent per mobile customer are determined by the National Regulatory Authority in each country. If left unregulated, firms would set *T* to maximize the rent per mobile customer (the corresponding price would be paid by fixed users calling own mobile customers), independently from the intensity of competition in the market for mobile customers. See Wright (2002).

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

The corresponding equilibrium profit of this interior solution is:

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

The equilibrium price and profit have all the desired properties. In particular, from totally differentiating the two equations (1), after a few manipulations, we obtain the following simple expression which captures the waterbed prediction with respect to the termination rent τ:

(3) $$\frac{\partial P^*}{\partial \tau} = -\frac{(1-\alpha^*)^2}{(1-\alpha^*)^2 + \alpha^* \alpha_0} < 0,$$

where $\alpha_0 = 1 - \alpha^* n$ represents the share of the residual market which is not served by any mobile service. Eq. (3) states that the lower the termination rent the higher the customer bill, i.e., the waterbed effect exists under general conditions of competition and product differentiation. The same qualitative result applies to the waterbed effect with respect to the termination rate *T*, instead of the termination rent τ, as

(3bis) $$\frac{\partial P^*}{\partial T} = N_F q_I \frac{\partial P^*}{\partial \tau} < 0.$$

Likewise, we can also obtain the impact on equilibrium market shares of a change of the termination rent τ:

(4) $$\frac{\partial \alpha^*}{\partial \tau} = \frac{1}{\sigma} \frac{(1-\alpha^*)^2 \alpha^* \alpha_0}{(1-\alpha^*)^2 + \alpha^* \alpha_0} > 0,$$

from which the impact on profits (2) is also immediate, as profits increase with α^*. Therefore, profits increase with MTR, although the magnitude of this effect depends on the intensity of competition and on how important the outside option is.

It is also straightforward to show that other comparative statics properties of the equilibrium are in line with one's intuition (see also Anderson et al., 1992). In particular, the price declines with the number of competing firms, and with the degree of product homogeneity. In equilibrium, profits also decline with the number of competing firms and with the degree of product homogeneity.

Notice from (3) and (4) the role played by market saturation. If the market is saturated (i.e., every customer has a mobile phone), then the residual market is zero, $\alpha_0 = 0$, and there is a "full" waterbed effect, $\partial P^* / \partial \tau = -1$, as any termination rent is entirely passed on to the consumer, having no overall impact on profits. If instead the market is not saturated, i.e., the demand for mobile phones is elastic at the equilibrium prices, then the waterbed effect is still be at work, but not in full. In particular, for a given level of $\alpha_0 > 0$, then the magnitude of the waterbed effect on the bill P^* given by (3) is greater the smaller is α^*, and therefore is bigger in absolute value when there are more competing firms. The converse applies to profits, in which case the less intense competition the bigger the impact of changes in termination rents.

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

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

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

$$(5) \qquad \varepsilon_W = \frac{\partial P}{\partial T}\frac{T}{P} = \frac{1+\varepsilon_I}{-c/\tau + 1 + \varepsilon_N} .$$

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

Since in our empirical analysis we run regressions in double logs, the coefficients of interest will be expressed directly in elasticity terms. Thus eq. (5) is of particular interest. The elasticity of incoming calls ε_I is negative and likely to be less than 1 in absolute value.[34] Also, $\varepsilon_N < 0$ and the termination rent is typically small compared to the overall cost per customer, so $-c/\tau + 1 < 0$ too, and the overall sign of the RHS of equation (5) is negative.

Equation (5) 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 (5), the elasticity of the waterbed effect could be above or below 1, in absolute value, depending on the relative sizes of (a) termination revenues relative to costs (τ vs. c); and (b) price elasticities for subscriptions and incoming calls ($|\varepsilon_N|$ vs. $|\varepsilon_I|$).

Let us now turn to the case of pure monopoly. The waterbed effect is also expected to be in operations since the price is determined by a classic inverse elasticity rule modified such that the "perceived" marginal cost per mobile customer also includes the termination rents (with a minus sign). Each time a customer is attracted, it comes with a termination rent: the higher the rent, the lower the perceived marginal cost. If regulation cuts termination rents, this is 'as if' marginal costs increase, and as a consequence retail prices will increase as well. Hence, the waterbed phenomenon is also expected under monopoly, as shown by the general eq. (3).

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

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

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

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

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APPENDIX D – RESULTS USING A DIFFERENCE-IN-DIFFERENCE SPECIFICATION

Difference-in-Difference specification An alternative empirical specification to that of model (4) and (4a) in the main text (Section 3) could be as follows:

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

(1a) $\ln EBITDA_{jct} = \alpha_{jc} + \alpha_t + \beta_1 Regulation_{jct} + \varepsilon_{jct}$

The dependent variable in (1) 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 (1a) is the logarithm of earnings before interest, taxes, depreciation and amortization ($\ln EBITDA_{jct}$) of operator j in country c in quarter t. $Regulation_{jct}$, is a binary indicator variable that takes the value one in the quarters when mobile termination rates are regulated (or any of the other two indexes introduced in the main text).

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 (1), and a negative or zero effect in (1a) depending on whether the effect is full or not.

In other words, a difference-in-difference model rests on very similar assumptions, but empirically is much less demanding than the two step IV specification. In Tables D1 and D2 we provide the results from a diff-in-diff specification for prices and profits respectively. The first three columns in Table D1 correspond to the same columns in Table 1, whereas the last two columns correspond to columns 3-4 in Table 2. Similarly, the first three columns in Table D2 correspond to the last three columns in Table 1, whereas the last two columns correspond to last two columns in Table 2. Finally, note that magnitude of the waterbed effect is exactly the same, as 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.

TABLE D1 – ESTIMATING THE "WATERBED" EFFECT (TELIGEN)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$	$\ln P_{ujct}$
Waterbed effect	*13.3%*	*4.7%*	*1.9%*	*15.2%*	*5.1%*
Regulation_{jct}	0.133***			0.152***	
	(0.033)			(0.033)	
$\text{MaxMTR index}_{jct}$		0.290***			0.316***
		(0.068)			(0.066)
$\text{UnregulatedMTR index}_{jct}$			0.127**		
			(0.051)		
Pre-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

Source: Author's calculations based on the Teligen data corresponding to the best deals available at every quarter.
Notes: The dependent variable is the logarithm of the PPP adjusted total bill paid by consumers with different usage at every quarter. All equations include country-operator-usage and a full set of time binary indicators (first three columns) or a full set of region-time binary indicators (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 clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) either at the country-operator-usage level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE D2 – ESTIMATING THE "WATERBED" EFFECT (MERRILL LYNCH)

	(1)	(2)	(3)	(4)	(5)
Estimation method	OLS	OLS	OLS	OLS	OLS
Dependent variable	$\ln EBITDA_{jct}$	$\ln EBITDA_{jct}$	$\ln EBITDA_{jct}$	$\ln EBITDA_{jct}$	$\ln EBITDA_{jct}$
Waterbed Effect	*-12.5%*	*-0.3%*	*-1.3%*	*-13.8%*	*-0.6%*
Regulation_{jct}	-0.125*			-0.138*	
	(0.070)			(0.076)	
$\text{MaxMTR index}_{jct}$		-0.024			-0.054
		(0.133)			(0.139)
$\text{UnregulatedMTR index}_{jct}$			-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

Source: Author's calculations based on the Merrill Lynch dataset.
Notes: The dependent variable is the logarithm of the EBITDA for each operator in a given country at every quarter. All equations include country-operator-usage and a full set of time binary indicators (first three columns) or a full set of region-time binary indicators (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 clustered (i.e. robust to heteroskedasticity and autocorrelation of unknown form) either at the country-operator level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.