Tower companies vs mergers in mobile networks

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***Abstract*—Tower companies own almost three quarters of the mobile telecom installations globally and continue to grow. The main driver of this change is linked to the reduction of capital expenditures by operators and the increasing sharing of infrastructure by tower companies that improves their assets' tenancy ratios. In this paper we review the evidence from tower company introductions in European markets and compare the operator financial outcomes along with the cost of services and market concentration that consumers experience. We also compare the wave of mergers during the same period in Europe, as an alternative cost-saving approach. We find that mergers primarily help operators improve their financial positions and EBITDA margin by 8.6 percentage points while consumers face significantly more concentrated markets with fewer options. Tower companies reduce average revenues per user by 1.41-1.79 Euros as increased tenancy ratios are passed-through to consumers and help operators reduce their capital expenditures. We provide policy and market recommendations based on these findings.**

***Index Terms*—Mobile network sharing, Tower companies, Mobile mergers**

I. INTRODUCTION

DIGITAL transformation is accelerating fast and it is generally accepted as the 'de facto' key for economic development and growth. Telecommunication networks are the platform for digital transformation and most countries around the world have set ambitious connectivity objectives. The deployment and operation of modern networks are capital intensive and appropriate policy and regulatory interventions are required to incentivise investments, to optimise deployment and operational costs but also to address the demand side in order to make networks accessible to consumers through offering competitively priced services.

Sharing network infrastructure is a cost saving strategy for telecommunication networks deployment and operation but it is also a strategic decision for the operators as certain challenges are present including collaboration and differentiation with a competitor and to some extent forfeiting the control of the network and its deployment. The transition from standard MNO-controlled networks towards some form of shared infrastructure has already appeared in a wide range of options. Network sharing can take many different forms, depending on the type of infrastructure shared (passive, active, spectrum, large/small cells), the area covered (white zones, grey zones, urban areas, national coverage, indoors), the market position of the partners (challenger & challenger, dominant & challenger, new entrant), the type of governance model (joint venture, agreement), the role of public authorities (funding for white zones, regulation in favour/against network sharing), greenfield deployment or sharing of existing infrastructure.

There have been several types of network sharing agreements in specific countries and regions which we organize into the following categories that match the region they were adopted and the type of the agreements. In this list we primarily focus on 5G network sharing:

- Deployment of network sharing with a focus in uncovered areas (white) which has been funded by the local councils or states (Germany and the United Kingdom)
- Similar to the above, deployment of network sharing in areas with poor coverage and low population density (France, Italy, Germany, Spain, Finland, Sweden)
- A top-down roaming agreement for national coverage between the local incumbent operator and one or more niche players (entrants) (China, France, Spain, Denmark)
- Similar to the above, there have been other national agreements for joint deployments between major operators in each country (China, Italy, Belgium, Sweden, Denmark)
- A micro sharing approach where operators deploy shared networks to boost coverage within cities using small cells (China, South Korea) and
- A replication of the MNO-controlled network by the state itself which buys or builds the essential infrastructure and operators lease from it (Malaysia).

Sharing of passive infrastructure has a long tradition and is widespread [1] with the earliest incidence in Europe in 2001, long before the 5G networks appeared. Coleago reports 16 passive sharing agreements in Europe across 11 countries over the period 2001-2020. Similarly 17 active sharing agreements took place in Europe from 2001-2018 and 7 new active sharing agreements during 2019-2020, showing significant increase and a clear industry direction [2]. While passive network sharing was commonplace for 3G and 4G deployments, active sharing agreements are gaining traction globally for 5G. The realisation that investments in infrastructure have to increase by more than 2.5 times until 2027 [3] to meet the needs for modern 5G deployments, especially in the mmWave bands which require network densification, led a significant shift in sharing patterns with TowerCos owning 74% of mobile telecom installations in 2023 [4]. According to ITU the percentage of countries around the world where infrastructure sharing was used rose from 34% in 2015 to above 65.8% in 2021. Within continents, American, European and African countries had some form of mobile infrastructure sharing in place for more than 70% of their countries during the same period.

The economic underpinning for network sharing builds on network deduplication assumptions which can reduce capital (CAPEX) and operating expenses (OPEX) and result in lower prices, increased investments in terms of coverage and/or quality. This coordinating but not collusive concept has deep roots in the economic literature and was first conceived as an attempt to combine research efforts [5] with the objective of jointly maximising profits for collaborating firms, without cooperating in price settings. [6]

In an early attempt to assess the potential savings in CAPEX and OPEX for their local mobile providers the Body of European Regulators for Electronic Communications (BEREC) conducted a survey [7] across National Regulatory Authorities (NRAs) . Several regulators did not have detailed information at that time about the range of these savings but some of the respondents reported that passive network sharing can lead to 16% - 35% savings in CAPEX and OPEX respectively while active network sharing can lead to 33% - 45% savings in CAPEX and 23% - 35% in OPEX respectively. The Swiss regulator reported that core network sharing was not expected to lead to further savings.

Greenfield 5G deployments are likely to result in higher cost savings [8] [9] which is the case for the 5G network jointly built by China Telecom and China Unicom. Network sharing can in theory also benefit consumers since reduced deployment costs could lead to lower prices, but this is by no means guaranteed. For example the increasing concentration in the network infrastructure market or, even under competitive infrastructure conditions, the imperfect pass-through from operators to consumers might reduce any price-related gains. Furthermore, network sharing can allow faster deployment and better coverage in low density areas and in cases where it is difficult to replicate equipment infrastructure, particularly indoors, or in dense areas where it is very difficult to find new sites, such as old city centres. Network sharing can also have a positive environmental and sustainability impact by reducing energy consumption and redundant equipment and waste.

In this paper we review the recent trends in terms of TowerCo agreements (Section II) and compare them with another cost-saving option that operators often resort to, mergers. To compare across the two cost-saving practices we use a dataset that covers 140 operators in Europe over the period 2001-2019. In Section III we use a standard difference-in-differences setup where our control group represents the operators that did not participate in mergers or TowerCo agreements over the same period, using a range of controls for region, year and telecommunications market characteristics. In Section IV we discuss the outcomes from recent merger activities in Europe over the past two decades and the early signs of TowerCo agreements including the percent of towers in each country they represent. Section V outlines the market and policy takeaways from our analysis and Section VI concludes.

II. The Landscape of Mobile Telcos Globally

According to research company TowerXchange [4], there were 324 TowerCos in 2Q 2023. They owned 3.83m of the world's 5.16m macro-sites (ground-based towers and rooftop towers) used for mobile telecom network installations (74%). Among them: China Tower Corporation (CTC) owned 2.06m macro-sites; ATC owned 225,656 macro-sites; Indus Towers owned 192,874 macro-sites; Summit Digitel Infrastructure owned 160,000 macro-sites; Cellnex owned 107,384 macro-sites.

The TowerCo business model was first adopted in the US in the 1990s as an alternative to the traditional MNO-controlled tower model. TowerCo ownership models generally fall under three broad categories:

- MNO-controlled. The parent MNO maintains an equity above 50% of the carved-out tower infrastructure (e.g.: Telstra's Amplitel, Vodafone's Vantage Towers).
- Independent. The TowerCo can either be fully independent from the MNOs leasing its passive infrastructure on a site (e.g. American Tower Corporation (ATC), Cellnex) or have one or more MNOs among its minority shareholders.
- Joint venture TowerCo. Joint ownership of a TowerCo and shared use of its tower infrastructure. China Tower Corporation (CTC) is a company co-owned by mobile network operators China Mobile, China Unicom and China Telecom, but managed independently from MNO activities.

We often observe that TowerCos manage to reach higher tenancy ratios compared to MNOs who also try to increase efficiencies in their network of towers. The reason behind this is that MNOs compete in the mobile service market in which they are often reluctant to jeopardise their position relatively to their competitors in their attempt to increase tower efficiency. On the other hand TowerCos are primarily looking to attract as many tenants as they can since their business model relies on the operation of MNO-agnostic infrastructure.

Beside this divergence in terms of incentives, the types of the towers often limit the capacity for high tenancy ratios. Towers that are build on rooftops can not accommodate as many tenants as their ground-based counterparts. Ground-based towers are usually larger than rooftop ones and they are often built in low population density or rural areas. The tenancy ratios for TowerCos average 2.8 for ground towers and 1.5 for those built on roofs, with an overall average tenancy ratio in their entire tower portfolio of 2.4. When we look for the tenancy ratios for MNO controlled portfolios we find an average of 1.5 for towers on the ground and 1.1

for rooftop towers, with an overall tenancy ratio of 1.3. The compositional characteristics of tower portfolios affect these outcomes significantly as MNO towers include a significantly higher percentage of rooftop towers whereas TowerCos own and operate predominantly ground towers. Even if we isolate the rooftop and ground tower tenancy ratios we still observe a significant disparity across MNOs and TowerCos due the the different incentives their business models create [10].

III. Empirical approach

A. Data description

In this paper we source our data from various sources to compile a unique dataset that covers both the operators (MNOs), their sharing agreements, the timing and scale of each agreement and the financial and market performance before and after these took place.

Specifically we gather data from GSMA Intelligence for 29 European countries which covers 140 operators and spans the period 2000-2019. Within this dataset we collect observations for the coverage of each operator within the focal country for different technologies (3G and 4G) as well as the market shares they control. With the latter we are able to construct the country level Herfindahd-Hirchmann Index (HHI) for each quarter of the year. Our coverage metrics refer to the proportion of the population rather than the geographic coverage of the country as this is the definition used by operators in the data collection exercise. In some cases operators do not report their coverage at a quarterly but at an annual level. In these cases GSMA Intelligence provides the quarterly information for technology and population coverage through an indirect estimation as the original data are reported at the country-year level. The financial data which include investment (CAPEX), earnings before interest, tax, depreciation and amortisation (EBITDA) and mobile data traffic are also sourced from GSMA Intelligence, based on the financial reports of mobile operators.

One of the hardest and most contested variables in these studies relates to the accurate depiction of mobile prices. Researchers often use the nominal prices of a unit of service (GB, call-minute, text message) sourced from specific bundles that are deemed to be representative for the country. Others report the average price of each service unit at the country level, again with distributional and compositional caveats. Last another metric often used is the ARPU which does not discriminate in terms of the volume or quality of service but indicates the level of spending per subscriber in each country and period. In the absence of micro-data for unit-level prices we employ the ARPU data in this study as this is sourced from the financial reports of the operators. This metric can only be interpreted as indicative of the level of spending and can be affected by usage (or behaviour) and unit-prices. The ARPU data also come from GSMA Intelligence for the operators in our sample for the period 2000-2019.

The data on TowerCo exchanges and mergers are sourced from a combination of GSMA Intelligence data and Coleago Mobile Network Sharing database. These contain the names and financial information of the acquiring and acquired operators along with the date of a TowerCo deal and the involved MNOs. The full list of mergers that is included in our sample is shown in Table I. We additionally use data from EY and Cullen to augment our analysis by looking into the number of tower sites exchanged during a deal and their percentage in terms of the total towers in each country. The latter (total towers) are sourced from the EY report on TowerCos [10] The original Coleago data do not provide information about the size of the exchange in terms of towers share but we source this information from Cullen to measure the number of sites that have been included in each TowerCo deal and divide by the total number of towers in a country [10]. This addition allows us to look into more detailed characteristics of each TowerCo agreement.

TABLE I
Telecommunications mergers in Europe 2000-2019

Country	Operators	Year
Austria	T-mobile & Tele.ring	Q2 2006
Austria	3 (CK Hutchison) & Orange	Q1 2013
Denmark	Telia & Orange	Q4 2004
Estonia	Tele2 & Televörgu AS	Q1 2012
Germany	E-Plus & Telefonica	Q4 2014
Ireland	3 (CK Hutchison) & O2	Q3 2014
Italy	Wind & H3G	Q4 2016
Netherlands	KPN & Telfort	Q4 2005
Netherlands	VodafoneZiggo (Liberty / Vodafone)	Q4 2016
Netherlands	T-Mobile & Tele2	Q1 2019
Norway	Telia & Tele2	Q1 2015
Poland	Plus & Aero2	Q2 2016
Romania	Telekom Romania (OTE) & Zapp	Q4 2009
Sweden	Tele2 & Spring Mobil	Q3 2010
Switzerland	Sunrise & Tele2	Q4 2008
United Kingdom	EE (Orange & T-Mobile)	Q2 2010

The macroeconomic variables used in this study (GDP per capita and rural population) are sourced from Eurostat.

B. DiD framework

In this section we largely follow [1], [11] and [12] in their approach to model the effects of various forms of network sharing agreements. More details about the theoretical underpinnings of this approach can be found in [11]. To assess the impact of mergers and TowerCo agreements on a range of market and financial outcomes , we implement a difference-in-difference (DID) model at the operator-level, which allows us to empirically test the framework. The model compares operator and consumer outcomes between 'treated' operators that enter into a merger or a TowerCo exchange, and 'non-treated operators' that do not participate in these. It is formulated as follows:

$$y_{it} = \alpha_i + \beta_t + \gamma NS_{it} + \mathbf{X}_{it}\theta + \epsilon_{it} \qquad (1)$$

where y_{it} is a market outcome for operator i in quarter t. NS_{it} is the variable of interest and is defined by an indicator variable equal to one if operator i is participating in a merger or a TowerCo exchange during period t (or zero otherwise). Separate specifications are run for different

TABLE II
TOWERCO AND MERGER RESULTS

VARIABLES	(1) 3G coverage (%)	(2) 4G coverage (%)	(3) ARPU (Euros)	(4) CAPEX (million Euros)	(5) EBITDA	(6) HHI
Merger	-0.004	0.061	-0.678	63.574**	0.086**	383.028***
	(0.026)	(0.036)	(0.854)	(30.215)	(0.041)	(109.376)
Observations	3,972	1,993	6,333	1,497	1,657	2,635
TowerCo	-0.029	0.002	-3.744***	-31.528***	-0.019	-95.176
	(0.027)	(0.025)	(1.246)	(7.798)	(0.021)	(78.137)
Observations	3,935	1,919	6,246	1,550	1,722	2,611
% towers owned by TowerCo	-0.107	0.013	-15.598**	-294.333***	-0.036	-421.793
	(0.202)	(0.167)	(7.226)	(26.912)	(0.177)	(312.924)
Observations	3,935	1,919	6,246	1,550	1,722	2,611

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All results include Operator and Year-quarter FEs. Income (GDP per capita and rural population controls are included in every regression. The testing period is limited between 3 years before the agreement and 2 years after.

types of agreements (mergers and TowerCo) and each market outcome.

The novelty of this paper compared to [1] is that we explicitly compare the network sharing outcomes with the incidence of mergers in mobile telecommunications markets. In doing so we can compare the different cost-saving approaches by the operators and inform both regulators and the industry about their implications. Second, we depart from a binary description of the tower transaction and shed light on the scale of each exchange. This information allows us to achieve two goals: first we get an accurate estimate of the scale of sharing with TowerCo agreements and second we use these estimates to understand the range of benefits that these agreements can produce.

In our model we test our results with and without controls ($\mathbf{X}_{it}$) along with operator (α_i) and year-quarter effects (β_t). The outcomes we present include coverage (3G, 4G), investment, EBITDA, HHI and ARPU. We also include a section with robustness checks where we test our results in more detail.

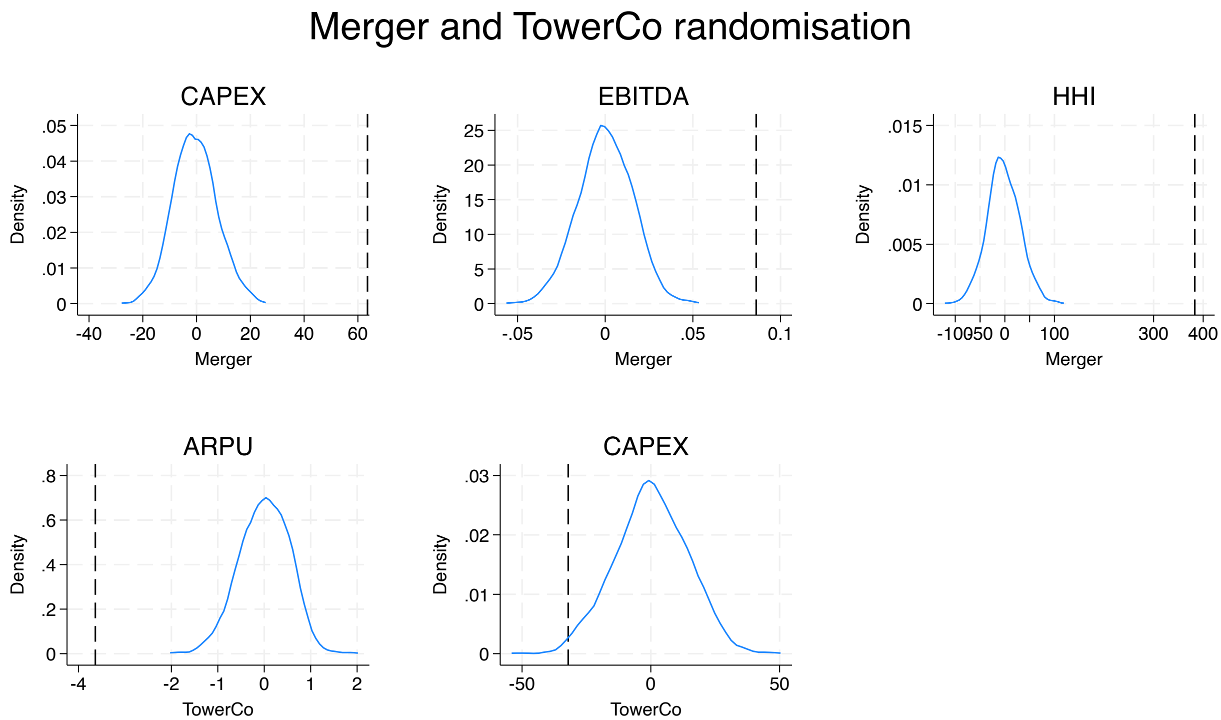
IV. MERGERS VS TOWERCO

In this section we present the results for mergers and TowerCo agreements. It is clear that mergers and TowerCos are not necessarily two mutually exclusive options in mobile telecommunications markets as there can be mergers across MNOs, across tower companies and sharing agreements within the same markets. However, the approach in this paper tries to distinguish between the effects of horizontal MNO mergers compared to different types of TowerCo agreements that took place over the period of study. Our specification limits the control group to operators which did not have a TowerCo or merger agreement in place for the window that spans between 3 years prior to the agreement and 2 years after the agreement (Table II).

The results indicate some positive effects from TowerCo agreements. Table II shows that operators entering a network sharing deal realised 31 million Euros in CAPEX savings and reduced their ARPUs by 3.7 Euros/month. These results echo the passive sharing outcomes in the literature albeit in a multilateral compared to a bilateral setting [1]. For a more accurate estimate on the actual ARPU savings we use the percentage of towers owned by TowerCos coefficient which suggests a 1.41-1.79 Euros of ARPU savings (median size of tower deals in our sample is 9.01% and the average 11.5%). On the other end, operators that merged appear to increase their capital expenditures by 63.6 million Euros, due to the fact that the merged entity is a larger operator compared to the operators that participate in the transaction. Similarly the merged operator exhibits higher EBITDA (8.6 percentage points) and the transaction leads to a more concentrated market compared to markets where operators did not merge. Quite strikingly, ARPUs do not appear to have increased post merger as we also see in [13], echoing that the use of different datasets (based on price per GB, call minute or text) can often lead to different results. The contrast across the TowerCo and merger results is quite significant and indicates why regulators often scrutinise mergers in the EU and elsewhere. Perhaps the most important aspect of TowerCo agreements in favor of 5G deployment is the size of CAPEX savings.

To further understand the relative importance of the scale of each deal we embark on a rather simple back-of-the-envelope calculation. According to a global survey across operators between 2019-2023 [14] the access network represents 37% of the total CAPEX for operators. In our sample, the average treated operator (with a TowerCo agreement) spent on average 157 million Euros per quarter in CAPEX (and 94 million Euros is the median value). If we extrapolate the operator survey estimates, passive TowerCo agreements can - in theory - save up to 58.09 million Euros for these operators which can

Fig. 1. Merger randomisation estimates



increase to 78.5 million Euros in case of a fully fledged active sharing agreement. The size of the deals in our sample that have been signed covers on average 11.5% of the national sites (with a median of 9.01%). In a relatively competitive mobile market with 3 or 4 players we use the reported market shares to assess the share of the national total towers and the sample ranges between 6%-30%. Using the CAPEX coefficient from the % Towers line in Table II we find a range of savings between 17.7-88.3 million Euros for the treated operators. As this estimation exceeds the expected 58.09-78.5 million range of the baseline TowerCo coefficient it might allude to diminishing returns with increasing numbers of tower agreements as the most CAPEX-intensive towers might be prioritised for sharing leaving the less costly for later transactions.

A. Robustness checks

There can be several issues with the identification process in our setting as there is no way to compare the same market with and without a change (merger or Tower company introduction) and provide an accurate picture of its impact. At the same time it is likely that the market itself might exhibit certain characteristics that lead operators to either merge or agree on a Tower company transaction.

To address these concerns we embark on a number of robustness checks. First we include in our analysis additional variables that may have played a role in these processes, namely incomes (GDP per capita), the size and proportion of rural population. Our results appear to hold without changes with these controls. In fact our baseline results presented in Table II are actually the ones with the control variables instead of the ones without controls.

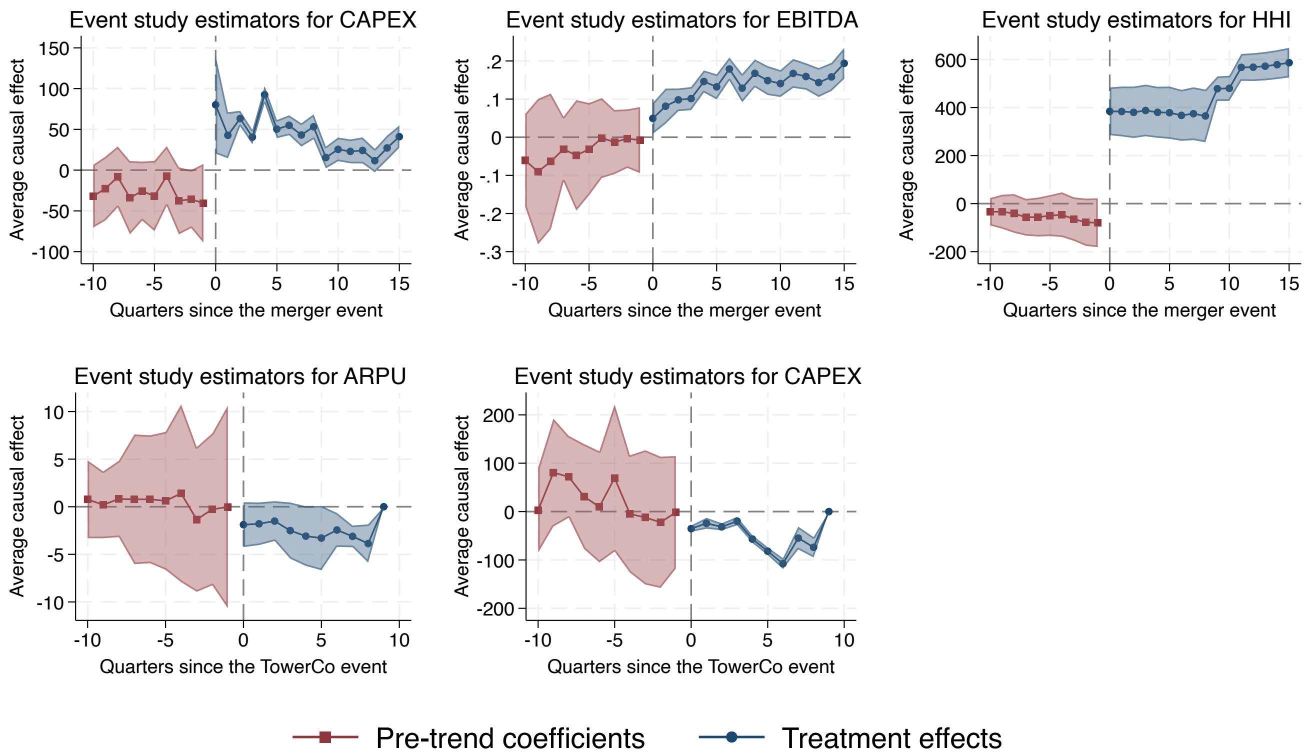
TABLE III
TOWERCO AND MERGER RESULTS UNCONSTRAINED

VARIABLES	(1) ARPU (Euros)	(2) CAPEX (mil Euros)	(3) EBITDA	(4) HHI
Merger	-0.230	63.581***	0.115**	389.641***
	(0.315)	(10.327)	(0.045)	(18.166)
Observations	7,454	1,823	1,989	3,038
TowerCo	-2.924***	-48.137***	0.003	-48.359*
	(0.496)	(14.008)	(0.057)	(26.903)
Observations	7,454	1,823	1,989	3,038
% towers of TowerCo	-10.068**	-354.771***	0.124	316.164
	(4.210)	(106.420)	(0.447)	(199.824)
Observations	7,454	1,823	1,989	3,038

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All results include Operator and Year-quarter FEs. Income (GDP per capita and rural population controls are included in every regression. The testing period is not limited .

Next we employ a falsification check through which we randomly assign the ”treatments” to other operators. In this setting we test 1,000 different allocations of a merger or a TowerCo introduction and rerun the analysis to explore the estimated coefficients. In Figure 1 we show these distributions for the statistically significant results we obtained from Table II. In every case we observe that the estimated β is clearly

Fig. 2. Event study design for mergers and TowerCos



far apart from the random distributions with the exception of the CAPEX estimate for Tower companies where it overlaps with the left tail of the distribution approximately for 3% of the cases.

Further we remove all the window-related constraints from mergers and Tower exchanges to allow for a much larger sample in our analysis that is not limited to the 3 years before and 2 years after constrain that we include in our baseline results. The results we observe for our variables of interest are very similar to our baseline ones.

Last, acknowledging the issues with TWFE model estimations and the comparisons made, especially in a staggered introduction of the treatment - even if we use a limited window in our analysis - we use [15] approach to provide an event study design that shows the pretrends and the post treatment behavior of our focal variables by quarter. In Figure 2 we present the results for all significant variables of our baseline both for mergers and Tower companies. The sharp discontinuities in each of them and the expected behavior of pretrends is reassuring about our results.

V. Regulatory challenges ahead

There are still concerns about potential side-effects and negative impacts of network sharing. Network sharing may reduce competition between the operators involved in the agreement (especially in majority MNO-controlled entities but also in cases they retain a minority stake but still control TowerCo management). This may directly or indirectly lead to the marginalisation of third party operators. Beyond the service-layer market affecting the access or infrastructure layer, operators even in an ideal scenario may not be able to differentiate their services sufficiently due to similarities in their network coverage and quality of service. In a market with 3 or 4 players a single entity providing passive or active infrastructure may reach up to a theoretical 3 or 4 tenants per tower (co-location ratio). As we explained before there are already ground based TowerCos that have achieved 2.8 ratios but this may not refer to MNO tenants alone [10].

Network sharing is usually not prohibited by regulators and is even encouraged. (Recent regulatory proposals in EU such as the Gigabit Infrastructure Act and the Gigabit Recommendation address the issue of passive infrastructure sharing from certain perspective.) Until today, TowerCo services are not regulated by the national regulatory authorities in the same way as MNOs are regulated, unless they also provide electronic communications services (i.e. they fall under the MNO umbrella). Only China, India and South Africa already require or have proposed the requirements through a licensing process for TowerCos to provide access to passive infrastructure.

Regulators and governments seem to be torn around other important issues around TowerCos, namely around safety and security. For this the EU, US, UK, Japan, Australia and China may impose restrictions on foreign ownership of towers on the grounds of national security. On this basis, the EU, UK, Australia and South Africa consider tower sites as critical infrastructure going beyond the limits of the mobile market regulations.

The fundamental shift of passive or active infrastructure to dedicated entities can help - as we saw in the empirical section - to achieve the technological targets set by national governments around the world. Technology developments such as edge computing, network virtualisation, openRAN and network slicing could address this issue for example in the case of 5G networks.

VI. Conclusion

In this paper we looked into the benefits of the separation of infrastructure for operators and consumers compared to standard horizontal mergers. It is likely that in the future, fully MNO-controlled infrastructure might be the exception instead of the norm which will likely affect market development, technological opportunities and network expansion.

In the future, we can expect new types of sharing with new players: dedicated connectivity providers working with operators, municipalities or public services, large industrial players, verticals, infrastructure companies such as railway companies, and others. Network sharing is a very interesting policy tool for the cost efficient network deployment and operation but there are still regulatory and market issues to be explored and relevant trade-offs to be evaluated on a case by case basis before making final decisions.

Acknowledgments

We acknowledge support by Chris Buist for the data on network sharing agreements in the Coleago Consulting network sharing database. We are also grateful to Yuzhou Tian from Visible Alpha for providing access to their mobile operator financial data and to Mat Edwards from TowerXChange for giving us access to their TowerCo dataset. Last, the authors are grateful to the GSMA and Pau Castells for providing access to the GSMA Intelligence dataset.

References

[1] P. Koutroumpis, P. Castells, and K. Bahia, "To share or not to share? the impact of mobile network sharing for consumers and operators," *Information Economics and Policy*, vol. 65, p. 101061, 2023.

[2] "Coleago - Network sharing managed services," https://www.coleago.com/services/network-sharing-managed-services/, accessed: 2024-05-01.

[3] ETNO, "Connectivity & Beyond: How Telcos can accelerate a digital future for all," 2021.

[4] "TowerXchange - Tower League Table Q2 2023," https://assets.euromoneydigital.com/40/86/1cc4c83c420389b367fb6ee59df6/tx-tower-league-table-q2-2023.pdf, accessed: 2024-05-01.

[5] C. d'Aspremont and A. Jacquemin, "Cooperative and noncooperative r & d in duopoly with spillovers," *The American Economic Review*, vol. 78, no. 5, pp. 1133–1137, 1988.

[6] P. Koutroumpis, K. Masselos, and D. Varoutas, "Infrastructure sharing in broadband networks: impact on telecommunications operators and consumers," *Frontiers in Computer Science*, vol. 5, 2023.

[7] BEREC, "Report on infrastructure sharing," 2018.

[8] E. J. Oughton and Z. Frias, "The cost, coverage and rollout implications of 5g infrastructure in britain," *Telecommunications Policy*, vol. 42, no. 8, pp. 636–652, 2018.

[9] E. J. Oughton, N. Comini, V. Foster, and J. W. Hall, "Policy choices can help keep 4g and 5g universal broadband affordable," *Technological Forecasting and Social Change*, vol. 176, p. 121409, 2022.

[10] EY Parthenon, "The economic contribution of the European tower sector," 2022.

[11] M. Motta and E. Tarantino, "The effect of horizontal mergers, when firms compete in prices and investments," *International Journal of Industrial Organization*, vol. 78, p. 102774, 2021.

[12] Ø. Foros, B. Hansen, and T. Vergé, "Co-operative investment by downstream rivals: network sharing in telecom markets," *Journal of Regulatory Economics*, vol. 64, no. 1-3, pp. 34–47, 2023.

[13] K. Bahia and P. Castells, "The dynamic effects of competition on investment: the case of the european mobile communications industry," *Journal of Information Policy*, 2023.

[14] "Omdia Global Telecoms Capex Tracker 14th februrary 2023," https://omdia.tech.informa.com/om029652/introduction-to-the-global-telecoms-capex-tracker, accessed: 2024-05-01.

[15] K. Borusyak, X. Jaravel, and J. Spiess, "Revisiting event study designs: Robust and efficient estimation," *Unpublished working paper, version May*, vol. 19, p. 2021, 2021.

VII. Biography Section

Dr Pantelis Koutroumpis is the Lead Economist and Director of the Programme of Technological and Economic Change at the Oxford Martin School.

He has a computer engineering degree from Athens (NTUA) an MPhil in Technology Policy from Cambridge University and a PhD in Economics from Imperial College London. Previously he was a Research Fellow at Imperial College Business School in the Innovation and Entrepreneurship Group and a Fellow of the Columbia Institute of Tele-Information.

Pantelis' main research interests are industrial economics, innovation, telecommunications economics and regulation. He is a member of the editorial board of Telecommunications Policy and has published in several journals including the Journal of the European Economic Association, Journal of Industrial Economics, Economic Policy and others. Pantelis has received funding from the EPSRC, ESRC and the EU for his research.

Pantelis has advised several bodies including the cost assessment and economic impact work of the Digital Agenda for Europe. Other assignments include the Department of Culture Media and Sport (UK), Ofcom, DG COMP, the European Investment Bank, the OECD, the World Bank, the ITU, and others.

Prof Konstantinos Masselos has been appointed as the President of the Hellenic Telecommunications & Post Commission (EETT) in February 2018.

He has been elected as President of the Body of European Regulators for Electronic Communications (BEREC) for 2023 and also, Vice-President for 2022 and 2024. Moreover, he served as Vice-President of BEREC in 2019.

He is Professor in the Department of Informatics and Telecommunications of the University of Peloponnese and he served as Rector of the above University during the period 2012-2017. From 2005 to 2008, he was Lecturer in the Department of Electrical and Electronic Engineering at the Imperial College London. Also, during the period 2010-2016 he was an Honorary Lecturer in the same Department.

During the period 2001-2004, he worked in the electronic communications industry. Since 2005 he has been collaborating as an expert with various units of the European Commission. Also, he was a member of the Scientific Committee of the European Cooperation in Science and Technology (COST) from 2015 to 2017.