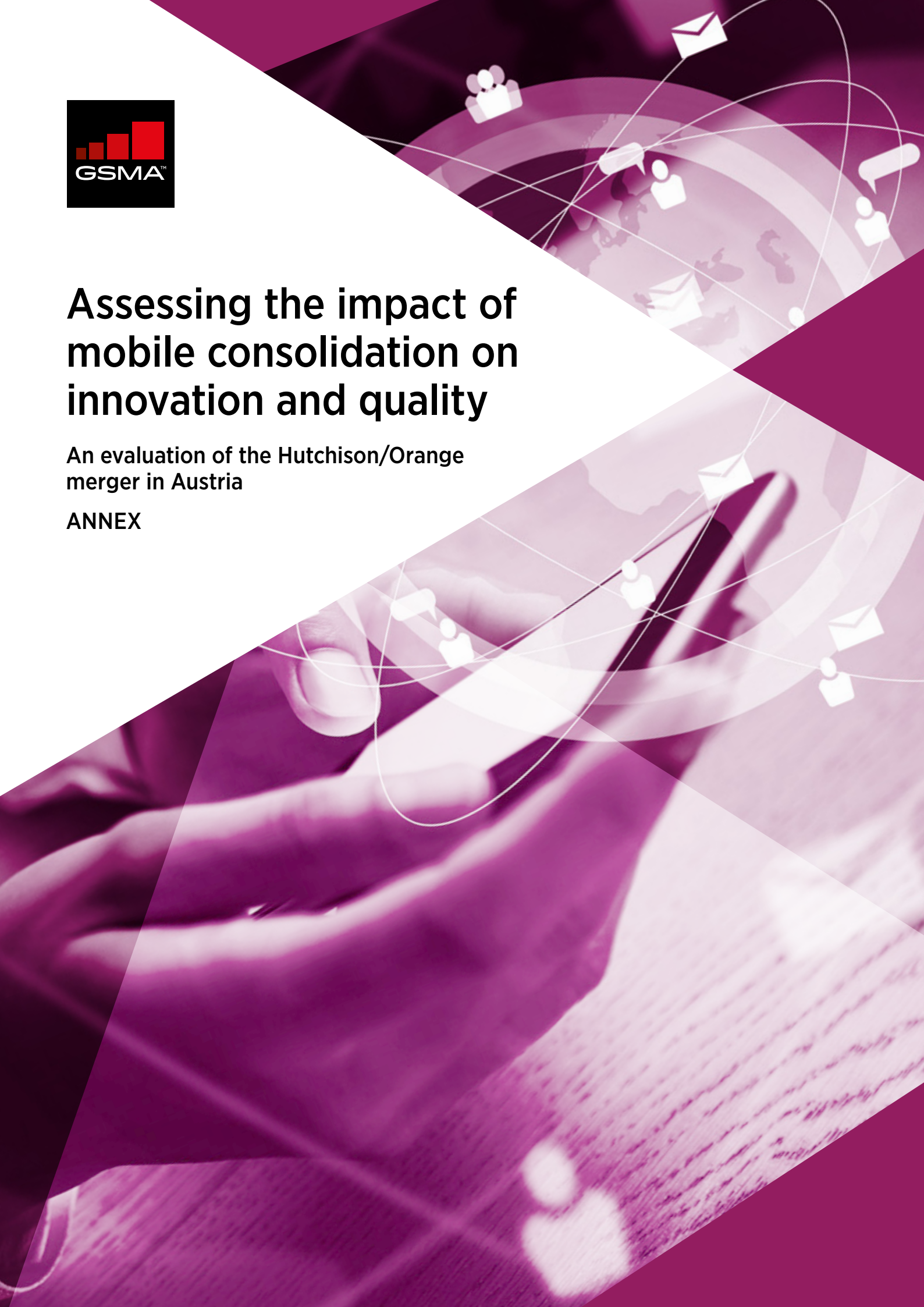




Assessing the impact of mobile consolidation on innovation and quality

An evaluation of the Hutchison/Orange merger in Austria

ANNEX





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A1. Methodology

A1.1 General counterfactual considerations

When assessing the effects of the Hutchison/Orange merger in Austria, the European Commission (EC) used the pre-merger status quo as the counterfactual scenario. As expressed by the EC, “the relevant comparison for evaluating the effects of the merger is constituted by the competitive conditions existing at the time of the merger as set out in paragraph 9 of the Horizontal Guidelines, namely that Orange would remain a comparably relevant competitor in the Austrian market for mobile telecommunications services to end customers as it has been to date”¹.

Being consistent with the above, the counterfactual scenario in this study is based on

a market that consists of four separate mobile networks in Austria after 2012 (as was the case before the merger). In its assessment, the EC suggested that a network sharing agreement could achieve some of the efficiencies claimed by Hutchison. However, there is no certainty about whether this would have happened absent of the merger; for example Hutchison argued that a network sharing agreement was not realistic due to different strategies around network design, concerns about losing a competitive edge over a competitor and confidentiality issues. It is beyond the scope of this study to consider a wide range of counterfactual scenarios (of which network sharing is only one).

A1.2 Difference-in-Difference

A1.2.1 Base model

In our Base model (Equation 1 below), we implement the DD approach using an OLS fixed-effects regression. In this basic DD framework the counterfactual evolution of the outcomes for treated units is the post-merger evolution in the control set

of operators. This Base model controls for all time invariant factors at the country level and time-specific events. The model is estimated at the operator level, in a multi-period setting, and allows for the identification of dynamic merger effects.

$$(1) \quad y_{i,j,t} = \alpha + \delta D_i + \sum_t \lambda_t T_t + \rho^{Y1} (D_i * T_{i,t}^{Y1}) + \rho^{Y2} (D_i * T_{i,t}^{Y2}) + \rho^{Y3} (D_i * T_{i,t}^{Y3+}) + \sum_j \gamma_j C_j + \sum_{k=1}^K \mu_k X_{i,j,t,k} + \varepsilon_{i,j,t}$$

where $y_{i,j,t}$ is one of the outcomes for operator i in country j at time t . The outcomes we look at are 4G

coverage, download speeds (3G and 4G) and upload speeds (3G and 4G).

1. See paragraph 401 of the EC decision on the Hutchison/Orange merger.

The DD has three main variables:

D_i is a treatment dummy, taking value 1 if operator i is in the treatment group. In the merged entity analysis, Hutchison is the only operator being treated, while in the market-wide effects A1 Telekom and T-Mobile are included in the treatment group as well. This variable captures fixed unobserved factors of the treated operator(s) that can be relevant for the outcome (i.e., business strategy, resources, firm structure and management).

T_t are quarterly time dummies², which account for time-specific events common to all operators that may impact some of the outcomes.

Examples include the launch of handsets that are compatible with 4G spectrum bands, which could drive 4G take-up (and is therefore likely to impact 4G rollout and the measures of quality).

q^{Y1} , q^{Y2} and q^{Y3+} are the merger effects. These result from the inclusion of interaction terms between the treatment dummy D_i and three post-treatment period dummies ($T_{i,t}^{Y1}$, $T_{i,t}^{Y2}$ and $T_{i,t}^{Y3+}$). The latter identify three time periods: first year (2013), second year (2014) and more than two years after the merger (2015 and 2016). This approach to capturing merger effects is consistent with DG Competition (2015) and RTR (2016).

Besides the main variables above, we add a number of controls. C_j are country dummies to account for time invariant characteristics of a country that will affect 4G coverage and network quality (geography, climate, regulation³, etc.) We also include a set of controls X with K variables ($\sum_{k=1}^K X_{i,j,t,k}$) likely to shape coverage and network quality, which vary within each country over time.

The *mobile-specific controls* we include are as follows:

$4G_{spectrum}_{i,j,t}$ and $3G_{spectrum}_{i,j,t}$ are the amount of 4G or 3G-relevant spectrum held by operator i in country j at time t . We consider 800, 1800⁴ and 2600 MHz bands to be 4G-dedicated, and 2100 and 900 MHz to be for 3G technologies. Spectrum holdings have been aggregated into '4G' and '3G' bands to increase variability of the data.⁵ The inclusion of spectrum controls for biases that would arise from differences in coverage that are attributed to

variation in spectrum holdings in both treated and control operators (i.e. via auctions or trading).

$4G_{spectrum}_{i,j,t}^{T0 < t < T1}$ are three spectrum dummies that represent the number of quarters that spectrum for 4G networks has been available for operator i in country j at time t . We include three dummies, taking value 1 if time t is 1-2 years, 2-4 years or 4-6 years since the first assignment of 4G spectrum to the operator.⁶ The rationale of their inclusion is that the more time an operator has had spectrum available, the more coverage and network quality it should have rolled out.

Only for 4G coverage models, we include the following:

$coverage3G_{i,j,t}$ is the 3G coverage of operator i in country j at time t . This is potentially relevant to 4G coverage because an operator with a large 3G network is likely to incur lower 4G rollout costs than another operator with a small 3G network (all else being equal) as they already have some of the key network elements in place (backhaul and core, cell sites etc).

$downloadspeeds3G_{i,j,t}$ is the average download speed of operator i 's 3G network in country j at time t . We include this because if an operator has made significant investments in upgrading its 3G network, it may wait some time before rolling out a large 4G network, partly to earn a return on the 3G investment and also because its customers may be less willing – or have less need – to upgrade to 4G.

Aside from the above, there are five mobile-specific factors that we have not included in our model, which may stand out at first glance.

First, spectrum holdings would ideally be estimated in separate frequency bands since they have different propagation and capacity properties that may have a bearing on the resulting coverage and network performance. While this approach should improve the precision of estimates, separating spectrum holdings substantially decreases variability in the dataset. We carried out a sensitivity check based on such an approach which showed that the overall results of the analysis in regards to the merger effects remain unchanged. However, the lack of variability across and within operators means that the

2. Each time period in the data has its own dummy variable. For example in the case of 2012q1, there is a dummy variable that takes the value 1 where the observation is for 2012q1 and 0 otherwise.

3. The country fixed effect will control for country-specific regulatory frameworks but it will not control for changes in regulation over time. The time fixed effect dummy will control for new regulations that impact all countries in the analysis (for example, those that are made at the European level, such as on roaming). However, with the exception of spectrum assignments, in-country changes in regulation over time are not included in the model. We are not aware of any specific regulatory policy in Austria in this period that could potentially bias our estimate of the merger effects.

4. 1800 MHz spectrum is included after it has been reformed for 4G or made technology-neutral by the national regulatory authority.

5. Given the different properties of the spectrum bands, in particular the fact that 800 MHz is better suited for achieving wide coverage, and spectrum above 1 GHz is better suited to high capacity rates, it would be preferable to have separate spectrum variables by band. However, as our base model is a fixed effects regression, it is driven by variation within each country. Spectrum holdings do not exhibit significant variation at this level – once it is assigned, it does not change unless there is a merger or spectrum is re-auctioned or re-assigned (neither of which is relevant for the vast majority of operators in our dataset). We therefore aggregate spectrum holdings into '4G' and '3G' bands to increase the variability of the data.

6. The baseline (or omitted variable) is the first year after 4G spectrum is assigned to the operator. The coefficients can therefore be interpreted as the impact of having spectrum for these three time periods compared to the first year in which it was assigned to operators.

estimated parameters for spectrum variables with separate frequency bands do not appear to be strong predictors of 4G coverage or network performance. Second, in the case of network performance models, there could be differences in quality across operators driven by network congestion effects. This could be controlled by including the number of connections in a 3G or 4G network (more users on a network will mean higher network congestion). However, we do not include these in our main results as it might introduce endogeneity problems.⁷ As a sensitivity check, we have run the models including the connections variables and our findings for network quality do not change.

Third, due to lack of data, we are not able to account for network sharing agreements, which we would expect to positively affect 4G coverage and network performance. In the period of study there were no network sharing agreements between operators in the Austrian market. However, some operators from other countries in the control group did share networks. Since some control operators and markets have this enhancing factor that we do not account for, the merger effect is likely to be underestimated via this mechanism.

Lastly, we do not model the MVNO remedy associated with the Hutchison/Orange merger because its impact on quality and innovation is unlikely to be material. MVNOs entered late in our period of study⁸ and with a limited impact in terms of market share⁹ – their impact on competition was likely to be limited in the period of our analysis. Furthermore, MVNOs are unlikely to directly exert competition in terms of network quality and coverage, since they rely on the infrastructure of the host MNO. In fact, the impact of MVNOs might be negative on host MNO investment, since they can create investment hold-up problems (Foros et al., 2002; Dwenter & Haucap, 2006).¹⁰ Consequently, the absence of the MVNO remedy in our simulations is likely to underestimate the merger effects on Hutchison.

We also add a number of *non-mobile-specific factors* that could affect the outcomes of interest, though we note that these do not exhibit as much variation within countries during our time period:

$\log(\text{popdense}_{j,t})$ is the population density in country j at time t . More densely populated countries should have lower costs of 4G rollout, meaning that any given network investment should more easily increase coverage. For the same reason, we would expect higher population density to impact network quality in the same direction.

$\text{ruralpop}_{j,t}$ is the proportion of population in country j at time t that live in rural areas. Over time, a fall in the proportion of population living in rural areas should mean that investment becomes more efficient in achieving coverage and network quality. Consequently, rural population should have a negative effect on both outcomes.

$\log(\text{GDPcapita}_{j,t})$ is the GDP per capita in country j at time t . This is used as a proxy for income, which could capture willingness to take up 4G services (which may drive rollout, i.e. as a demand factor).

A1.2.2 Trend model

After including the set of observed controls presented above, the unbiasedness of the merger effect estimate in the Base model relies on Austria and the group of control countries being subject to the same unobservable effects. The latter is not testable but it is likely to hold if the treatment and control group have similar pre-merger trends. Besides graphically inspecting these, we assess the Parallel Trends assumption statistically with two approaches. It is important to assess this assumption statistically because graphical inspection does not take into account the fact that the Base model has a set of factors that controls for some of the key determinants of 4G coverage and network quality.

We apply a formal test of the Parallel Trends assumption based on the approach proposed in Angrist & Pischke (2008), which in turn is based on the Granger causality test and which was also implemented in DG Competition (2015). The test substitutes the merger dummy in Equation 1 with one dummy variable per quarter for the treated operator (Hutchison). If the pre-merger slope of these linear dummies is statistically different from zero, then this suggests that the Parallel Trends assumption does not hold between the treatment and control.¹¹

Additionally, we estimate the Base model with a 'lead' dummy. The 'lead' dummy takes value 1 in the four quarters prior to the merger if the operator is Hutchison or, where we test for market-wide effects, if the operator is Austrian. If the coefficient of the 'lead' is insignificant, this gives us reassurance that the post-merger dummies are likely capturing merger effects and are not being confounded by other unobservable factors. For each model where we report results, 'lead' dummies are included in separate regressions (with outputs table reporting the result of the test – i.e. a 'Pass' or 'Fail' at the 5% level of confidence).

7. There may be simultaneity between connections and network quality in that, while connections may drive network quality through network congestion, an increase in connections on a given technology may also be due to better network quality.

8. The first MVNO agreement Hutchison finalised based on the reference offer was with UPC in December 2014. Another was signed in May 2015 and two more in May 2016.

9. See Figure 3 in main report

10. MNOs' investment efforts may not be fully internalised, especially when access prices do not accurately reflect these. In this context, host MNOs may lose the incentives to differentiate in terms of network quality and coverage, since their efforts also spill downstream (Foros et al., 2002; Dwenter & Haucap, 2006).

11. Similar tests to the Parallel Trends assumptions have been applied in related literature about market structure in the mobile market, such as Hounghonon (2015) and HSBC (2015).

Where the Parallel Trends assumption is not passed (i.e. 4G coverage and network quality is affected by unobserved factors that we cannot fully control for),

we modify the DD framework suggested in Equation 1 and introduce a different linear trend for the treatment country. This is presented in Equation 2 below.¹²

$$(2) \quad y_{i,j,t} = \alpha + \delta D_i + \sum_t \lambda_t T_t + \sum_{t>TM} \rho_{it} (D_i * T_t^{t>TM}) + \sum_j \theta_j (C_j * T) + \sum_j \gamma_j C_j + \sum_{k=1}^K \mu_k X_{i,j,t,k} + \varepsilon_{i,j,t}$$

In this equation θ_j represents a country-specific linear trend coefficient. The trend is constructed by interacting the country fixed effect dummy with the time variable T . For control units, this means that the coefficient θ_j picks up a linear trend based on the entire period. For the treated units, the coefficient θ_{it} is a country-specific linear trend based on pre-merger outcomes only. This is because we introduce an interaction between the treatment dummy D_i and multiple time dummies $T_t^{t>TM}$ for each of the post-treatment periods.

The identification of merger effects in Equation 2 relies on the assumption that without the merger, the outcome (be it 4G coverage or network quality) would have followed the same trend that existed before the merger (after controlling for the other explanatory variables). As explained in Angrist & Pischke (2008) “DD estimation with state-specific trends is likely to be more robust and convincing when the pre-treatment data establish a clear trend that can be extrapolated into the post-treatment period”.

In the case of 4G coverage, the linear trend assumption may not be reasonable as the rollout of new technologies often follows a logistical function or ‘S-curve’. As discussed below, we also run two non-linear models as sensitivity tests. Furthermore, we do not rely solely on a trend model to make a robust finding.

A1.2.3 Robustness checks

Robustness checks of merger effects on Hutchison

We implement a set of robustness checks detailed below. For results to be regarded as robust, merger effects have to be significant in the majority of relevant checks (i.e. those where the underlying assumption of the model is validated – for the Base DD model, we look at specifications where there are common trends).

Robustness checks are carried out on models where the underlying assumptions hold (i.e. in the case of Base DD, pre-merger parallel trends). We also take into account the specification that incorporates explanatory variables that turn out significant.

a. Restrictions to the control group

In order to avoid biased estimates, our full sample only includes European countries that experienced no significant entry, exit or merger in the period of the study. The countries in the control group are Belgium, Croatia, Czech Republic, Denmark, Greece, Hungary, Italy, Latvia, Malta, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland and the UK.¹³ However, this may not be enough to avoid having biased estimates. In order to further control for unobserved factors, we implement our models on three additional sub-samples:

- i. Markets with four players, which may provide a more direct comparison between a market that went from four to three operators with those that have four players only. These are Denmark, Italy, Latvia, Poland, Romania, Spain, Sweden and the UK.
- ii. Third and fourth operators in the sample, as given by their market shares for connections. These may represent better comparators for Hutchison and will determine whether there is a merger effect relative to other smaller operators (though at the expense of reducing data and variation).
- iii. Close markets to Austria, in terms of an index we construct based on Mahalanobis distance.¹⁴ This index summarises closeness in terms of GDP per capita, subscribers, population density, rural population and country elevation. Based on these calculations, the closest countries to Austria just before the merger were Romania, Italy, Poland, Denmark, Czech Republic, Sweden, Portugal and Spain.

12. This approach was proposed in Angrist (2008) and implemented in DG Comp (2015).

13. We exclude markets with significant market structure changes (e.g. Germany and Ireland) because this would violate the assumption behind the Base model – i.e. we would not be able to say that the trends in the control group reflect the outcomes that would have occurred in Austria (as they will be affected by changes to market structure).

14. Mahalanobis distance is calculated as $D^2 = (x-m)^T C^{-1}(x-m)$ where D^2 is Mahalanobis distance, x is a vector of data (e.g. GDP per capita, population density etc), m is a vector of mean values of independent variables, C^{-1} is the inverse covariance matrix of independent variables and T indicates that the vector should be transposed.

b. MNO fixed effects

As an additional sensitivity check, we estimate the Base and Trend models with MNO fixed effects. We do so because there may be unobservable factors that need to be controlled with regards to operators within each country. For instance, it may be the case that operators differ in business strategies, resources, firm structure, size and management. These factors may have some effect on the degree of innovation and/or quality of each operator.

c. Non-linear functional forms (4G coverage only)

There are two outstanding issues in the OLS framework behind the Base and Trend models when modelling 4G coverage. First, OLS assumes a linear relationship between the variables, but this may not be correct in variables that follow diffusion or S-type curves such as 4G coverage.¹⁵ OLS estimates may particularly fail in predicting the bottom and top 'tails'. Secondly, coverage values are bounded between 0 and 1 (as the dependent variable is a proportion of total population), but standard OLS results can give predictions outside this range.

To address the issue of the linearity in OLS, the Base and Trend models described previously are only applied to the period of actual 4G rollout by each operator. This means that repeated observations of 0% or 100% were dropped. Additionally, we carry out two non-linear models as robustness checks: a log-linear model, where the dependent variable is

expressed in logarithms; and fractional regression¹⁶, which performs a logistic transformation of the dependent variable (keeping all predictions within the 0-1 range and assuming a non-linear relationship).

d. Normalised time (4G coverage only)

To address the issue around S-curves discussed above, we also estimate 4G coverage models by synchronising the timelines of operators in the sample. We do so by setting time 0 as the year and quarter where the operator had spectrum that could be used for the rollout of 4G. Once this transformation of the time variable has been implemented, we estimate models with both OLS and the non-linear models presented above.

Robustness checks of market-wide effects

In addition to the checks above, in the analysis for market-wide effects (i.e. where all Austrian operators are considered as treated) we also run the models with a country-level dataset (i.e., the units are countries rather than operators) where Austria itself is considered as a treated unit.

Standard errors and inference

In order to account for the existence of heteroskedasticity and serial correlation in our models, we use a cluster-robust estimator with clustering at the country level. We also carried out sensitivity checks using clustering at the operator level and found all the results still held.

A1.3 Synthetic control

A1.3.1 Framework

In order to provide reassurance that the results from Base and Trend models are valid we also apply the synthetic control method. The synthetic control approach constructs a counterfactual for Hutchison by assigning weights to each operator in the control group, based on how they resemble the treated unit on a set of predictors. It has some advantages with respect to the Base and Trend DD models:

i. It is robust to having a limited pool of control units with characteristics that do not fully match. In

other words, the synthetic control can work when there is no control unit that individually resembles the treated unit – i.e. when the Parallel Trends assumption is not accomplished.

ii. Whereas the DD method assumes that unobserved effects affecting the outcome are constant in time (controlled for using the fixed effect), the synthetic control allows the effects of confounding unobserved characteristics to vary with time (Abadie, 2010).

iii. By giving different unequal weights to control

15. It is important to note however that due to the inclusion of time fixed effects and controls for the amount of time that spectrum has been assigned to the operator, the OLS model does not assume a linear trend in 4G coverage over time.

16. Implemented in Stata using the command 'fracreg'.

observations, the synthetic control can better deal with biases arising from comparisons based on average observed characteristics and their statistical distribution. This is in contrast with the DD approach, where all units have equal weights in a standard OLS framework.

The synthetic control requires three sets of inputs: a vector of ‘predictor’ variables used to estimate the outcome of interest; a matrix of ‘predictor weights’ to reflect the importance of each predictor with respect to the outcome; and a vector of ‘operator weights’ to reflect the importance given to each control group operator (or country) in the synthetic Hutchison (or Austria). This basic framework is complemented with cross-validation procedures geared at the selection of the set of predictors and at the application of placebo tests to assert the robustness of results (Abadie, Diamond & Hainmueller, 2003 and 2010).

We follow the original framework of Abadie & Gardeazabal (2003) where operator and predictor weights are assigned to minimise prediction errors of the outcome in the pre-intervention period.¹⁷ This is because if the synthetic control closely matches the development of the outcome in the treated country before the intervention, then post-treatment it may follow a trend similar to what would have happened in the treated country had there not been an intervention.

In this study, the variables used as predictors are chosen based on which group provides the lowest RMSPE for the outcome in the pre-intervention period. To provide further reassurance, we also look at the difference-in-Difference results (i.e. the variables that consistently appear to be relevant). We test the following as potential predictor variables for 4G coverage and network quality in our approach to the synthetic control:

- average of outcome (4G coverage or network quality measures) in the pre-merger period
- value of the outcome at the start of the period
- value of the outcome just before the merger (2012q4)
- time that 800 MHz, 1800 MHz and 2600 MHz had been available just before the merger
- average 3G/4G spectrum holdings before the merger

- average population in the pre-merger period
- average rural population in the pre-merger period
- 3G coverage just before the merger (where the outcome is 4G coverage)
- average proportion of 3G and 4G connections in the pre-merger period (where outcomes are network quality).

Having derived weights for predictors and operators, the outcome for the synthetic control can be estimated – the trend in the post-merger period represents the counterfactual of what would have happened to the outcome in the treated country absent the merger.

A1.3.2 Robustness checks

Statistical significance

To assess the statistical significance of the merger effect¹⁸, we implement the “placebo approach” proposed by Abadie et al. (2010 and 2015). This applies the synthetic control method to every country in the control group (as if they experienced a merger at the same time as Austria). We then compute the post-merger RMSPE to the pre-merger RMSPE¹⁹ ratio for each country. A higher ratio indicates a larger merger effect; if it is higher in Austria than other countries, then it is likely that the impact was driven by the merger and not by random effects. The rank of the treated country can be translated into the probability of finding a RMSPE ratio which is not below the RMSPE ratio observed in the treated country (the smaller the probability of finding a RMSPE ratio which is larger than the RMSPE ratio of the treated country, the more likely that there was an effect of the merger).

However, given the relatively small number of observations in the control group, we follow the approach in DG Competition (2015) whereby if the RMSPE ratio is higher than the placebos, then the effect of the merger is assumed to be significant.

The pool of placebo studies we use for statistical inference is restricted to the synthetic operators or countries where the pre-merger MSPE is less than five times that of Hutchison or Austria. This is consistent with the approach taken in Abadie et al. (2010).

17. More recently, Abadie et al. (2015) applied a different approach by dividing the pre-intervention period into a ‘training period’ and a ‘validation period’. Predictor weights are computed based on the former and chosen to minimise prediction errors in the latter. This approach is well-suited if the pre-intervention period sample is large, allowing it to be divided into two groups. However, our study does not have sufficient data for this. We also note Klossner et al. (2016) found that the cross-validation approach used in Abadie et al. (2015) did not have a unique solution to defining predictor weights, resulting in ambiguity in the results. They instead recommended the standard synthetic control method.

18. Large sample inferential techniques (of the kind used in regression analysis) are not well suited to comparative case studies when the number of units in the comparison group is small. See Abadie et al. (2010).

19. This is the magnitude of the gap in the outcome variable between each country and its synthetic control. It is calculated as the root of the average squared difference between outcomes in the treated country and the synthetic control.

A2. Data

Our complete panel dataset covers 63 operators and 18 European countries: Austria, Belgium, Croatia, Czech Republic, Denmark, Greece, Hungary, Italy, Latvia, Malta, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland and the UK (see Annex A1). Some of the robustness checks we carry out include restrictions to this sample (markets with four players²⁰, close markets²¹ and third and fourth operators before the merger).

The datasets for the 4G coverage analysis run from 2009q4 to 2016q3, while in the case of quality the time series covers 2011q2 to 2016q3. Both the DD and Synthetic control are implemented using the same panel datasets.

A2.1 Data sources

Table A2.1

Additional data

Model notation	Variable name	Description	Source	Scope
$4GSpectrum_{i,j,t}$	4G spectrum	Amount of spectrum holdings in 800, 1800 and 2600 MHz bands.	GSMA Intelligence	Quarterly (2010–2016)
$4GSpectrum_{i,j,t}^{T0 < X < T1}$	4G spectrum X-Y Years	Dummy variable indicating whether 4G spectrum has been available between X and Y years.	GSMA Intelligence	Quarterly (2010–2016)
$connections4G_{i,j,t}$	4G connections	Number of connections based on 4G technologies	GSMA Intelligence	Quarterly (2010–2016)
$conn_pen4G_{i,j,t}$	4G connections penetration	Share of connections based on 4G technologies among all types of connections	GSMA Intelligence	Quarterly (2010–2016)
$3GSpectrum_{i,j,t}$	3G spectrum	Amount of spectrum holdings in 900 and 2100 MHz bands.	GSMA Intelligence	Quarterly (2010–2016)
$connections3G_{i,j,t}$	3G connections	Number of connections based on 3G technologies	GSMA Intelligence	Quarterly (2010–2016)
$conn_pen3G_{i,j,t}$	3G connections penetration	Share of connections based on 3G technologies among all types of connections	GSMA Intelligence	Quarterly (2010–2016)
$coverage3G_{i,j,t}$	3G coverage	3G coverage (based on proportion of population covered)	GSMA Intelligence	Quarterly (2010–2016)
$GDPcapita_{j,t}$	GDP per capita	GDP per capita in 2010 euros	Eurostat	Quarterly (2010–2016)
$ruralpop_{j,t}$	Rural population	Percentage of population living in rural areas	World Bank and UN	Quarterly ²² (2010–2016)
$popdense_{j,t}$	Population density	Population per square km of land	World Bank and UN	Quarterly ²³ (2010–2016)

Source: GSMA Intelligence

20. Four-player markets include Denmark, Italy, Latvia, Poland, Romania, Spain, Sweden and the UK.
 21. The closest countries are Romania, Italy, Poland, Denmark, Czech Republic, Sweden, Portugal and Spain.
 22. The original data is annual. We have used linear interpolation to obtain quarterly estimates.
 23. The original data is annual. We have used linear interpolation to obtain quarterly estimates.

A2.2 List of operators included in study

Table A2.2

Operators and countries included in the sample

Operator	Country	Operator	Country
Hutchison	Austria	Go	Malta
A1 Telekom	Austria	Melita Mobile	Malta
Orange	Austria	Plus	Poland
T-Mobile	Austria	T-Mobile	Poland
BASE (Telenet)	Belgium	Orange	Poland
Proximus	Belgium	Play	Poland
Mobistar (Orange)	Belgium	NOS	Portugal
Vipnet	Croatia	MEO	Portugal
Hrvatski Telekom	Croatia	Vodafone	Portugal
Tele2	Croatia	Telekom Romania	Romania
Vodafone	Czech Republic	Vodafone	Romania
O2	Czech Republic	Orange	Romania
T-Mobile	Czech Republic	DigiMobil	Romania
Hutchison	Denmark	Telekom Slovenije	Slovenia
Telenor	Denmark	Si.Mobil	Slovenia
TDC	Denmark	T-2	Slovenia
Telia	Denmark	Telemach Mobil	Slovenia
Cosmote	Greece	Movistar	Spain
WIND	Greece	Vodafone	Spain
Vodafone	Greece	Yoigo	Spain
Telenor	Hungary	Hutchison	Sweden
Magyar Telekom	Hungary	Tele2	Sweden
Vodafone	Hungary	Telia	Sweden
Hutchison	Italy	Telenor	Sweden
TIM	Italy	Salt	Switzerland
Vodafone	Italy	Swisscom	Switzerland
WIND	Italy	Sunrise	Switzerland
LMT	Latvia	Hutchison	United Kingdom
Tele2	Latvia	O2	United Kingdom
Bite	Latvia	EE	United Kingdom
Triatel	Latvia	Vodafone	United Kingdom
Vodafone	Malta		

Source: GSMA Intelligence

A2.3 Network quality test statistics

Table A2.3

Number of speed tests at the country level

Time	All tests			3G			4G		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2011q2	41,263	497	215,340	36,709	473	193,600	-	-	-
2012q2	99,290	3,647	497,764	89,525	3,533	469,980	1,904	173	8,925
2013q2	129,983	1,301	620,765	99,428	1,195	523,651	19,928	107	91,636
2014q2	209,030	2,237	1,417,000	107,276	1,289	622,394	94,617	879	768,363
2015q2	356,293	4,490	1,835,329	169,044	2,786	1,018,824	183,426	1,627	929,013
2016q2	413,055	5,296	2,500,959	149,987	2,044	1,065,400	260,050	3,215	1,422,100

Source: Ookla

Table A2.4

Number of speed tests at the operator level

Time	All tests			3G			4G		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2011q2	12,379	155	75,945	11,013	140	67,526	-	-	-
2012q2	29,787	1,417	231,697	26,857	493	231,696	1,178	111	7,439
2013q2	38,995	549	256,662	30,333	215	256,623	8,458	107	85,625
2014q2	63,456	596	600,196	32,621	571	285,783	32,518	147	314,412
2015q2	106,856	1,506	651,135	50,704	1,154	353,819	55,937	324	321,309
2016q2	123,887	2,415	760,765	44,990	911	324,523	77,992	1,488	505,416

Source: Ookla

A3. Results

A3.1 4G coverage

A.3.1.1 Merger effects on Hutchison

a. Difference-in-Difference (DD) approach

The Base DD model in Table A3.1 approximates the merger effect by building a counterfactual for Hutchison based on the post-merger trend of control operators.

Differences between treated and control operators seem to be to a certain extent captured by statistically significant country and time fixed effects, population density, and 3G network factors, with signs as expected in Annex A1. The significance of spectrum variables both in terms of overall holdings and in timings suggests that merger effect estimates are not biased due to changes in spectrum across the sample either.

Table A3.1

4G coverage base DD model – merger effect for Hutchison

	(1) 4G cov.	(2) 4G cov.	(3) 4G cov.	(4) 4G cov.	(5) 4G cov.	(6) 4G cov.	(7) 4G cov.
Effect in 1st year	-0.032	-0.0199	-0.0503	-0.053	-0.067	-0.069	-0.082
Effect in 2nd year	0.048	0.0274	0.0357	0.026	0.012	0.016	-0.033
Effect after 2 years	0.277***	0.258***	0.241***	0.220***	0.208***	0.207***	0.214***
Treated unit dummy	-0.084***	-0.080***	-0.063***	-0.055**	-0.048**	-0.045**	-0.070*
4G spectrum holdings		0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
4G spectrum 1–2 years			0.0423	0.0470	0.049	0.060	0.051
4G spectrum 2–4 years			0.0965*	0.101*	0.107*	0.117**	0.102*
4G spectrum 4–6 years			0.157***	0.160***	0.165***	0.176***	0.161**
GDP per capita (log)				-0.480			
Rural population					0.074**		0.0268
Population density (log)						2.259*	2.832***
3G coverage							0.438**
3G download speeds							-0.031***
Observations	948	948	948	948	948	948	923
Adjusted R-squared	0.74	0.75	0.76	0.76	0.76	0.76	0.77
Lead Effect test	Fail	Pass	Pass	Pass	Pass	Pass	Pass
Parallel Trends test	Fail	Fail	Fail	Fail	Fail	Fail	Pass
Country and time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Significance level: *** 1%, ** 5%, * 10%. Standard errors are clustered at country level. Lead Effect test is given as 'Pass' if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as 'Pass' if passed at the 5% level. There are fewer observations for Model 7 because of unavailable 3G network performance data for two operators.

The tests we carry out to inspect if the Base DD satisfies the condition of pre-merger trends pass in Model 7. This specification proves to pass the common trends tests specifically due to the inclusion of 3G coverage and 3G download speeds (with the former enhancing 4G rollout via cost savings in existing infrastructure, and the latter having a negative impact due to operators investing in 3G upgrades and technology substitutability). Altogether, the model specification Model 7 suggests that post-merger changes observed in the control group of operators can be used to approximate Hutchison’s counterfactual without incurring biases.

The long-term merger effects found in the Base DD in an OLS framework are confirmed in the sensitivities with restrictions to the sample (Table A3.2).²⁴ Only the OLS simulations with normalised time and with MNO fixed effects identify a negative effect in the first year, but none of these results pass the two tests for pre-merger common trends required for unbiased DD results. Separately, taking into account the S-diffusion type of curve, as discussed in Annex A1, special weight should be given to non-linear functional forms and normalised time results. Effects after two years are confirmed by the non-linear functions.

Table A3.2

4G coverage robustness checks on Base DD model – merger effect for Hutchison

(7) 4G coverage									
Model	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg
Check	All sample			Four-players sample			Close markets sample		
Effect in 1st year	-0.082	0.295*	0.010	-0.064	0.449**	0.032	-0.118	0.209	0.014
Effect in 2nd year	-0.033	0.639***	0.011	0.017	0.795**	0.065	-0.054	0.367	0.025
Effect after 2 years	0.214***	1.037***	0.288***	0.254***	1.182***	0.347***	0.200***	0.747**	0.305***
Lead Effect test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Parallel Trends test	Pass	Fail	N/A	Pass	Fail	N/A	Pass	Pass	N/A
Model	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg
Check	MNO fixed effects			Third and fourth MNOs sample			Normalised time		
Effect in 1st year	-0.103***	0.303***	-0.015	-0.093	0.452**	0.055	-0.146***	0.270**	-0.027
Effect in 2nd year	-0.035	0.739***	-0.004	0.013	1.014***	0.064	-0.089**	0.808***	-0.007
Effect after 2 years	0.171***	1.111***	0.217***	0.220***	1.397***	0.285***	0.135**	1.154***	0.201***
Lead Effect test	Fail	Pass	Pass	Fail	Pass	Pass	Fail	Fail	Pass
Parallel Trends test	Pass	Pass	N/A	Pass	Pass	N/A	Pass	Fail	N/A

Significance level: *** 1%, ** 5%, *10%. Fractional regression coefficients represent marginal effects. Robustness checks carried out with the model specification as defined in Model 7 of Table A3.1. Lead Effect test is given as ‘Pass’ if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as ‘Pass’ if passed at the 5% level.

Source: GSMA Intelligence

We note that Model 7 of Table A3.1 passes the tests for pre-merger common trends. While we already consider this – together with the checks described above – the basis of a robust result, we have run Trend DD models for completion.

Looking at the results of the Trend DD model (Figure A3.1) merger effects are still significant two years after the merger. These results have also proven to hold in the same set of checks as in Table A3.2.

24. Robustness checks are carried out with Model 7 of Table A3.1 as this passes the underlying assumption of Base DD.

Figure A3.1

4G coverage trend DD model – merger effect for Hutchison



Merger effect coefficients (as given by each post-merger time dummies for Hutchison) and 95% confidence intervals. Estimates based on Model 7 of Table A3.1.

Source: GSMA Intelligence

We note that the Trend DD may raise issues around whether the pre-merger rollout observed on Hutchison is a useful basis for the post-merger counterfactual. Particularly, the pre-merger rollout for Hutchison is in the left tail of the S curve, so the extent to which this trend can be used as counterfactual could be questioned. As discussed in Annex A1, we have addressed this issue by estimating merger effects from Trend DD models with non-linear functional forms, with the positive impact after two years confirmed.²⁵

b. Synthetic control approach

Given the synthetic control requires pre-merger data in coverage and in the set of predictors, we have restricted the sample to operators that had launched 4G networks at least four quarters before the merger (in our full sample, this leads to 13 “donor” operators). The variables used to predict 4G coverage are the ones that provide the lowest RSMPE pre-merger, and are also consistent with the DD results. The weights given to each predictor shown in Table A3.3 are broadly consistent with the results derived from the inclusion of additional variables (e.g. rural population, elevation).

25. A second aspect to take into account is that one difference between the pre- and post-merger period in the Austrian market is the 800 MHz spectrum auction, which took place in the post-merger period. While we control for spectrum holdings, Hutchison in any case did not obtain 800 MHz spectrum, so this cannot bias the merger effect.

Table A3.3

4G coverage synthetic control operator key parameters

Operator	Weight	Predictor	Predictor balance		Predictor weight ²⁶
			Hutchison	Synthetic	
Hrvatski Telekom (Croatia)	0.952	4G coverage (pre-merger mean)	0.066	0.061	0.6720
Vipnet (Croatia)	0.048	4G coverage (2011q4)	0	0	0.1002
		4G coverage (2012q4)	0.08	0.130	0.2244
		4G count (2012q4)	9	3	0.0027
		4G spectrum (pre-merger mean)	65	22	0.0006

The pool of donor operators is restricted to operators that had active 4G networks (i.e., 4G coverage values above 0) at least four quarters before the merger and that receive a positive weight in the synthetic Hutchison.

Source: GSMA Intelligence

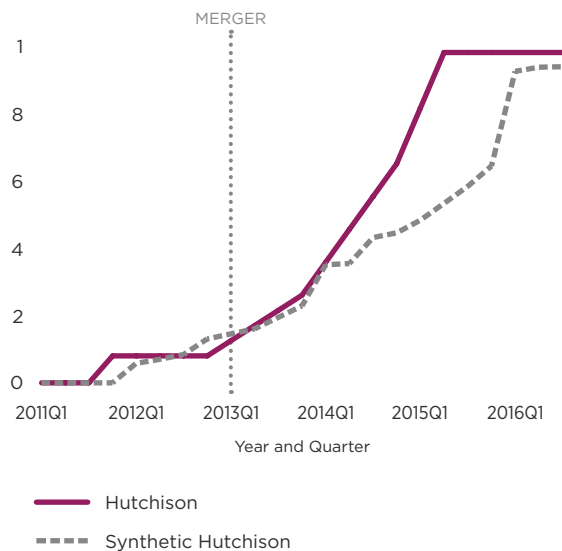
The resulting synthetic operator (Table A3.3) appears to be reasonably well balanced, with predictor values being very close to Hutchison in terms of 4G coverage, though the 4G count and 4G spectrum holdings are not as balanced. The overall post-/pre-merger MSPE ratio ranking in the placebo analysis is 4/14 while the ranking after two years is 3/14.

With only 14 placebo studies (Chart B in Figure A3.2) the synthetic control provides little evidence as a standalone exercise, though it gives some reassurance of the results found in the DD framework as there is a noticeable difference between the actual and synthetic result around two years following the merger (in 2015).

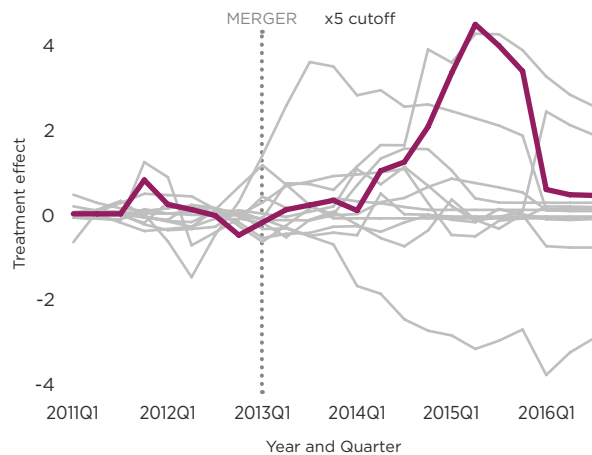
Figure A3.2

4G coverage synthetic control operator

A. HUTCHISON AND SYNTHETIC HUTCHISON



B. PLACEBO STUDIES



Placebo studies in Chart B show operators that had active 4G networks before the Austrian merger and where the pre-merger MSPE is less than five times that of Hutchison.

Source: GSMA Intelligence

26. Predictor weights may not sum to 1 due to rounding.

A.3.1.2 Market-wide effects

a. Difference-in-Difference (DD) approach

If we assign all Austrian operators to the treatment group, we find no conclusive effects. Base and Trend DD give contradictory results, with the former not passing tests for pre-merger common trends and the latter reporting estimates that are not robust across alternative models.

The Base DD specifications in Table A3.4 find negative effects in the first two years after the

merger and, in some models, a positive effect after two years. While the Parallel Trends test is passed in each model, the fact that the lead effect is significant when included in the separate regressions makes it unclear whether it was the merger that caused a reduction in 4G coverage or something else. One possible candidate behind the significance of the lead effect (and potentially the negative effect in the first year after the merger, i.e. 2013) could be the delay in the 800 MHz auction in Austria.²⁷ In any case, the significant lead effects suggest that control operators may not offer a good counterfactual for all Austrian operators due to some factors remaining unobserved.

Table A3.4

4G coverage base DD model – merger effect for Hutchison

	(1) 4G cov.	(2) 4G cov.	(3) 4G cov.	(4) 4G cov.	(5) 4G cov.	(6) 4G cov.	(7) 4G cov.
Effect in 1st year	-0.094**	-0.085**	-0.099*	-0.100*	-0.119**	-0.102**	-0.082*
Effect in 2nd year	-0.058*	-0.089**	0.079*	-0.089*	-0.107**	-0.093**	-0.085**
Effect after 2 years	0.089***	0.051*	0.074**	0.052	0.036	0.046	0.091**
4G spectrum holdings		0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
4G spectrum 0–2 years			0.043	0.046	0.048	0.059	0.0529
4G spectrum 2–4 years			0.105*	0.107*	0.113**	0.122**	0.111**
4G spectrum 4–6 years			0.166***	0.167***	0.172***	0.184***	0.172***
GDP per capita (log)				-0.475			
Rural population					0.079**		0.027
Population density (log)						2.294*	2.803***
3G coverage							0.431**
3G download speeds							-0.031***
Observations	948	948	948	948	948	948	923
Adjusted R-squared	0.74	0.75	0.74	0.74	0.75	0.75	0.76
Lead Effect test	Fail	Fail	Fail	Fail	Fail	Fail	Fail
Parallel Trends test	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Country and time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Significance level: *** 1%, ** 5%, *10%. Standard errors are clustered at country level. The ‘Treated unit dummy’ is not reported in market-level analyses because it is, in effect, a country fixed effect. Lead Effect test is given as ‘Pass’ if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as ‘Pass’ if passed at the 5% level.

Source: GSMA Intelligence

27. The 800 MHz auction in Austria was planned to take place in 2012 but was delayed until after the merger decision. It is possible that because operators would have been uncertain as to how much 800 MHz spectrum that would obtain, they delayed rollout of their 4G networks in the first year following the merger.

We have estimated the same models with the usual set of alternative specifications, using Model 7.²⁸ Table A3.5 below shows that the Log-Lin model is the only specification appropriate when applied to four-player countries, in the close markets and in the MNO fixed effects framework, as well as the OLS model with normalised time. The other models do not fully pass pre-merger trends tests. Even though most of the valid models point towards a positive impact of the merger, these results alone do not provide sufficient evidence considering the opposite impact that the OLS with normalised time suggests. With regards to the negative effects in the latter model, as discussed

above it is possible that the delay in the 800 MHz auction could also be a factor in slowing down rollout in the first year or two after the merger, making it difficult to isolate the impact of the merger.

Table A3.5

4G coverage robustness checks on Base DD model – market-wide effects

(7) 4G coverage									
Model	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg
Control	All sample			Four-players markets			Close markets		
Effect in 1st year	-0.082*	0.339**	-0.043	-0.072	0.492**	-0.020	-0.109	0.310	-0.003
Effect in 2nd year	-0.085**	0.626***	-0.112*	-0.046	0.804***	-0.067	-0.074	0.488	-0.039
Effect after 2 years	0.091**	0.941***	-0.020	0.126*	1.131***	0.019	0.111**	0.740**	0.032
Lead Effect test	Fail	Fail	Pass	Fail	Pass	Pass	Fail	Pass	Pass
Parallel Trends test	Pass	Pass	N/A	Pass	Pass	N/A	Pass	Pass	N/A
Model	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg	OLS	Log-Lin	Fracreg
Control	MNO fixed effects			Normalised time			Country-level		
Effect in 1st year	-0.129***	0.272*	-0.098**	-0.095**	0.339**	-0.098***	-0.169***	-0.121	-0.173***
Effect in 2nd year	-0.121**	0.643*	-0.163**	-0.126***	0.626***	-0.195***	-0.223***	-0.161	-0.275***
Effect after 2 years	0.0117	0.916**	-0.148	-0.002	0.941***	-0.148*	-0.0835	0.242	-0.155**
Lead Effect test	Fail	Pass	Fail	Pass	Fail	Pass	Pass	Fail	Fail
Parallel Trends test	Pass	Pass	N/A	Pass	Pass	N/A	Fail	Pass	N/A

Significance level: *** 1%, ** 5%, *10%. Fractional regression coefficients represent marginal effects. Robustness checks carried out with the model specification as defined in Model 7 of Table A3.4. Lead Effect test is given as 'Pass' if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as 'Pass' if passed at the 5% level.

Source: GSMA Intelligence

28. Robustness checks are carried out with Model 7 of Table A3.4 because it incorporates the additional explanatory factors of 3G coverage and 3G download speeds, which prove to be significant drivers of 4G rollout.

With the underlying assumption in Base DD not being accomplished across the majority of simulations, we also present the result of the Trend DD model. This suggests insignificant impacts

(Figure A3.3). Running alternative Trend DD models results in mixed findings (some positive and some negative) – hence, we cannot conclude if there was a merger effect at the market level in Austria.

Figure A3.3

4G coverage trend DD model – market-wide merger effects



Merger effect coefficients (as given by each post-merger time dummies for Austrian operators) and 95% confidence intervals. Estimates based on the Trend DD application following the Base DD set-up in Model 7 of Table A3.4.

Source: GSMA Intelligence

b. Synthetic control approach

Aside from Austria, in our sample there are only seven other countries with 4G networks in place for more than one year before the merger. The synthetic control is, consequently, of limited use – the pool of ‘donor’ countries is reduced and, moreover, the number of

placebo studies to determine the significance of the results makes it difficult to draw any conclusions from the analysis. Hence, we conclude that based on the data available to us, it is not possible to say what impact the merger had (if any) at the market level.

A3.2 4G network quality

A.3.2.1 Merger effects on Hutchison

a. Regression-based approach

Due to the lack of pre-merger data on 4G performance for Hutchison, the only model that we can estimate is the Base specification, for which the Parallel Trends assumption cannot be directly inspected. In this case, the DD framework cannot be estimated using the standard approach, since the double difference cannot be calculated.

The estimates in Table A3.6 point to a significant positive merger effect across all years after the merger for download speeds, while the second year effect is not significant in upload speeds. These merger coefficients represent, in effect, an operator fixed effect for Hutchison. These capture whether the merged entity had better or worse network performance than would have been expected by assessing other operators' network performance and controlling for other distinctive factors between the treatment and the control. In this case, the factors that turn out significant are the country and time fixed effects.

Table A3.6

4G network quality Base model – merger effects for Hutchison

	4G download speeds			4G upload speeds		
	(1)	(2)	(3)	(1)	(2)	(3)
Effect in 1st year	3.686**	3.381*	3.687**	3.792***	3.667***	3.793***
Effect in 2nd year	2.705***	2.769***	2.727***	-0.0630	-0.0370	-0.0552
Effect after two years	7.635***	8.398***	7.673***	3.732***	4.045***	3.745***
4G spectrum holdings	0.0337	0.0353	0.0331	0.00441	0.00507	0.00422
Rural population		-4.632			-1.903	
Population density (log)			-0.177			-0.0643
Observations	904	904	904	904	904	904
Adjusted R-squared	0.35	0.36	0.35	0.31	0.32	0.31
Country and time FE	Yes	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes

Significance level: *** 1%, ** 5%, * 10%. Standard errors are clustered at country level. Lead Effect test and Parallel Trends tests cannot be applied due to lack of pre-merger data.

Source: GSMA Intelligence

Considering the limitations above, the alternative specifications we can carry out provide some useful insights (we use Model 1 of Table A3.6 as Models 2 and 3 add explanatory factors without significance).

By limiting the sample to operators and markets with closer characteristics to Hutchison, these estimates should limit the sources for unobserved factors that could confound the merger effect. Separately, the MNO fixed effects model should be able to control for unobserved structural differences across operators that could be biasing merger effects.

In terms of download speeds, the models reported in Table A3.7 appear to confirm both the effect after two years (which remains significant on all checks) and the effect in the second year (which only dilutes in the third/fourth operator sample) – with both effects intensified when controlling for operator fixed effects. Considering upload speeds, most alternative models suggest coefficients similar in significance and magnitude for the first year after the merger and two years after. We treat the former with caution given it seems to dilute in the second year after the merger, suggesting that it could be driven by something other than the merger.

Table A3.7

4G network quality Base model robustness checks – merger effect for Hutchison

	4G download speeds				4G upload speeds			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Effect in 1st year	11.68***	4.076	1.959	5.390*	3.518***	4.529***	1.739	5.304***
Effect in 2nd year	11.13***	2.523**	1.583	1.858*	0.053	-0.277	-2.124	-0.709*
Effect after two years	15.80***	7.209***	8.094**	7.328***	3.787***	3.508***	1.623	3.373***
Check	MNO FE	Four-player sample	Third/fourth operator sample	Close markets sample	MNO FE	Four-player sample	Third/fourth operator sample	Close markets sample

Significance level: *** 1%, ** 5%, *10%. Robustness checks carried out with the model specification as defined in Model 1 in Table A3.6. Lead Effect test and Parallel Trends test cannot be applied due to lack of pre-merger data.

Source: GSMA Intelligence

This analysis cannot be complemented with estimates from Trend models given the lack of pre-merger data.

b. Synthetic control approach

The synthetic control approach cannot be applied in this case either, since there is no 4G network quality pre-merger data on which we can generate optimal weights.

A.3.2.2 Market-wide merger effects

a. Difference-in-Difference (DD) approach

When assigning all Austrian operators to the treatment group, the only treated operator with pre-merger data on 4G network quality is A1 Telekom and this only exists for four quarters prior to the merger. Therefore, although we have pre-merger data on which to carry out a Parallel Trends test, this should be treated with some caution.

Table A3.8

4G network quality base DD model – market-wide merger effects

	4G download speeds			4G upload speeds		
	(1)	(2)	(3)	(4)	(5)	(6)
Effect in 1st year	13.93***	15.88***	14.08***	5.075***	5.853***	5.127***
Effect in 2nd year	13.09***	15.57***	13.28***	4.171***	5.161***	4.240***
Effect after two years	8.322**	11.57***	8.536**	2.587**	3.880***	2.662**
4G spectrum holdings	0.0342	0.0354	0.0336	0.00461	0.005	0.004
Rural population		-4.936			-1.969	
Population density (log)			-0.187			-0.066
Observations	827	827	827	827	827	827
Adjusted R-squared	0.46	0.46	0.46	0.42	0.42	0.42
Parallel Trends test	Pass	Pass	Pass	Pass	Pass	Pass
Country and time FE	Yes	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes

Significance level: *** 1%, ** 5%, * 10%. Standard errors are clustered at country level. Lead Effect test cannot be applied due to lack of pre-merger data. Parallel Trends test results are presented but should be treated with some caution as there is only data for four quarters pre-merger and this is primarily based on the network performance of A1 Telekom. The 'Treated unit dummy' is not reported in market-level analyses because it is, in effect, a country fixed effect.

Source: GSMA Intelligence

Due to the limited amount of pre-merger data, the alternative models that can be carried out are particularly important, especially the checks done with the market-level dataset – where Austria as a whole is the relevant unit of treatment and where we have pre-merger data. Using the specification of Model 1 in Table A3.8²⁹, Table A3.9 shows that the country-level model passes the two tests of pre-merger trends, and the size and significance of the merger effects are along the lines of that found in Table A3.8 across the three post-merger periods.

The other alternative models (restrictions to sample and MNO fixed effects) provide results in the same general direction. In almost all specifications, the effects in the first two years after the merger are statistically significant. However, in some of the simulations the significance of the merger effect two years after the merger is diluted. Due to the limited length of pre-merger data, we prefer to have a statistically significant result in the majority of alternative models in order to be confident of a finding. Given this is not the case for the effect after two years, we conclude that the results found after two years are inconclusive.

29. Checks are carried out using Model 1 in Table A3.8 because the inclusion of variables in the other simulations does not seem to add substantial explanatory power.

Table A3.9

4G network quality Base DD robustness checks – market-wide merger effects

	4G download speeds				4G upload speeds			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Effect in 1st year	15.31***	12.45***	14.89***	15.42***	5.255***	5.025***	5.531***	5.709***
Effect in 2nd year	15.30***	10.97**	10.82**	15.19***	4.783***	3.144*	2.038	4.996***
Effect after two years	10.35**	5.465	5.861	8.756**	3.211**	1.267	0.268	2.343**
Parallel Trends test	Fail	Fail	Pass	Pass	Fail	Fail	Fail	Pass
Check	MNO FE	Four-player sample	Close markets sample	Market-level dataset	MNO FE	Four-player sample	Close markets sample	Market-level dataset

Significance level: *** 1%, ** 5%, *10%. Robustness checks carried out with the model specification as defined in Model 1 in Table A3.8. Lead Effect test cannot be applied due to limited pre-merger data.

Source: GSMA Intelligence

b. Synthetic control approach

The synthetic control approach cannot be applied in this case, since there is not enough 4G network

quality pre-merger data on which we can generate optimal weights.

A3.3 3G Network quality

A.3.3.1 Merger effects on Hutchison

a. Difference-in-Difference (DD) approach

With respect to 3G download speeds, the Base DD model reported in Table A3.10 suggests that the

merger had a negative impact in the first two years after the merger, disappearing thereafter. The Base DD comfortably passes the Parallel Trends test and the Lead Effect test in Model 2, meaning that this is an appropriate specification to use.

Table A3.10

3G network quality Base DD – merger effect for Hutchison

	3G download speeds			3G upload speeds		
	(1)	(2)	(3)	(1)	(2)	(3)
Effect in 1st year	-0.730**	-0.713**	-0.704**	-0.184*	-0.194*	-0.185*
Effect in 2nd year	-1.388***	-1.360**	-1.356***	-0.313**	-0.328**	-0.313**
Effect after two years	0.513	0.554	0.544	-0.301	-0.325	-0.302
Treated unit dummy	0.244	0.223	0.221	0.641**	0.653**	0.642**
3G spectrum holdings	0.024	0.024	0.024	0.008	0.008	0.008
Rural population		-0.092			0.053	
Population density (log)			0.088***			-0.001
Observations	1,320	1,320	1,320	1,320	1,320	1,320
Adjusted R-squared	0.81	0.81	0.82	0.68	0.68	0.68
Lead Effect test	Fail	Pass	Fail	Fail	Fail	Fail
Parallel Trends test	Pass	Pass	Pass	Fail	Fail	Fail
Country and time FE	Yes	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes

Significance level: *** 1%, ** 5%, * 10%. Standard errors are clustered at country level. Lead Effect test is given as 'Pass' if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as 'Pass' if passed at the 5% level.

Source: GSMA Intelligence

Nevertheless, the sensitivity tests on Model 2 for 3G download speeds do not fully support negative impacts in the first two years after the merger³⁰ (see Table A3.11). While the 'close markets' sample does report negative merger effects in the first and second year as well, the two other sample restrictions report

insignificant estimates. Additionally, the MNO fixed effects model produces inconsistent estimates, with a negative effect in the second year and a positive effect after two years. With these inconsistencies, we cannot determine with confidence that there was an impact on this metric.

30. Sensitivities are carried out with Model 2 because this specification is robust to common pre-merger trends. Model 3 includes population density, which proves to be significant, but this leads to the specification not passing both tests on pre-merger trends.

Table A3.11

3G network quality Base DD robustness checks – merger effect for Hutchison

	3G download speeds			
	(1)	(2)	(3)	(4)
Effect in 1st year	-0.394	-0.799	-0.382	-1.564**
Effect in 2nd year	-0.937*	-1.248	-0.782	-2.548***
Effect after two years	1.070*	0.628	1.288	-0.890
Lead Effect test	Pass	Pass	Pass	Pass
Parallel Trends test	Pass	Pass	Pass	Pass
Check	MNO FE	Four-player sample	Third/fourth operator sample	Close markets sample

Significance level: *** 1%, ** 5%, *10%. Robustness checks carried out with the model specification as defined in Model 2 of Table A3.10 for download speeds. Lead Effect test is given as 'Pass' if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as 'Pass' if passed at the 5% level.

Source: GSMA Intelligence

Regarding 3G upload speeds, Table A3.10 shows some negative merger effects in the first and second year, but these models do not pass any of the tests for common trends. Given Base DD estimates are not appropriate, we run Trend DD simulations.

Figure A3.4 reports the merger coefficients that result from the Trend DD version of the Base DD application in Model 1 of Table A3.10.³¹ This suggests the merger effect was insignificant for the entire post-merger period.

31. We carry the Trend DD application of Model 1 because the additional explanatory variables in Models 2 and 3 lack significance.

Figure A3.4

3G upload speeds trend DD model – merger effect for Hutchison



Merger effect coefficients (as given by each post-merger time dummy for Hutchison) and 95% confidence intervals. Estimates based on the Trend DD application following the Base DD set-up in Model 1 of Table A3.10.

Source: GSMA Intelligence

b. Synthetic control approach

The synthetic part of the analysis for 3G download and upload speeds does not appear to provide a good framework to determine whether the merger induced significant effects at the merged entity level. We find that the combination of data across operators in the dataset does not generate a synthetic control that can be feasibly compared against Hutchison.

The predictors that we have included (pre-merger mean of the outcomes, as well as the values in 2011q2 and 2012q4, 3G spectrum and connections penetration) give the lowest pre-merger MSPE and generally prove to be relevant in the DD models. The synthetic Hutchison takes values from operators in the full sample, with the results shown in Table A3.12. For both upload and download speeds, the predictor balance indicates that Hutchison and its synthetic counterpart are close in terms of observed characteristics (with the exception of 3G connections penetration in upload speeds).

Table A3.12

3G Network quality synthetic control operator key parameters

DOWNLOAD SPEEDS

Operator	Weight	Predictor	Predictor balance		Predictor weight ³²
			Hutchison	Synthetic	
Hutchison (Denmark)	0.817	3G download speed (pre-merger mean)	3.20	3.20	0.7192
Hutchison (Sweden)	0.023	3G download speed (2011q2)	2.50	2.48	0.0942
Tele2 (Croatia)	0.161	3G download speed (2012q4)	3.74	3.73	0.1858
		3G spectrum (pre-merger mean)	36.20	45.20	0.0004
		3G connections penetration (pre-merger mean)	0.98	0.88	0.0001

UPLOAD SPEEDS

Operator	Weight	Predictor	Predictor balance		Predictor weight ³³
			Hutchison	Synthetic	
Vodafone (Czech Republic)	0.855	3G upload speeds (pre-merger mean)	1.65	1.63	0.7391
Vodafone (Malta)	0.145	3G upload speeds (2011q2)	1.23	1.20	0.1160
		3G upload speeds (2012q4)	1.88	1.67	0.1446
		3G spectrum (pre-merger mean)	36.20	66.05	0.0001
		3G connections penetration (pre-merger mean)	0.98	0.33	0.0002

The pool of donor operators includes all operators in the sample. Only those operators with positive weights are listed in the operator weights vector.

Source: GSMA Intelligence

Charts A and B in Figure A3.5, however, indicate that the resulting predictions of download and upload speeds do not match Hutchison’s values during the pre-merger period. Hence, the resulting synthetic control does not prove to be useful. This could indicate that the variables chosen to predict

download and upload speeds do not work well because of their static nature (i.e. average and snapshot values do not capture the dynamics on a time series); and/or that the operator dataset simply does not provide an efficient combination of firms in terms of synthetic control.

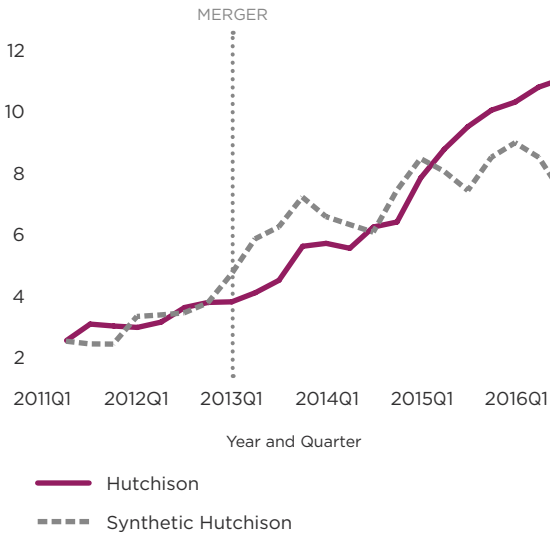
32. Predictor weights may not sum to 1 due to rounding.

33. Predictor weights may not sum to 1 due to rounding.

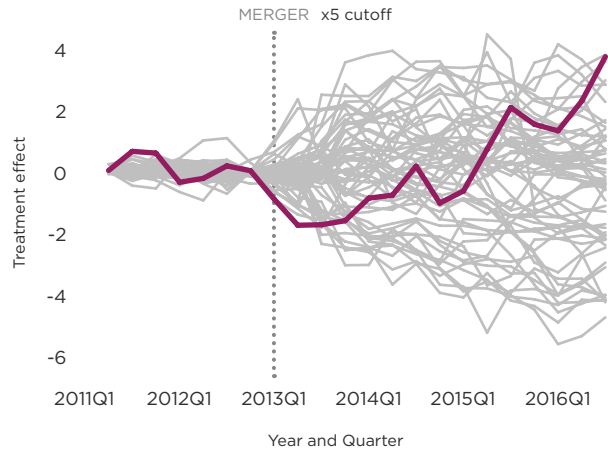
Figure A3.5

3G network quality synthetic control operator

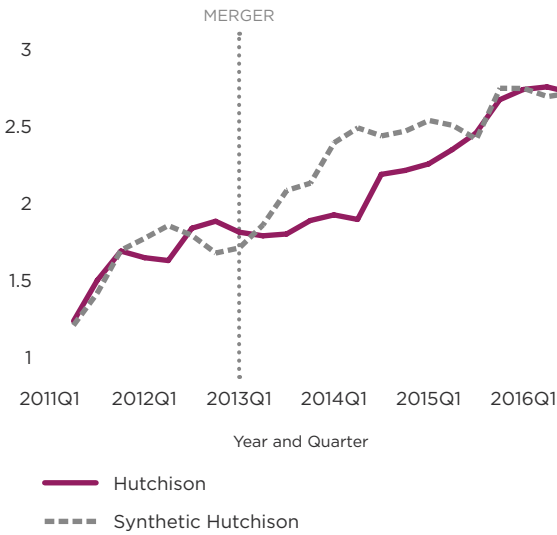
A. HUTCHISON AND SYNTHETIC HUTCHISON (DOWNLOAD SPEEDS)



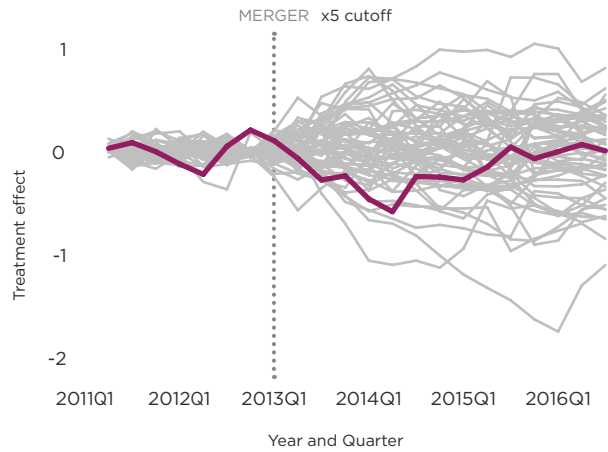
B. PLACEBO STUDIES (DOWNLOAD SPEEDS)



A. HUTCHISON AND SYNTHETIC HUTCHISON (UPLOAD SPEEDS)



B. PLACEBO STUDIES (UPLOAD SPEEDS)



Placebo studies in Charts B show synthetic operators whose pre-merger MSPE is less than five times that of Hutchison.

Source: GSMA Intelligence

A.3.3.2 Market-wide merger effects

a. Difference-in-Difference (DD) approach

For both 3G download and upload speeds we rely on the results from the Base DD model. Model 2 of Table A3.13 passes the tests for common pre-

merger trends, reporting significant merger effects in the second year and after two years (positive for download and negative for upload speeds). The other models do not pass both tests for common trends.

Table A3.13

3G network quality Base DD model – merger effects across all Austrian operators

	3G download speeds			3G upload speeds		
	(1)	(2)	(3)	(1)	(2)	(3)
Effect in 1st year	0.144	0.176	0.170	-0.046	-0.0583	-0.047
Effect in 2nd year	0.527*	0.579*	0.559**	-0.189***	-0.209**	-0.189***
Effect after two years	1.434***	1.512***	1.465***	-0.228***	-0.258**	-0.229***
3G spectrum holdings	0.023	0.023	0.0234	0.006	0.006	0.006
Rural population		-0.165			0.063	
Population density (log)			0.0887***			-0.001
Observations	1320	1320	1320	1320	1320	1320
Adjusted R-squared	0.81	0.81	0.82	0.68	0.68	0.68
Lead Effect test	Pass	Pass	Pass	Pass	Pass	Pass
Parallel Trends test	Fail	Pass	Fail	Fail	Pass	Fail
Country and time FE	Yes	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes	Yes

Significance level: *** 1%, ** 5%, * 10%. Standard errors are clustered at country level. Lead Effect test is given as 'Pass' if estimating the Base model with a lead coefficient produces an insignificant effect at the 5% level. Parallel Trends test is given as 'Pass' if passed at the 5% level. The 'Treated unit dummy' is not reported in market-level analyses because it is, in effect, a country fixed effect.

Source: GSMA Intelligence

The effect on download speeds after two years from Model 2 in Table A3.13 holds to MNO fixed effects, the four-player sample and the exercises with the market-level dataset where we test the treatment for Austria as a whole. Meanwhile, the checks on the negative effects on upload speeds indicate that the impact appears in both the second year and after two years in the majority of alternative models, including

the market-level dataset. In both metrics we have only one of the robustness checks where estimates are insignificant, so we are confident overall about the key findings (i.e., a significant effect on download speeds two years after the merger and a negative effect on upload speeds in the second year and thereafter).

Table A3.14

3G network quality Base DD robustness checks, market-wide merger effects

	3G download speeds				3G upload speeds			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Effect in 1st year	0.284	0.241	-0.0698	-0.140	0.007	-0.0634	-0.138*	-0.127**
Effect in 2nd year	0.721	0.936**	0.222	0.053	-0.123	-0.203**	-0.364***	-0.276***
Effect after two years	1.658**	1.901***	1.130	1.355**	-0.170	-0.270**	-0.446**	-0.317***
Lead Effect test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Parallel Trends test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Check	MNO FE	Four-player sample	Close markets sample	Market-level dataset	MNO FE	Four-player sample	Close markets sample	Market-level dataset

Significance level: *** 1%, ** 5%, *10%. Robustness checks carried out with the model specification as defined in Model 2 of Table A3.13.

Source: GSMA Intelligence

b. Synthetic control approach

As with the synthetic control at the operator level, the analysis for 3G download and upload speeds does not appear to provide a good framework to determine whether the merger induced significant effects at the market level. We find that the combination of data across countries in the dataset does not generate a synthetic control that can be feasibly compared against Austria.

The predictors that we have included (pre-merger mean of the outcomes, as well as the values in 2011q2 and 2012q4, 3G spectrum and connections penetration) give the lowest pre-merger MSPE. The synthetic Austria takes values from countries in the full sample, with the results reported in Table A3.15. For both upload and download speeds, the predictor balance indicates that Hutchison and its synthetic counterpart are close in terms of observed characteristics (with the exception of 3G connections penetration in upload speeds).

Table A3.15

3G Network quality synthetic market key parameters

DOWNLOAD SPEEDS

Country	Weight	Predictor	Predictor balance		Predictor weight ³⁴
			Hutchison	Synthetic	
Croatia	0.112	3G downloads (pre-merger mean)	3.20	3.22	0.7233
Slovenia	0.087	3G downloads (2011q4)	2.57	2.44	0.0754
Sweden	0.801	3G downloads (2012q4)	3.63	3.61	0.1998
		3G spectrum (pre-merger mean)	216.45	201.42	0.0002
		3G connections penetration (pre-merger mean)	0.63	0.68	0.0013

UPLOAD SPEEDS

Country	Weight	Predictor	Predictor balance		Predictor weight ³³
			Hutchison	Synthetic	
Sweden	1	3G uploads (pre-merger mean)	1.59	1.34	0.7454
		3G uploads (2011q4)	1.28	1.07	0.1056
		3G uploads (2012q4)	1.75	1.47	0.1472
		3G spectrum (pre-merger mean)	216.45	203.8	0.0003
		3G connections penetration (pre-merger mean)	0.63	0.76	0.0015

Source: GSMA Intelligence

34. Predictor weights may not sum to 1 due to rounding.

35. Predictor weights may not sum to 1 due to rounding.

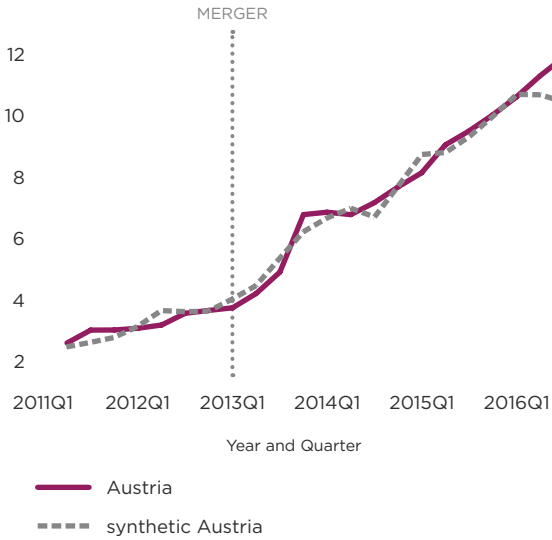
Charts A and B in Figure A3.6, however, indicate that the resulting predictions of download and upload speeds do not match Austria's values

during the pre-merger period, meaning that the synthetic control is not useful to confirm or verify the findings of the DD analysis.

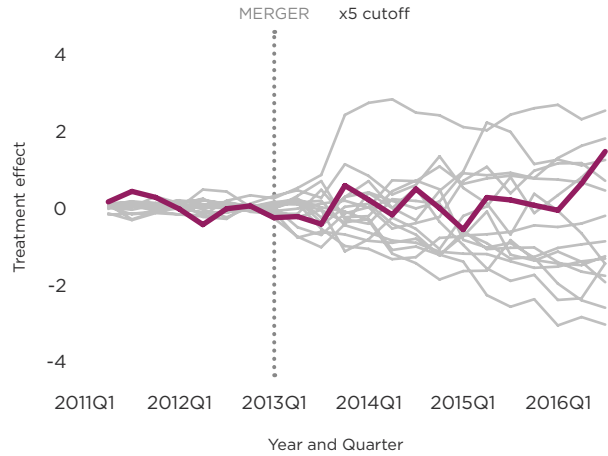
Figure A3.6

3G network quality synthetic control market

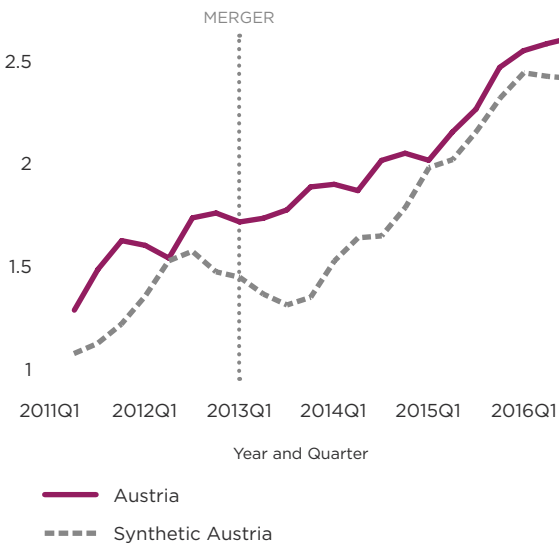
A. HUTCHISON AND SYNTHETIC AUSTRIA (DOWNLOAD SPEEDS)



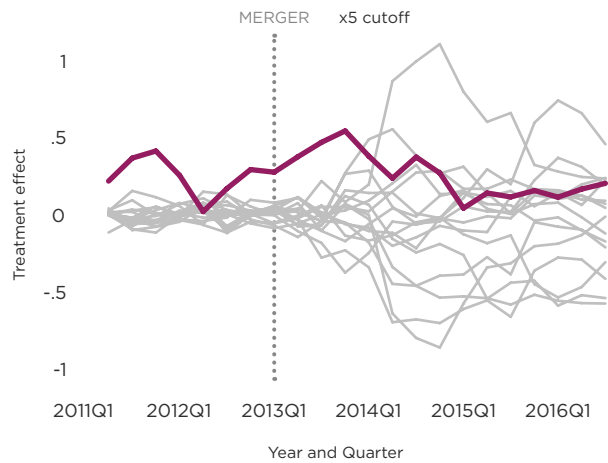
B. PLACEBO STUDIES (DOWNLOAD SPEEDS)



A. HUTCHISON AND SYNTHETIC AUSTRIA (UPLOAD SPEEDS)



B. PLACEBO STUDIES (UPLOAD SPEEDS)



Source: GSMA Intelligence

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