The role of Standard Essential Patents as barriers to entry to the 5G industry in European countries

Empirical Methods for Market Analysis

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1 Summary

This report investigates the potential for Standard Essential Patents (SEPs) to create entry barriers within the European 5G Radio Access Network (RAN) industry, hereinafter the "5G industry". SEPs cover technology essential to a technical standard, such as 5G. Since these patented inventions are incorporated directly into the standard, manufacturers cannot "design around" them; any firm aiming to produce standard-compliant equipment (like a 5G base station or smartphone) must license these SEPs, otherwise their equipment would not be considered "5G" and could not be sold as such.

My objective is to develop an empirical strategy that can distinguish to what extent the high supplier concentration observed in the market is due to artificial barriers to entry created by SEPs, or if all of the concentration can be explained away by high infrastructure costs. This leads to the central research question: "Do SEPs create entry barriers to the 5G RAN industry in European countries?".

To address it, I utilize a natural experiment stemming from the divergent national security policies concerning Huawei, a dominant supplier, across Europe. Since 2019, some nations (eg, Sweden) implemented statutory bans to remove Huawei from the market. Other nations (eg, Finland) maintained market-led approaches. This divergence creates a "supply vacuum" in banned countries that, under standard economic theory, should induce entry from marginal competitors.

To study this case, I employ a generalized difference-in-differences (DiD) strategy on a panel of 20 European countries, treating each country as a separate market. By controlling for country-specific heterogeneity, this design aims to isolate the causal impact of the ban. Specifically, I test whether the removal of Huawei induces new market entry (as standard economic theory would predict) or if the market instead consolidates into a duopoly (of mainly Ericsson and Nokia), which would reveal the persistence of SEP-driven barriers.

The theory of harm suggests that SEPs create a binding structural barrier to entry. To see this, note that while the ban removed Huawei's hardware, it does not invalidate its patent portfolio in the given market (here the banning country). Therefore, new entrants (eg, Samsung) face an asymmetric cost structure: they must pay royalties to the patent holders (including the banned Huawei) without the benefit of cross-licensing (unlike the incumbents, who already cross-

licensed before the ban). If this "patent tax" is prohibitive, the market will not self-correct via entry. Instead, the number of firms will permanently contract to a duopoly (Nokia/Ericsson), leading to higher prices and reduced innovation compared to markets where the patent-holder remains active as a competitor.

The rest of the report is structured as follows. Section 2 provides the industry context. Section 3 reviews the relevant literature. Section 4 details the empirical strategy. Section 5 presents potential remedies and recommendations. Finally, section 6 concludes.

2 Context

The 5G standard is established through a global consensus process, led primarily by the 3rd Generation Partnership Project (3GPP), which is made of seven telecommunications standard development organizations. In Europe, the relevant organizational partner is the European Telecommunications Standards Institute (ETSI). They play a crucial role: once a technology is adopted into the 3GPP standard, any patent covering that technology is deemed an SEP. This designation grants the patent holder significant market power, as compliance with ETSI is mandatory for deploying networks in Europe. This means other firms wishing to implement equipment using those technologies are required to license the patent and pay royalties to the patent holder.

This mechanism creates a distinctive competitive dynamic: firms initially compete ex-ante (before standardization) to have their technology chosen as the standard. Once successful, they gain ex-post monopoly power over that specific technology through the resulting SEP (Lerner & Tirole, 2015).

To mitigate this monopoly power, ETSI requires SEP holders to commit to licensing their IP on Fair, Reasonable, and Non-Discriminatory terms (FRAND). The problem is that the interpretation of FRAND is a constant source of litigation, due to its loose and vague definition. Moreover, the licensing of SEPs is a significant burden for firms: there are thousands of SEPs, many of which stack on top of each other. This phenomenon is called royalty stacking ("Patent Holdup, Royalty Stacking, and the FRAND Standard", 2023).

There is high supplier concentration in the industry: 75 percent of SEPs are owned by the top 10 owners globally (Patently, 2025) as seen in Fig. 1. In the 5G industry, each country is considered one distinct market, since each country has their own telecom operators (even though they can be present in multiple markets). In Europe, each market is covered by an average of 2 to 4 patent holders, primarily Ericsson, Nokia, and Huawei (EuropeanStudiesReview, 2025). These suppliers sell their products (patents, hardware for 5G base stations, software to operate it) to telecom operators (eg, Elisa, Telia, DNA in Finland), who in turn sell network subscriptions and services to end-users (individuals and businesses).

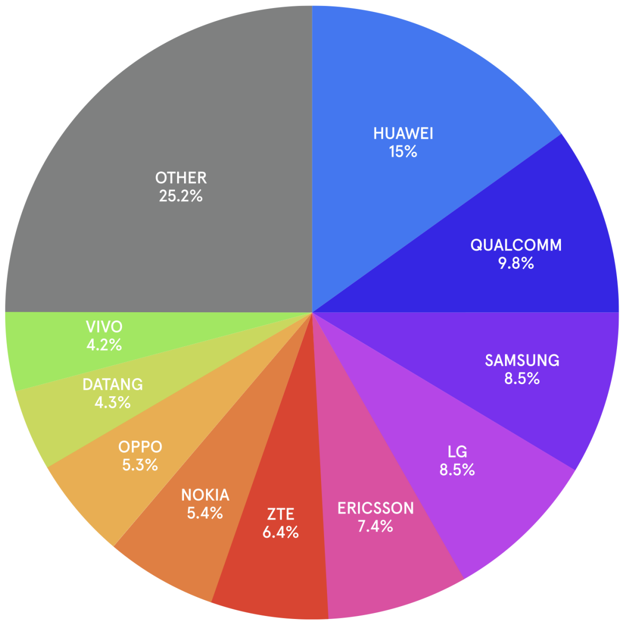

Figure 1: Share of global 5G SEPs owned by a given firm (Patently, 2025)

Moreover, the industry presents a cost asymmetry between incumbents and potential entrants driven by cross-licensing. The two European incumbents, Ericsson and Nokia, possess portfolios of legacy patents from the 2G, 3G, and 4G eras. This allows them to engage in cross-licensing agreements with each other and with Huawei, trading access to their patents for access to others'. On the other hand, new entrants or firms lacking the same level of European patent footprint thus face a royalty stack, meaning cumulative cash payments to all SEP holders. This represents a surcharge on their marginal cost. An example of a firm in this situation is Samsung, with only 4.8 percent of market share in Europe (EuropeanStudiesReview, 2025), despite being a key player in the global scale, especially in South Korea. Samsung possesses the manufacturing infrastructure to compete, but they lack the deep portfolio of European legacy standards (GSM/UMTS) held by the incumbents, forcing them to face higher licensing barriers than Nokia, Huawei, or Ericsson.

The equilibrium of this oligopoly was disrupted by a geopolitical shock serving as the "treatment" in this study. In May 2019, the United States Department of Commerce placed Huawei on its "Entity List", citing national security risks regarding the potential for Chinese state espionage. This triggered a regulatory cascade in Europe, starting with the EU's "5G Cybersecurity Toolbox" in January 2020, which advised member states to restrict "high-risk vendors". Following this guidance, European nations adopted divergent policies. The United Kingdom issued a ban in July 2020, prohibiting the purchase of new Huawei equipment after December 2020 and mandating the removal of all existing gear by 2027. Some countries, like France, issued soft bans, still allowing telecom operators to work with Chinese 5G vendors (Huawei, ZTE), but preventing renewals. Other nations, such as Sweden, Denmark, Estonia, Latvia, and Romania, passed more stringent bans between 2020 and 2021, explicitly forbidding their operators from engaging with Chinese vendors (Reuters, 2023). Other countries, such as Finland, have not implemented restrictions.

3 Literature review

The empirical strategy of this paper draws upon three distinct strands of industrial organization literature: structural models of market entry, the impact of regulatory barriers on competition, and the economics of standard-essential patents (SEPs).

My analysis is based on the relationship between market size and market structure. Bresnahan and Reiss (1991) established the framework for estimating entry thresholds. They suggested that in concentrated industries, the ratio of market size required to support N versus $N + 1$ firms reveals the toughness of post-entry competition. They argue that if a market grows significantly without inducing new entry, unobserved fixed costs must have shifted. In this paper, I lack the data to perform the full structural estimation, but I adopt their theoretical intuition: a failure of entry in a large, "vacated" market (eg, post-ban Sweden) implies that the entry threshold has been artificially raised by a non-infrastructure cost, which I identify as the SEP barrier.

In the literature, past empirical works have exploited regulatory variation to measure the causal impact of barriers. For instance, Schivardi and Viviano (2011) utilized regional variation in Italian retail entry laws to demonstrate that artificial barriers effectively increase incumbent profit margins while reducing overall sectoral productivity. Similarly, I treat the Huawei ban not as a trade policy, but as a "regulatory shock" that restricts the choice set of firms (ie, an exogenous supply contraction).

Finally, my proposed mechanism is grounded in the theoretical literature on standard-setting by Lerner and Tirole (2015). They provide the analysis of the trade-off inherent to SEPs: on one hand, standardization reduces coordination costs and accelerates technology adoption; on the other, it grants "ex-post" monopoly power to patent holders. The authors argue that without binding price commitments (which FRAND attempts to be, but often fails), SEP holders can engage in holdup, essentially taxing downstream innovation. Cross-licensing often mitigates this for incumbents, so this supports the "asymmetric cost" argument: the holdup problem is not universal, but falls disproportionately on entrants (like Samsung) who lack the EU portfolio to cross-license, thereby making SEPs function as a structural barrier to entry.

4 Empirical analysis

To quantify the impact of the Huawei ban on market structure and isolate the role of SEPs, I employ a causal inference framework using panel data. The strategy relies on the exogenous variation introduced by divergent national security policies across Europe to estimate the causal effect of removing a dominant incumbent.

4.1 Data description

I construct a panel dataset covering about 20 European countries over the period 2018–2023. So that the ban is around the middle. I exclude countries that are ambiguous or that had soft-bans like France. I only keep countries that have either explicitly banned Huawei, or not banned it at all. The unit of observation is the country-year ($N * T = 120$ observations).

The dependent variable is N_{it}: the number of active suppliers, defined as the count of 5G RAN equipment vendors holding a market share greater than 5 percent in country i in year t. I would get data on market shares using reports from Strand Consult and contract announcements monitored by the European 5G Observatory.

The treatment variable is Ban_{it}: dummy variable that equals 1 if country i

has an active ban or exclusion order against high risk vendors (including Huawei) in year t, and 0 otherwise. Based on the regulatory timeline we've mentioned previously, the treatment group would include: Sweden, Denmark, Estonia, Latvia, Lithuania, Romania, Belgium, UK. The control would be: Finland, Austria, Hungary, Poland, Spain, Greece, Germany, Ireland, Cyprus, Croatia, Slovakia, Bulgaria.

The vector of control variables is X_{it}: it includes log GDP per capita to control for economic development and willingness to pay (WTP). It also includes population density to proxy for deployment costs, the reason being that denser markets theoretically support more entrants due to lower per-capita infrastructure expenses. This data could be sourced from Eurostat.

4.2 Methodology: generalized difference-in-difference

The countries that banned Huawei did so in different dates. For instance, for the UK it was in 2020, and for Denmark in 2021. Therefore, a simple 2x2 DiD approach would not be appropriate, because of the staggered adoption of the bans. For this reason, I use a generalized difference-in-differences (two way fixed effects) approach. This way we can use the full panel, and use the "not treated yet" and "never treated" units as the counterfactual for the banned nations.

This brings the following regression equation:

$$N_{it} = \alpha_i + \delta_t + \beta(Ban_{it}) + \gamma \mathbf{X}_{it} + \varepsilon_{it} \tag{1}$$

Where α_i are country fixed effects absorbing time-invariant unobservables (eg, national champions like Ericsson in Sweden or Nokia in Finland), δ_t are year fixed effects controlling for global shocks (eg, COVID or chip shortages), Ban_{it} is the treatment indicator ($Ban_{it} = Treat_i * Post_{it}$). Then $varepsilon_{it}$ is the error term.

Given that treatment is assigned at the national level, I cluster standard errors at the country level. However, since we only have 20 clusters (ie, 20 countries) there would be downward bias, which creates a risk of false positives (ie, over-rejecting the null hypothesis). An appropriate number of clusters would be around 50, because standard cluster-robust inference relies on asymptotic theory. The problem is that there are not 50 countries in Europe, so we can't have 50 clusters. To address this shortcoming, I would compute p-values using the Wild cluster bootstrap process (Cameron et al., 2008). This method does not rely on a theoretical t-distribution, but instead it generates an empirical distribution of the test statistic by resampling the residuals at the cluster level, so that we can make robust inferences even with smaller samples. At least better than with normal clustering.

4.3 Identification strategy

The causal interpretation of β relies on three assumptions.

First, the parallel trends assumption, which poses that in the absence of the ban, the market structure in treated countries would have evolved along the same trend as in the control group. To test for this, I verify that there were no pre-existing divergences between the two groups by estimating an event study specification. In this test, I replace the single post-treatment variable with a set of time-relative dummy lags. For Example D^{-2} for 2 years before, and so on. If the coefficients on these dummy lags are statistically insignificant, that would support the parallel trends assumption. That would mean that the control group is likely a valid counterfactual.

Second, the no anticipation assumption. The US entity list was published in 2019, but the European legislation remained uncertain until 2020. To mitigate potential anticipation bias, I consider the treatment year based on the announcement of the ban, instead of the final compliance deadline. This approach is more likely to capture the immediate reaction of the market.

Third, the Stable Unit Treatment Value Assumption (SUTVA), meaning no spillovers. I assume that a ban in Sweden (for example) does not affect the Finnish market. My reasoning is that while vendors might theoretically lower prices in open markets to maintain revenue, there's enough friction to prevent it. The firms likely can't adjust that quickly, given the complex and costly infrastructure in the 5G industry. Although I agree that this might be up for debate.

4.4 Isolating the causal mechanism

A potential critique to this approach would be that a drop in N might reflect high infrastructure costs (F_{infra}) rather than SEP barriers (F_{SEP}). To disentangle these two barriers, I employ a logic of process elimination which I'll refer to as the "Samsung test".

Assume that potential entrants like Samsung possess the necessary manufacturing scale and technical infrastructure, as evidenced by their significant market share in the US and South Korea. Therefore, F_{infra} is not the binding constraint for these firms. If infrastructure costs were the only barrier, the supply vacuum created by the ban should induce Samsung to enter, bringing back N to its pre-ban equilibrium.

However, if the estimator yields a negative coefficient (ie, $\beta < 0$), it implies that the market consolidates to a duopoly ($N = 2$) and stays there. In other words, Samsung is facing a barrier that they cannot overcome. But Samsung has the factories, the required knowledge, expertise, and capital. So, the remaining binding constraint would likely be the asymmetric cost of SEPs. Unlike incumbents who cross-license, entrants must pay the full royalty stack to patent holders. Thus, a persistent drop in competition suggests that SEPs can be causally identified as the structural barrier.

4.5 Robustness checks

To check the robustness of the model, I propose two tests.

First, a placebo test in time by re-estimating the model assuming a placebo ban occurred in 2016 (or any earlier date when nothing relevant to 5G bans happened). Finding a null result (insignificant β) in this pre-treatment period would strongly suggest that the model is not capturing spurious trends or noise.

Second, I propose to use synthetic controls to some of the largest markets, like Sweden or the UK for example. With this method, I would construct a synthetic Sweden (for example) composed of parts of the controls (eg, 40 percent Finland, 20 percent Austria, 40 percent Spain) so that the pre-treatment prediction error is minimized. Essentially that would make a copy of Sweden, to use as a counterfactual. If the divergence between the actual and synthetic trend lines are the same or very similar to the DiD estimates, it strongly suggests that the results are robust to control group selection.

5 Remedies and recommendations

If the model confirms that SEP barriers prevent market self-correction, that would imply that the security concerns about China are solidifying a duopoly. These security concerns are outside the scope of this paper, therefore I will not discuss policy measures to address national security in telecommunications. Instead, I propose three measures to reinstore competitive pressure without compromising national security.

First, I would subsidize the Open Radio Access Network (Open RAN). Currently, the market is vertically integrated, meaning an operator must buy the radio, the baseband unit, and the software from the same vendor (eg, Nokia). Open RAN separates these components, thus it allows operators to mix and match vendors (eg, Samsung radios with Nokia software). By subsidizing Open RAN, European governments can artificially lower the fixed entry costs for specialized firms that lack the scale to build a full end to end stack of hardware and software. This would reduce the incumbent advantage, because it would change the unit of competition from "entire network" to "individual components".

Second, it is important to address the root cause of the "SEP tax". This is directly in line with what is proposed by Lerner and Tirole (2015). The authors explain that the current system relies on ex-post FRAND negotiations, which occur after the standard is set and the technology is locked in. At this stage, the patent holder has total monopoly power, which creates the holdup problem. Therefore, the problem could be addressed by mandating ex-ante licensing disclosures within standard-setting organizations like ETSI. This way, patent holders would be required to commit to specific maximum royalty rates before a technology is voted into the standard. This creates competition by forcing firms to compete on price during the standard-setting phase. It would induce auction-like behaviour from the patent holders. Granted, it's possible that they might not bid true valuations. However, that is not a big issue, because it would still be a step towards more competition, which is better than the current system. Right now, standard setting organizations (SSOs) select a standard based on technical criteria, and royalty price is not a factor. Therefore, they might choose to standardize a technology that is technical superior, but there might be another technology that is only marginally lower "quality" (in technical criteria) but considerably cheaper in price (ie, royalty price). The latter option would be the most optimal, from a welfare optimization stand point. Considering price as a feature in the selection process, would add competition and likely result in a more efficient outcome for the market as a whole, meaning less deadweight loss. I recognize that there's a shortcoming to this suggestion. For instance, it might be hard to price a patent for a technology, because it is often implemented many years later, so the context and future potential might be hard to assess. Still, I believe it's a suggestion worth exploring and considering.

Third, and finally, I would suggest to the competition authorities to consider extending FRAND obligations beyond patents to interoperability interfaces. There is a legal precedent similar to this: the 2004 antitrust decision of the European Commission against Microsoft (Wikipedia, 2004). The complaint was filed by competitor Sun Microsystems, and the European Commission ruled that Microsoft's refusal to disclose server interoperability information constituted an abuse of dominance. The Commission mandated that Microsoft release its proprietary API documentation to competitors, arguing that withholding "interface protocols" stifled innovation in the secondary market. Following this incident, Linux, Unix, Solaris, and other server architectures could finally interact with Windows. I believe the same ruling could be applied to the 5G industry, to enhance interoperability. This suggestion is related to the first one, about subsidizing Open RAN, but it takes it a step further by bringing the FRAND requirements to it as well.

6 Conclusion

In this report, I proposed an empirical strategy to address the problem that SEPs might be weaponized (intentionally or not) as entry barriers in the 5G industry in Europe. This is a relevant issue, because high royalty costs mean higher costs, which are likely passed on the end-users (us). Moreover, the current system lacks ex-ante pricing competition (before a standard is decided), which exacerbates welfare inefficiency.

On a separate note, policymakers should take into account the negative welfare externalities stemming from their security concerns regarding China. The models and suggestions detailed in this report also aim to clarify the underlying mechanisms of this phenomenon.

To ensure that Europe's digital infrastructure remains both secure and cost-effective, I suggest policymakers move beyond simple exclusionary bans and instead opt for more active market-shaping measures. Specifically, the promotion of Open RAN and the enforcement of ex-ante licensing transparency. Without such interventions, European consumers might be left indefinitely subsidizing an inefficient duopoly under the guise of national security.

Disclaimer: an AI tool in Google Docs was used to check for grammatical errors and slightly tweak the flow of certain sentences. This was done only to boost clarity and minimize possible misunderstandings.

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