Policy framework for 5G market inefficiencies: addressing royalty-stacking and information asymmetry in the EU

Microeconomic Policy: Case Study

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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 the chance of possible misunderstandings. AI was also used to turn my handwritten graph sketches into latex commands.

1 Executive summary

The deployment of 5G infrastructure is the backbone of Europe's digital transition, yet the market mechanism governing its critical technology (Standard Essential Patents, hereinafter SEPs) is structurally failing. This report presents a revised policy framework to address the two fundamental market failures distorting the 5G industry: adverse selection, driven by information asymmetry regarding patent validity, and the hold-up problem, driven by the timing of investment. These failures generate significant inefficiencies, inflating costs and delaying the deployment of essential infrastructure.

To understand these frictions, we must first define the asset class in question. SEPs cover technology essential to a technical standard. 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 a smartphone) must license these SEPs. Without a license, their equipment would not be considered "5G" and could not be sold. This unique "lock-in" feature grants SEP holders significant market power.

From an economic perspective, the 5G market is characterized by a natural monopoly cost structure (Fig. 2). The fixed costs (F) of R&D required to develop the standard are considerable, while the marginal cost (c) of licensing the technology to an additional user is negligible. Consequently, the Average Cost (AC) curve is strictly downward-sloping and lies above the Marginal Cost (MC) curve. This structure implies that perfect competition ($P = MC$) is unsustainable, necessitating an oligopolistic market structure dominated by a few incumbents (e.g., Nokia, Ericsson).

High concentration is inherent to the industry's cost structure, but the current friction arises from information asymmetry and coordination failure. In April 2023, the European Commission proposed a regulation (COM(2023) 232, EuropeanCommission (2023)) aiming to solve these issues by mandating a central register of SEPs and introducing "essentiality checks" to filter out invalid patents. However, this proposal has stalled due to concerns that it creates excessive bureaucratic overhead without adequately addressing the holdup problem; that is the ability of patent holders to extract excessive rents after implementers have sunk costs into infrastructure.

The goal of this report is to provide an alternative policy pathway. I argue that while the transparency goals of the 2023 proposal were sound, the mechanism was flawed. Instead of relying solely on ex-post bureaucratic checks, I suggest a framework based on ex-ante price commitments to address the market failures, consistent with Lerner and Tirole (2015).

The remainder of the report is structured as follows. Section 2 analyzes the economic nature of the 5G market, modeling the Cournot complements problem and royalty stacking. Section 3 and Section 4 identify the specific market failures of adverse selection (the lemons problem) and investment timing. Section 5 discusses the social cost and positive externalities. Section 6 outlines the policy recommendations. Finally, section 7 presents concluding remarks.

2 The economic nature of the 5G industry

To regulate the 5G market effectively, policymakers must first recognize that it does not and cannot function like a perfectly competitive market. The industry is structurally defined by high fixed costs, complementary assets, and time-inconsistency problems that distort pricing signals. In this section, I present the context of the 5G landscape in the EU, then explain why it's a natural monopoly, and discuss the interdependability concept that is present with 5G SEPs.

2.1 Context in Europe: the regulatory gap

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).

To address these inefficiencies, the European Commission proposed a new regulation on SEPs in April 2023 (COM(2023) 232). This proposal sought to shift the governance of SEPs away from purely private litigation towards a more regulated framework overseen by the European Union Intellectual Property Office (EUIPO). The regulation contained five building blocks: (1) a centralized register of SEPs to improve transparency; (2) mandatory "essentiality checks", where independent evaluators verify a sample of declared patents to filter out invalid claims; (3) a non-binding "aggregate royalty" notification process, allowing patent holders to signal the total cost of the standard; (4) a mandatory FRAND determination procedure that parties must conclude before they are permitted to initiate infringement litigation in national courts; (5) SME support measures, that is free advisory services and reduced fees for SEP registrations and essentiality checks (EuropeanCommission, 2023).

However, this regulation was never implemented. Despite being adopted by the European Parliament in February 2024, the proposal faced fierce opposition from major SEP holders (eg, Nokia, Ericsson) and stalled in the Council of the European Union due to a lack of consensus among Member States. In February 2025, the Commission officially withdrew the proposal, citing "no foreseeable agreement". Consequently, the market remains unregulated, and the structural failures described in the following sections persist without legislative correction.

The industry in question is one with high supplier concentration: 75 percent of 5G 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).

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.

2.2 A natural oligopoly

The industrial organization of the 5G sector is fundamentally determined by its cost structure. Firms such as Nokia and Ericsson invest billions of euros in R&D to develop the standard before a single unit of technology can be licensed. I denote this upfront investment as a fixed cost F. Once, the technology is developed, the marginal cost c of licensing is negligeable. Therefore, the cost function is $C(q) = F + cq$, where $F >> c$. As illustrated in Fig. 2, this structure dictates that the average cost (AC) curve is strictly downward sloping, as the considerable fixed costs are distributed over an increasing number of units. The AC curve lies strictly above the marginal cost (MC) curve for all relevant quantities.

Standard microeconomic theory suggests that allocation efficiency is achieved when price equals marginal cost (P=MC). However, as shown by the financial

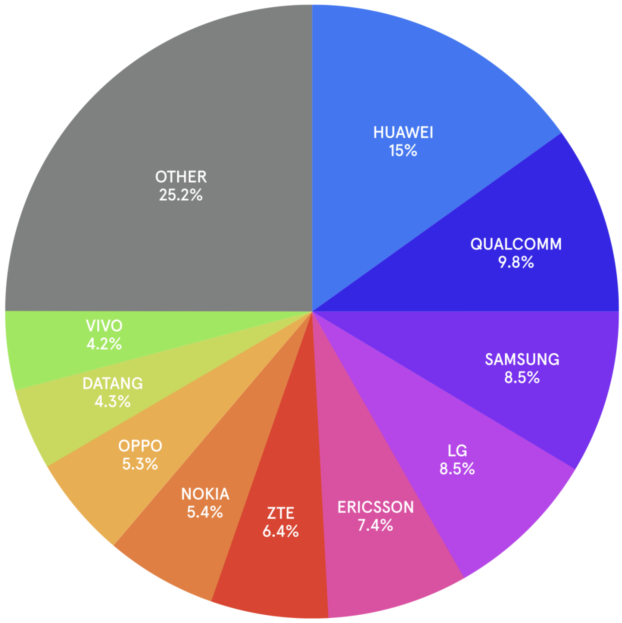

Figure 1: Share of global 5G SEPs owned by a given firm (Patently, 2025)

loss gap in Fig. 2, a regulator cannot impose perfect competition pricing in this market because patent holders would generate revenue insufficient to cover their fixed R&D costs (since P<AC), leading to insolvency.

Thus, the market needs a markup (P>MC) to remain viable. This deviation from perfect competition is not a market failure in itself, but a structural necessity of high-innovation industries. The policy challenge, therefore, is not to force the market structure into a competitive state, but to regulate the resulting oligopoly to prevent the markup from becoming exploitative while ensuring that the fixed costs of innovation are recouped.

Here, I consider monopoly pricing for theoretical and argumentation purposes, meaning that would consider only one incumbent, but the idea can be further applied to oligopoly structures (e.g., Nokia/Ericsson).

2.3 Inter-dependability: the Cournot complements problem

A unique and complicating feature of the 5G standard is its fragmentation. Unlike a traditional monopoly where a single firm sells a complete product, the 5G standard is a composite good requiring inputs from n distinct patent holders (eg, patents for antennas, coding, and modulation). This structure creates a

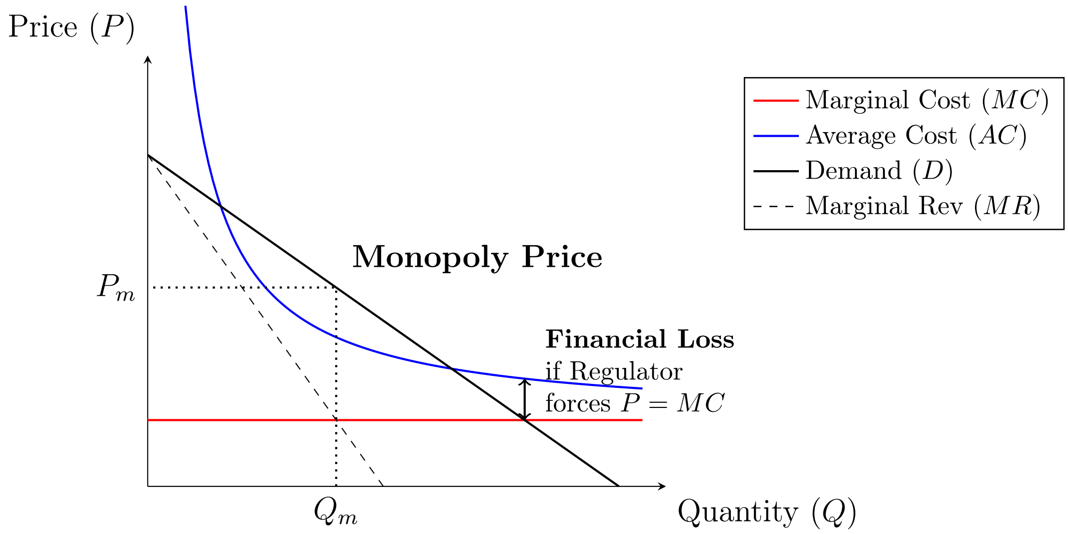

Figure 2: Natural Monopoly Pricing. The firm sets quantity Q_m where $MR = MC$. If a regulator forces competitive pricing ($P = MC$), the firm incurs a loss because $AC > P$.

problem of inter-dependability referred to as the Cournot complements problem.

The 5G standard is a bundle of complementary goods where manufacturer compliance requires access to all essential patents. Let p_i represent the royalty charged by firm i for its specific component. The total price of accessing the standard, P, is the sum of these individual royalties, $P = \sum p_i$. Because the patents are perfect complements (meaning a manufacturer cannot produce a compliant device without licensing all of them) each patent holder acts as a monopolist for their specific component.

Friction arises because these firms set their prices non-cooperatively. In an uncoordinated ex-post setting, when firm i sets its profit-maximizing royalty p_i, it ignores the negative externality that its price increase imposes on other patent holders. Specifically, if Nokia raises its royalty rate, the total cost of the standard increases, which reduces the downstream demand for the final product and consequently reduces the royalty revenue for Ericsson and Huawei for example. This lack of coordination causes royalty-stacking to occur. Thus, the uncoordinated price will be higher than the price a monopoly would charge for the entire bundle $P^{unc} > P^M$. The sum of the individual monopolies creates a "double marginalization" effect, resulting in a total royalty burden that is higher than the joint profit-maximizing level. This inefficiency is distinct from the natural monopoly markup described in the previous subsection. It is a coordination failure that stifles downstream adoption and generates a deadweight loss for society that exceeds even that of a standard monopoly.

3 Market failure I: asymmetric information and adverse selection

While the natural monopoly structure describes the cost of producing the standard, a distinct market failure arises in the licensing of the standard: information asymmetry. As noted by Lerner and Tirole (2015), Standard Setting Organizations (SSOs) perform a "discovery function" to identify valuable technologies, but they do not verify whether a declared patent is truly essential. This creates a "lemons market" problem (Akerlof, 1970).

3.1 Overdeclaration and junk patents

In the 5G ecosystem, the seller (the patent holder) has private information about the quality of their patent portfolio that the buyer (the implementer) lacks. A patent holder knows whether their specific patent is truly essential to the 5G standard or merely "declared" essential. The implementer, facing a thicket of thousands of declared SEPs, cannot cost-effectively verify the validity of every claim. Rational patent holders thus have an incentive to over-declare. By flooding the registry with marginal or invalid patents ("junk patents"), they inflate their perceived portfolio strength to demand higher royalties. For instance, the EU suggests that as much as 85% of declared 5G SEPs are not actually essential when scrutinized in court (ParolaAnalytics, 2025). This creates a pooling equilibrium: implementers cannot distinguish high-quality (ie, true SEPs) from low quality (ie, junk/fake SEPs) ex-ante.

3.2 The adverse selection mechanism

We can model this situation using the Rothschild-Stiglitz framework for asymmetric information, adapted to the context of patent licensing (Fig. 3). The figure illustrates the decision-making problem of an implementer who must decide whether to sign a license without knowing if the underlying patents are valid SEPs or invalid SEPs. Whether a patent is a valid SEP or not is decided in court, after litigation. Therefore, we can visualize the license as an insurance against getting sued in future periods.

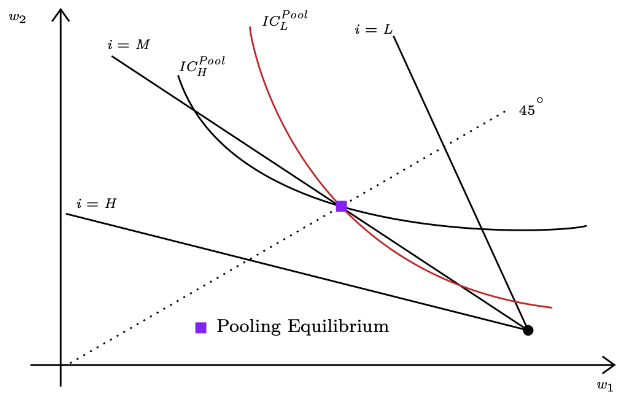

Figure 3: Rothschild-Stiglitz framework (graph from Lecture 7)

The axes w_1 and w_2 represent the implementer's profit in two distinct states. The vertical axis w_2 represents the "bad state" where the patent is valid; here, an unlicensed firm faces litigation and significant damages. The horizontal axis w_1 represents the "good state" where the patent is invalid (junk), and the unlicensed firm faces no liability. The black dot on the bottom right (the endowment point) depicts the implementer's position if they choose not to license. This position is highly volatile: if the patent is junk ($i = L$), profit is high, but if the patent is valid ($i = H$), the firm suffers severe losses. This variance reflects the litigation risk inherent to the ex-post holdup problem.

To mitigate this volatility, the implementer often chooses to settle (license the portfolio), which acts as insurance. The 45 degree line represents a certainty equivalent, where the firm pays a fixed royalty regardless of the actual validity of the individual patents. However, because the implementer cannot cost-effectively distinguish "junk" from "true" SEPs ex-ante, the market settles at the pooling equilibrium. At this equilibrium, the royalty rate is set based on the average probability of validity. The indifference curves (IC) show that the firm is forced to accept a cross-subsidy: to ensure coverage for the necessary true SEPs, the implementer must effectively pay a premium that subsidizes the fake SEPs in the portfolio. This structural inefficiency provides a theoretical justification for the EU's proposed essentiality checks, which aimed to screen out invalid patents before this bargaining phase begins.

The problem with the EU proposal is that having an independent body conduct these essentiality checks would require considerable transactional costs.

Moreover, the body might lack the technical expertise required to accomplish this task.

4 Market failure II: investment timing and the holdup problem

The second market failure in the 5G market is the holdup problem, a form of time inconsistency inherent to standard setting. While Section 4 addressed the uncertainty regarding patent quality, this section addresses the shift in market power over time.

As described by Lerner and Tirole (2015), the economic relationship between a patent holder and an implementer (e.g., a connected car manufacturer) evolves through two distinct phases. In phase 1, before the standard is finalized (ex-ante), the market is competitive. For any specific functionality i (eg, data encoding), there are usually $j \geq 1$ substitute ways (or technologies) to implement the functionality. We can index this ex-ante competition by a maximum markup $m_i \geq 0$. If the best implementation of the functionality is in the public domain or under open source license, then $m_i = 0$.

The hold-up problem arises in phase 2 (ex-post), after the standard is finalized. Once the implementer has sunk specific investments (I) into the standard, the chosen technology becomes essential, and the alternative substitutes from phase 1 are no longer viable. In an unconstrained ex-post negotiation, the SEP holder acts as a monopolist. They can set a royalty $p_i > m_i$, extracting not just the value of the technology, but also a portion of the implementer's sunk costs I. This ability to ignore the ex-ante competitive constraint (m_i) is the holdup problem.

Anticipating this ex-post opportunism, the implementer rationally expects their return on investment to be taxed by the SEP holder. If the expected hold-up is severe enough, the implementer may refuse to invest in the first place (if the net present value $NPV < 0$), which would result in under-deployment of 5G infrastructure.

As suggested by Lerner and Tirole (2015), vague commitments to license on FRAND terms are often insufficient to solve this problem. Without a binding price commitment determined ex-ante (before lock-in) that forces $p_i \leq m_i$, FRAND declarations function as "cheap talk", and fail to prevent the SEP holder from exercising ex-post market power. This necessitates structural remedies that mimic ex-ante competitive constraints, such as royalty price caps for example.

This explains the limitation of the EU proposal: it introduced a notification for an aggregate royalty, but the mechanism was non-binding. Therefore, it failed to enforce the ex-ante markup constraint (m_i), leaving the commitment problem unresolved.

5 The social cost: positive externalities

The market failures described in Section 3 (adverse selection) and Section 4 (holdup) would be concerning in any industry. However, they generate a disproportionately high social cost in the context of 5G due to the presence of significant positive externalities.

For instance, 5G is an enabling technology for the broader industrial economy. It serves as a critical input for "smart" devices, autonomous vehicles, remote medical procedures, and the Internet of Things (IoT), to cite a few applications. Therefore, economically, we can argue that 5G functions as a "general purpose technology" and that its deployment lowers the cost of innovation in downstream sectors. This mechanism could constitute a factor of growth in the economy as a whole. The macro-level repercussions are outside the scope of this paper, as the focus is on microeconomic policy; however, it is useful to keep in mind the bigger picture as well.

If we subscribe to the idea that 5G is a "general purpose technology", then we have divergence between private and social value. The marginal private benefit (MPB) is the revenue a telecom operator (eg, Elisa) can generate from selling 5G subscriptions. However, the marginal social benefit (MSB) includes the spillover effects: productivity gains in manufacturing, energy savings in smart grids, accident reductions in autonomous driving, and more. The telecom operator cannot fully monetize those spillovers. Therefore, for any given quantity of 5G infrastructure, we have $MSB > MPB$.

Standard microeconomic theory dictates that markets with positive externalities naturally under-provide the good even under perfect competition. Needless to say, the oligopolistic nature of the 5G SEP market only exacerbate this inefficiency: through the hold-up problem (acting essentially as a tax on investment), and through royalty stacking (inflating the marginal cost), restricting the deployment of 5G even further below the social optimum.

As an example, if a licensing dispute delays the rollout of 5G in a region by two years, the cost is not merely the lost royalty revenue for Nokia or the lost subscription revenue for Telia. The true social cost is the two-year delay in the transition to safer autonomous vehicles, remote medical devices, and so on. I suggest that this "shadow cost" further justifies regulatory intervention.

6 Policy recommendations

The EU proposal focused on ex-post remedies, primarily attempting to fix the information asymmetry through transparency registers and essentiality checks. While these measures address the adverse selection problem, they fail to resolve the fundamental hold-up problem because they leave the bargaining process in the ex-post phase, when the implementer's costs are sunk and the standard locked. To improve allocative efficiency, the policy must shift the locus of competition from ex-post to ex-ante.

In the current system, standard-setting organizations (SSOs) select technologies based purely on technical merit, ignoring price. This effectively sets the ex-ante elasticity of demand to zero. The approach by Lerner and Tirole (2015) restores the competitive benchmark by forcing patent holders to bid for inclusion in the standard. Therefore, I suggest mandating all SSOs to operate under the following framework.

Phase 1: discovery phase (technical discussion), where the SSO members discuss which technology is technically better for a given feature. This would allow to assess their valuations $V(S)$ for a set S of features i.

Phase 2: the holders of patents to the features included in S commit to royalty price caps $\bar{p}_i$, non-cooperatively and simultaneously.

Phase 3: the SSO (made of users) selects the standard that maximizes user welfare W, such that

$$\max_{S} \left\{ V(S) - \min \left\{ P(S), P^m(S) \right\} \right\},$$

where $P(S)$ is the total royalty price implied by the set S of features given the price caps.

Phase 4: the owners of patents mapping to the selected standard decide if they form a pool or not (still allowing for individual licensing). They set a price for the bundle, and an individual-license price $p_i = p^{IL} \leq \bar{p}_i$.

Phase 5: the users choose whether to license individually or through the patent bundle, according to their needs.

This approach alters the role of FRAND. In the current EU framework, FRAND is the primary constraint on monopoly power, but fails due to its vagueness. In the new framework, there is theoretically no need for FRAND because the price caps already deliver the competitive benchmark price. However, SSOs may make mistakes or fail to identify every relevant patent during the discovery phase. Therefore, FRAND should be retained not as a primary pricing mechanism, but as a complementary safety net to cover these unidentified functionalities, serving as insurance against the shortcomings of the discovery process.

Thus, as far as the EU proposal is concerned (whose five building blocks are listed in Section 2), I suggest keeping the centralized registry, the random essentiality checks, and the SME support. Then, I suggest discarding the non-binding aggregate royalty and the FRAND determination procedure (which would be replaced by the 5-phase framework I described).

Finally, as a complement to the licensing reform, policymakers could consider subsidizing Open Radio Access Network (OpenRAN) architectures. OpenRAN enables operators to "mix and match" components from different vendors. For example, deploying Samsung radios with Nokia software, thus unbundling the vertically integrated stack that currently dominates the market. This architecture holds the potential to further mitigate the holdup power of incumbent firms by lowering entry barriers, but it represents a significant industrial shift and thus needs its own dedicated welfare analysis paper to determine its long-term efficiency.

7 Conclusion

The policy recommendations shift the locus of competition from ex-post to ex-ante, which the 2023 EU proposal had failed to do. However, the new framework is not perfect and presents room for improvement. First, one could argue it is socially efficient for an IP holder to charge different royalty rates to different classes of users. That is, distinguishing between a high-value connected car (higher class) and a low-value IoT sensor (lower class). This would make prices multidimensional (ie, vectors of prices) and would make competition follow Ramsey pricing, where markup is inversely related to demand elasticity. By adding more granularity in the pricing scheme, we can theoretically achieve more efficiency, but at the cost of additional administrative complexity and thus transactional costs. On the other hand, a uniform price cap may price out low-margin applications. Future policy must therefore balance the precision of user classes with the simplicity required for a functional market. Second, the suggested framework does not capture the dynamic evolution of technology. Backward compatibility imperatives imply that the inclusion of a patent today grants market power for decades. For SSOs, anticipating the endogenous evolution of technology when selecting a standard is challenging. Thus, future research should focus on quantifying this endogenous evolution.

References

Akerlof, G. A. (1970). The Market for "Lemons": Quality Uncertainty and the Market Mechanism. *The Quarterly Journal of Economics*, *84*(3), 488. https://doi.org/10.2307/1879431

EuropeanCommission. (2023). EU 2023 Proposal: COM(2023) 232. https://single-market-economy.ec.europa.eu/industry/strategy/intellectual-property/patent-protection-eu/standard-essential-patents_en

EuropeanStudiesReview. (2025). EU Sanctions Against Russia: A Study of Their Evolution Disinformation, Subversion, and the Challenge of Resilience for Democracies Divergence amid Unity: Hungary's Approach to EU Migration Policy. https://europeanstudiesreview.com/wp-content/uploads/2025/09/esrsept25-f.pdf

Lerner, J., & Tirole, J. (2015). Standard-Essential Patents. *Journal of Political Economy*, *123*(3), 547–586. https://doi.org/10.1086/680995

ParolaAnalytics. (2025). 5G Standard Essential Patents:Key Players and Trends in 2025. https://parolaanalytics.com/blog/5g-standard-essential-patentskey-players-and-trends-in-2025/

Patent Holdup, Royalty Stacking, and the FRAND Standard: (2023, December). In J. M. Barnett & S. M. O'Connor (Eds.), *5G and Beyond* (1st ed., pp. 51–108). Cambridge University Press. https://doi.org/10.1017/9781009274289.006

Patently. (2025). The world's leading 5G patent owners. https://app.patently.com/Patently-100-5G-2025.pdf