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The Future is Under the Glass
Digital Design Protection and Appropriation Strategy

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WIPO

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Abstract

We examine how legal certainty shapes protection and appropriation of digital designs such as icons, animations, and layouts. Leveraging the 2012 *Apple v. Samsung* verdict as a decisive clarification of their protectability and enforceability, we analyze USPTO design patents from 2009–2015 using a matched difference-in-differences approach. We show that legal certainty reduces due diligence costs far more than monitoring costs. This asymmetry lowers the threshold for securing protection, leading to a 9 percent increase in digital design patents. At the same time, appropriation shifted away from licensing toward transfers, with the effect strongest in dense design spaces where monitoring costs remain high despite increased legal certainty. These findings extend transaction cost theory by showing that legal certainty unevenly reduces transaction costs, which in turn alters protection thresholds and shifts appropriation strategies. They also demonstrate how policy changes influence innovation when value is created "under the glass."

Keywords: Digital designs; Design patents; Appropriation; Transaction costs

JEL Codes: O31, O34, K11

1 Introduction

Most of what made contemporary products desirable and appealing is no longer hidden "under the hood" but visible "under the glass." Digital designs such as animations, icons, and layouts came to define adoption, willingness to pay, and brand meaning (e.g., Boudreau et al., 2022; Chan et al., 2018; Miller and Wang, 2024). Yet considerable uncertainty surrounded the development of these assets. Courts had not clarified whether and how digital assets could be protected or enforced, a challenge that extended to designs (Cockburn and MacGarvie, 2011; Hall and Ziedonis, 2001; Nagaraj, 2018). Hence, legal (un)certainty shapes the choices concerning protection and appropriation of design intellectual property (IP) (Pisano and Teece, 2007).

Transaction cost theory provides a starting point for understanding these choices (Arora and Fosfuri, 2003; Arora and Ceccagnoli, 2006; Fosfuri, 2006; Gaessler et al., 2025; Gans and Stern, 2003; Williamson, 1985). The theory predicts that when legal certainty increases, transaction costs—including valuation, negotiation, and enforcement—decrease (Arora and Ceccagnoli, 2006; Fosfuri, 2006), making licensing more efficient than internal development or outright sales (Arora and Fosfuri, 2003; Gans and Stern, 2003). From this perspective, legal certainty should encourage both more protection activities and greater reliance on licenses (Aydin Ozden and Khashabi, 2023; Teece, 1986).

However, digital designs exhibit distinctive characteristics that disrupt this logic: while legal certainty reduces due diligence costs (valuation, contracting), monitoring costs (enforcement) could remain persistently high. This asymmetry arises because digital designs evolve rapidly, creating fluid infringement boundaries (Contigiani et al., 2018; Kallinikos et al., 2013; Yoo et al., 2012). In particular, determining visual similarity (i.e., the basis of design patent infringement) across digital designs is highly context-dependent, i.e., contingent on the density of design space they belong (Amoncio et al., 2025), and enforcing rights remains time-consuming (Aguiar and Waldfogel, 2018; Hegde and Luo, 2018; Mezzanotti, 2021). This tension motivates our central research question: *How does increased legal certainty affect design protection and appropriation strategies?*

In this paper, we exploit the August 2012 *Apple v. Samsung* verdict, which provides an ideal empirical setting to examine this question. The $1.05 billion award from a California jury settled long-standing uncertainty about both the protectability and enforceability of digital designs in the US. We analyze USPTO design patents from 2009 to 2015, identifying all digital design subclasses and matching them with their physical design counterparts. This enables us to compare protection and appropriation strategies before and after the verdict.

Our findings reveal two clear shifts. First, protection of digital designs increased relative to matched physical designs. This increase was particularly pronounced for commercializable designs. Consistent with this pattern, practitioner interviews indicate that the verdict signaled firms could now protect their digital designs with confidence. This shift spurred not only additional protection activities but also renewed investment in creating innovative designs once enforceability became clearer.

Second, design patent transfers rose. Licensing, by contrast, remained exceedingly rare and showed no measurable post-verdict change, underscoring that appropriation of digital designs was not pursued through licenses. The shift toward transfers was especially pronounced in contexts where monitoring costs remained high, such as in dense design spaces. Robustness checks across alternative specifications confirm these results.

These findings contribute to the literature in two ways. First, we extend transaction cost theory. Prior work typically treats increased legal certainty to uniformly reduce transaction costs, without distinguishing between due diligence and monitoring costs (Arora and Fosfuri, 2003; Gans et al., 2008). We show instead that legal certainty lowers due diligence costs far more than monitoring costs, producing a distinctive appropriation of digital designs.

Second, we extend the markets-for-technology literature by highlighting that appropriation strategies depend on IP types. Whereas legal certainty in technology markets typically promote licensing (Arora et al., 2001; Gans and Stern, 2003), we find a distinct pattern for digital designs: appropriation strategy shifts toward transfers. This contrast complements recent work on licensing failures in utility patents (Gaessler et al., 2025), underscoring that the appropriation mechanism of transactions is sensitive to the nature of the underlying IP.

Taken together, our study demonstrates how legal certainty shapes both the extent of digital design protection and the form of appropriation. These dynamics extend transaction cost theory by highlighting how uneven reductions in transaction costs alter the balance between transfers and licensing. More broadly, they inform ongoing debates on the policies of fast-moving digital assets and the structure of IP regimes that support innovation.

The remainder of the paper proceeds as follows. Section 2 sets out the institutional background, formal model and derives testable predictions. Sections 3 and 4 present the empirical strategy and the results, respectively. Section 5 provides a concluding discussion on the implications for theory and policy.

2 Background and Theory

This section develops predictions for how legal certainty impact digital design patent protection and appropriation strategies,[1] drawing on a formal model and its extension. We first outline the legal and economic features of design patents, highlighting why legal certainty is pivotal for digital design protection (Section 2.1). We then present a transaction cost model (e.g., Arora and Fosfuri, 2003; Gans and Stern, 2003) with asymmetric cost reduction that analyzes the decision to protect a digital design and, conditional on protection, whether to appropriate it via transfer or license (Section 2.2). Finally, we extend the model to allow monitoring costs to scale with design space density (Section 2.3).

2.1 Design Patents and Legal Certainty

US design patents have long been grounded in the protection of physical products. Historically, design patents applied mainly to physical products such as apparel, appliances, or furniture (Amoncio et al., 2025; Chan et al., 2018). In this domain, protectability and enforceability were rarely questioned—courts consistently upheld physical design patents. As one legal expert noted, design patents "effectively come out of the industrial revolution [. . .] that's very much in the physical realm" (Interviewee C1).[2]

By contrast, digital designs (e.g., animations, icons, layouts) were riddled with legal uncertainty. One industry expert recalled that applying for digital design patents in the early 2000s felt like a "leap of faith" (Interviewee C1) given the ambiguity around their protectability and enforceability. Courts diverged on basic questions—for example, whether a digital design such as a graphical user interface constituted a protectable design. This uncertainty undermined confidence in digital design patents (Interviewee T1) and raised upfront due diligence costs for potential acquirers.

In 2012, a jury in the Northern District of California awarded Apple $1.05 billion for infringement of its highly recognizable digital design (see Figure 1).[3] The magnitude of this award is unprecedented in any patent litigation, often dubbed the "patent trial of the century" (Jones and Vascellaro, 2012). This decision, reinforced by subsequent USPTO guidance (USPTO, 2023), confirmed that digital designs are both protectable and enforceable.

[1] "Appropriation" is used in the economic sense to denote value capture from a design right after protection is secured. Legal acts of protection (prosecution) are treated separately, while licensing and transfer are modeled as post-protection appropriation strategies, not as legal appropriation or assignment.

[2] We conducted seven rounds of interviews with legal experts, practitioners, and policymakers; details appear in Online Appendix B.

[3] Because design patents are defined solely by their drawings, infringement turns on visual similarity. Under the ordinary-observer test, an accused product infringes if an ordinary observer, familiar with prior art, views the two designs as substantially the same (Chan et al., 2018). If infringement is found, the patent holder may recover the infringer's total profit on the relevant article (Stigler, 2014).

Figure 1: *Apple v. Samsung* Case.

Notes: The left image depicts Apple's US Design Patent D604,305, covering the digital design of its iPhone home screen. The right image shows Samsung's Galaxy S smartphone interface. At issue in *Apple v. Samsung* was whether the overall look and feel of the core operating system constituted protectable design and whether Samsung's implementation infringed Apple's design patent.

Thus, *Apple v. Samsung* decisively demonstrated that digital design patents are both protectable and enforceable, with substantial economic consequences. In contrast, protection for physical designs remained unchanged, offering a natural counterfactual for our empirical strategy (see Section 3.3). The Online Appendix C documents the litigation timeline underlying this shift.

2.2 Main Model

Commercializing a digital design begins with the decision of whether to seek protection. If unprotected, imitation reduces its stand-alone market value through copycat entry (Dell'Era and Verganti, 2007; Posen et al., 2023). If protected, the design generates enforcement value because the design patent can be asserted against imitators. The size of this value depends on legal certainty, as recognition and enforceability by courts determine whether protection yields meaningful returns.

Once protection is in place, the design can be appropriated through licensing or transfer,[4] generating appropriation value. Realizing this surplus requires overcoming transaction costs. Due diligence costs arise when

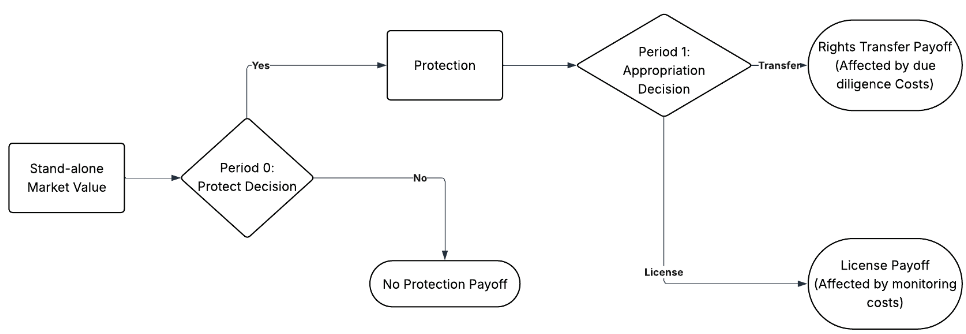
[4] Design patents are often perceived as the "face" of the firm. Hence, licensing and transfer differ not only in transaction costs but also in how they relate to firm identity. Licensing leaves the original owner active in the market while another firm uses the same design, which can dilute brand identity and is difficult to monitor. Transfers, by contrast, involve a complete change in ownership, meaning the design no longer represents the original firm. This identity-preserving nature of designs helps explain why licensing remains rare relative to transfers.

clarifying what the design patent covers, who owns it, and what it is worth in a transaction, corresponding to the contracting and valuation frictions discussed in the markets-for-technology literature (Arora and Fosfuri, 2003; Arora and Ceccagnoli, 2006; Fosfuri, 2006; Gans and Stern, 2003; Gans et al., 2008). Monitoring costs arise when detecting infringement and proving compliant use over time, particularly in licensing agreements, and remain substantial in digital markets where enforcement is difficult (Aguiar and Waldfogel, 2018; Hegde and Luo, 2018; Mezzanotti, 2021; Stigler, 2014).

We argue that legal certainty lowers due diligence costs far more than monitoring costs. Prior work shows that clarified IP rights reduce valuation and contracting frictions that align with our notion of due diligence (Arora and Ceccagnoli, 2006; Fosfuri, 2006; Mullally, 2009), whereas litigation and enforcement expenses—our monitoring costs—remain high, especially in fast-moving digital markets (Hegde and Luo, 2018; Mezzanotti, 2021; Stigler, 2014). This asymmetry underpins our theoretical prediction that greater legal certainty raises protection incentives but shifts appropriation toward transfers rather than licensing.

Figure 2 illustrates this sequence. At Period 0, the stand-alone market value of a design is weighed against imitation risk in the protection decision. If protection occurs, Period 1 brings the appropriation choice. A transfer payoff depends primarily on due diligence costs, whereas a licensing payoff depends primarily on monitoring costs.[5]

Figure 2: Decision Flow for Design Patent Protection and Appropriation



Notes: At Period 0, the stand-alone market value of a design is compared to imitation risk in deciding whether to protect it. If protection is chosen, Period 1 brings the appropriation choice. A transfer payoff is more sensitive to costs, whereas a licensing payoff is more sensitive to monitoring costs.

Formally, we model legal certainty as a continuous index $\theta \in [0, 1]$ that can vary across cases and over time. We denote design patent protection costs as $c > 0$, a stand-alone market value as $v \geq 0$,[6] and imitation loss

[5] Note that the model abstracts from commercialization as a separate branch, not because it is empirically unimportant, but because it is not conditional on holding a right: firms could commercialize with or without protection. The right shapes whether commercialization is protected and enforceable, and whether it can be transferred or licensed.

[6] This represents the profit that the eventual owner could earn by commercializing the product.

from launching unprotected as $m \geq 0$. If launched unprotected, profit is $\pi^{NP} = v - m$. When protected, the design generates an enforcement value of $\Delta(\theta) = \theta\bar{\Delta}, \quad \bar{\Delta} > 0$, which captures the gross surplus created by legal recognition of the design patent.

The design patent holder ultimately secures an appropriation value, which depends on the chosen mode of appropriation (transfer or licensing). In either of the strategy, appropriation is a share of the enforcement value—denoted by $\beta(\theta)\Delta(\theta)$ or $\alpha(\theta)\Delta(\theta)$, respectively—net of transaction costs. Protection is therefore chosen whenever the best appropriation payoff exceeds the unprotected payoff:[7]

$$\max\{\pi^T(\theta), \pi^L(\theta)\} \;\geq\; v - m. \tag{1}$$

Under transfer, the buyer pays $\beta(\theta)\Delta(\theta)$ where $\beta(\theta) \in (0, 1]$ represents the design patent holder's (seller's) share of the enforcement value $\Delta(\theta)$. This share increases with legal certainty $\beta'(\theta) > 0$ because the design patent becomes easier to value and enforce, reducing the risk discount that buyers demand. Higher certainty strengthens the patent holder's bargaining position by making the asset's value more transparent and verifiable. Completing a transfer requires due diligence costs $\tau(\theta)$, which decrease sharply with legal certainty ($\tau'(\theta) < 0$). As courts clarify protectability and enforceability, valuation and contracting become more standardized (Arora and Ceccagnoli, 2006; Fosfuri, 2006; Mullally, 2009).[8] The design patent holder's payoff under transfer is therefore:

$$\pi^T(\theta) = v - c + \beta(\theta)\Delta(\theta) - \tau(\theta). \tag{2a}$$

Under licensing, the holder retains the patent and earns $\alpha(\theta)\Delta(\theta)$, where $\alpha(\theta) \in (0, 1)$ represents the design patent holder's (licensor's) share of the enforcement value. This share also increases with legal certainty $\alpha'(\theta) > 0$, but remains lower than in transfers $\alpha(\theta) < \beta(\theta)$ for two reasons. First, licensees face residual risks—courts might narrow design scope or subtle variations could escape enforcement—requiring compensation through a larger share of the enforcement value. Second, the design patent holder (licensor) bears ongoing monitoring costs $M(\theta)$ to detect infringement and ensure compliance. These costs decline only marginally with legal certainty ($M(\theta) \approx 0$) because digital designs evolve rapidly. Every software update can alter "look-and-feel," requiring continuous reevaluation of substantial similarity (Stigler, 2014). Licensing also invites product-market competition. Following Arora and Fosfuri (2003), we include a rent-dissipation term $RD > 0$. The payoff under licensing is

[7] Equivalently, this condition can be summarized by the protection threshold $\bar{\Delta}_P(\theta)$ defined in Online Appendix A.
[8] Practitioners report that standard templates cut review time by more than half (Interviewee B1).

$$\pi^L(\theta) = v - c + \alpha(\theta)\Delta(\theta) - M(\theta) - RD. \tag{2b}$$

Given these payoffs, the design patent holder prefers transfer whenever

$$\pi^T(\theta) \;\geq\; \pi^L(\theta). \tag{2c}$$

This inequality defines the transfer–license margin and will guide our empirical analysis of appropriation strategy.

2.2.1 Main Model Predictions

Higher legal certainty affects both the enforcement value $\Delta(\theta)$ and the transaction costs of appropriating design patents. While it increases enforcement value and reduces due diligence costs substantially, monitoring costs remain largely unchanged. These asymmetric effects generate two predictions. First, higher enforcement value allows more designs to cross the protection threshold. Designs that previously would have been left unprotected now become viable to protect.

Prediction 1. Higher legal certainty increases the probability of protection.

Second, the asymmetric reduction in transaction costs tilts appropriation toward transfers. Transfers require only one-time due diligence while licensing requires ongoing monitoring. Since legal certainty reduces due diligence costs far more than monitoring costs, the relative payoff from transfers increases.

Prediction 2. Conditional on protection, higher legal certainty increases the relative probability of transfer.

2.3 Model Extension: The Role of Design Space Density

Our main model assumes monitoring costs are uniform across design contexts. However, the difficulty of detecting and proving infringement varies substantially across design spaces. In design spaces with high density, where many similar designs coexist, monitoring becomes particularly challenging. Consider smartphone interfaces: with thousands of apps featuring similar icon grids and navigation patterns, detecting infringement requires extensive surveillance and proving violations becomes contentious. In contrast, in spaces with low density, designs face lower monitoring burdens as they are more distinctive and easily distinguishable.

To capture this heterogeneity, we extend the model to incorporate design space density d. Monitoring costs are driven by both the frequency of potential infringements and the difficulty of detection. In dense spaces, infringements occur more frequently ($\lambda(d)$ with $\lambda'(d) > 0$), while legal certainty improves detection capability ($p(\theta)$ with $p'(\theta) > 0$). This yields

$$M(\theta, d) = \kappa\lambda(d)\,[1 - p(\theta)]. \tag{3a}$$

Hence, monitoring costs rise with density ($M_d > 0$), fall with certainty ($M_\theta < 0$), and their interaction is negative ($M_{\theta d} < 0$). Legal certainty provides less relief in dense spaces where similarity makes infringement inherently harder to prove.

Due diligence costs may also vary with density, though the effect is weaker. Intuitively, dense spaces require scanning more prior designs to ensure clearance, but this burden grows only logarithmically in the number of designs. Formally, if clearance requires scanning $N(d)$ prior designs, with cost $\kappa_\tau \log(1 + N(d))$, then $\tau_d > 0$ but small relative to M_d.

2.3.1 Model Extension Predictions

Because monitoring costs scale more strongly with density than due diligence costs, the model yields two predictions:

Prediction 3a (Level Effect). Transfers will be relatively more likely than licenses in high density design spaces, independent of legal certainty.

Prediction 3b (Interaction Effect). The shift toward transfers following higher legal certainty will be stronger in high density design spaces than in low density spaces.

3 Empirical Strategy

This section explains how we bring the model to the data. Our empirical setting focuses on designs with high potential for commercialization—contexts in which firms are likely to launch products and therefore face strategic decisions about how to protect and appropriate design patents. We describe the data sources and sample construction (Section 3.1), the research design (Section 3.2), and the econometric specifications to test our theoretical predictions (Section 3.3).

3.1 Data and Sample Construction

We construct our main sample from four data sets. First, we use the USPTO Patent Examination Research Dataset[9] to obtain a list of *all* the design patents. This dataset includes the design patents' title, claim, filing date, USPC class, and subclass. We use this dataset as the basis to construct our panel at the subclass–year. We initially observe 4,818 unique USPC subclasses from 2009 to 2015.

Second, we employ the USPTO Assignments Dataset (Graham et al., 2018). This dataset contains how often protected design patents were transferred or licensed. We employ this dataset for our main appropriation strategy outcomes. A potential concern with recorded assignments is that many may reflect internal reorganizations rather than genuine market transactions. To address this, we implement extensive cleaning procedures detailed in Online Appendix D. Importantly, the presence of defensive patent aggregators such as RPX Corporation in our data provides additional validation. Founded in 2008, RPX acquires patent portfolios exclusively from unrelated parties to mitigate litigation risks for its members—its entire business model depends on arm-length transactions with independent sellers. RPX emerges as a notable assignee of design patents in our sample, particularly in digital categories following the *Apple v. Samsung* verdict. Because RPX has no parent-subsidiary relationships with the firms from which it acquires patents, transactions involving RPX constitute unambiguous evidence of genuine market exchange. The systematic presence of such specialized intermediaries in our data reinforces confidence that recorded transfers capture economically meaningful appropriation activity rather than administrative reclassifications.

Third, we build on Amoncio et al. (2025), who develop and validate a computer-vision-based measure of design similarity—adapted from the structural similarity index (SSIM)—to quantify visual overlap across large sets of US design patents. This measure captures how dense a design space is, making it an ideal proxy for monitoring difficulty. Thus, it serves as the operational foundation for testing our third prediction.

Lastly, we use *patentsview.org*'s patent citation network. This network serves as the basis for our identification strategy in matching digital design subclasses to their physical counterparts. The network analysis shows that digital and physical design subclasses are closely connected but distinct, enabling us to identify matched subclasses that share visual and technological proximity yet differ in their exposure to the *Apple v. Samsung* shock. We discuss this in Section 3.2.

[9] See https://www.uspto.gov/ip-policy/economic-research/research-datasets/patent-examination-research-dataset-public-pair for further details.

Note that we focus on subclasses rather than individual design patents because our theoretical framework predicts shifts in the volume of design patent protection activities in response to changes in legal certainty. Analyzing data at the individual design patent level would not capture these trends effectively. Similar to the approach Gaessler et al. (2025), subclasses provide a granular yet meaningful categorization of design patents, allowing us to observe variations in protection activity across distinct design domains (e.g., Amoncio et al., 2025).

In addition, to define our window of analysis, we use a three-year cutoff before and after the 2012 *Apple v. Samsung* decision. The pre-period begins in 2009, after the Federal Circuit's Egyptian Goddess v. Swisa (2008) ruling, which substantially revised the infringement test for design patents, thereby avoiding overlap with earlier doctrinal changes. The post-period ends in 2015 to exclude any confounding effects of the 2016 Supreme Court ruling on the definition of article of manufacture. The final sample includes 21,553 subclass-year observations, evenly split between digital design subclasses (treated) and their matched physical counterparts (control).

3.2 Research Design and Identification

To evaluate the impact of increased legal certainty on digital designs, we employ a matched difference-in-differences (DiD) approach. This method compares changes over time between treated units (digital design subclasses) and control units (visually and functionally similar physical design subclasses) before and after the *Apple v. Samsung* jury decision in 2012. We analyze three outcomes: the volume of design protection activities, the frequency of design patent transfers, and licensing. In what follows, we explain why the *Apple v. Samsung* verdict constitutes a suitable source of identifying variation, define our treated units, and describe how we identify control units.

The pivotal role of the *Apple v. Samsung* verdict was emphasized repeatedly in our practitioner interviews. Attorneys described design patenting before 2012 as a "leap of faith," noting that although firms experimented with filings, there was widespread uncertainty over whether digital designs were protectable and enforceable (Interviewee C1, Interviewee T1). One practitioner remarked that clients were "just throwing money away" on digital design patents prior to the verdict, since no court had validated their enforceability (Interviewee C1). Another stressed that the billion-dollar award "solidified the legitimacy of design rights" and spurred a surge in demand, particularly for digital design protection (Interviewee T1). An industry expert likewise observed that only after 2016 did boards become willing to invest heavily in digital design protection, precisely because earlier uncertainty had constrained its strategic use (Interviewee R3). Together, these accounts confirm that although the litigation attracted early attention, the 2012 verdict provided the decisive clarification that resolved legal uncertainty and reshaped firm behavior.

Classifying digital designs within the broader dataset poses challenges because of overlaps with physical designs, such as display screens or panels. To address this, we rely on the 2023 USPTO supplemental guidance (USPTO, 2023), which specifies that computer icons and graphical user interfaces displayed on screens qualify as statutory subject matter because they are “integral and active components in the operation of a programmed computer,” rather than mere illustrations. Following this guidance, we construct a searchable text field combining each design patent’s title and claims and filter designs using the key terms identified in the guidance (e.g., “graphical user interface,” “user interface,” “interactive display,” “animated icon,” and “virtual button”). We also exclude applications that list only generic terms such as “display screen” or “display panel” without descriptors linking them to interactive functionality (e.g., “user interface in a display screen”). This filtering removes legacy hardware cases while retaining those consistent with the USPTO’s definition of digital designs. Taken together, these steps reduce misclassification risk and provide a reliable basis for distinguishing digital from physical designs.

A credible DiD design further requires a control unit that closely resembles the treatment unit in relevant aspects. To construct such counterfactuals, we leverage the design patent citation network. This builds on the insights of Chan et al. (2018), who show that citation links embedded in design patents capture substantive visual and functional similarity between designs. Our process involves several steps. First, as described in Section 3.1, we construct a citation network using USPTO design patent data, where each node represents a subclass and edges denote citation links weighted by frequency. Next, we calculate cosine similarity (Arts et al., 2018; Chan et al., 2018) between subclasses based on their citation patterns (Moser et al., 2018), which quantifies how similarly subclasses engage in citation behavior. For each digital subclass, we then identify the physical subclass with the highest similarity score as its counterfactual. We do not impose an absolute threshold: each digital subclass is paired with its closest physical counterpart, and residual variation in similarity is absorbed through pair fixed effects. Each control subclass is used only once to preserve the integrity of the matching.

As a concrete example, USPC subclass D14/488, which covers information retrieval systems such as digital keyboards, is paired with D14/138, which encompasses the physical design of traditional keyboards. This outcome illustrates how the procedure links digital subclasses to their closest physical counterparts in both functional role and visual form. Online Appendix F provides further details on the matching process.

3.3 Empirical Specification

For each outcome Y_{ist}, we estimate a matched difference-in-differences specification at the subclass-pair level:

$$\log(1 + Y_{ist}) = \beta \left(Digital_s \times Post_t \right) + \gamma_i + \varepsilon_{ist}, \tag{3}$$

where $Digital_s$ takes a value of 1 for digital design subclasses and 0 for their matched physical counterparts, and $Post_t$ is 1 for $t > 2012$. Subclass-pair fixed effects γ_i absorb all time-invariant differences between digital subclasses and their physical counterparts, ensuring identification comes from within-pair changes around the *Apple v. Samsung* decision. Standard errors are clustered at the subclass level to allow for arbitrary serial correlation.

As robustness, we extend the specification with year fixed effects to account for aggregate shocks and include time-varying controls such as mean grant lag. We also included pair-year fixed effects to account for technology-specific evolution patterns that might confound the treatment effect. Lastly, we re-estimate the model using Poisson pseudo-maximum likelihood, which is well-suited for skewed, non-negative outcomes and accommodates zeros without transformation (Amoncio et al., 2025).

4 Results

We first present descriptive evidence (Section 4.1). We then estimate the impact of legal certainty on design protection (Section 4.2) and its appropriation strategies (Section 4.3) using OLS as the baseline. Next, we analyze heterogeneity by design space similarity density (Section 4.4). Finally, we report robustness checks—adding fixed effects, controls, and Poisson estimators (Section 4.5) and event-study validations (Section 4.6).

4.1 Descriptive Results

Table 1 presents summary statistics. On average, there are, on average, 4.47 design protection activities per subclass–year, with a high standard deviation indicating substantial heterogeneity across subclasses and over time. The mean number of design patent transfers is 1.43 per subclass–year,[10] with transfers averaging 2.20 in digital subclasses and 0.65 in physical subclasses. Licensing is rare, with an average of only 0.01 licenses per subclass–year and little difference between digital and physical subclasses. The binary variable *Digital*

[10] These transfers are largely concentrated among incumbent holders, defined as those with design patents before the legal shift.

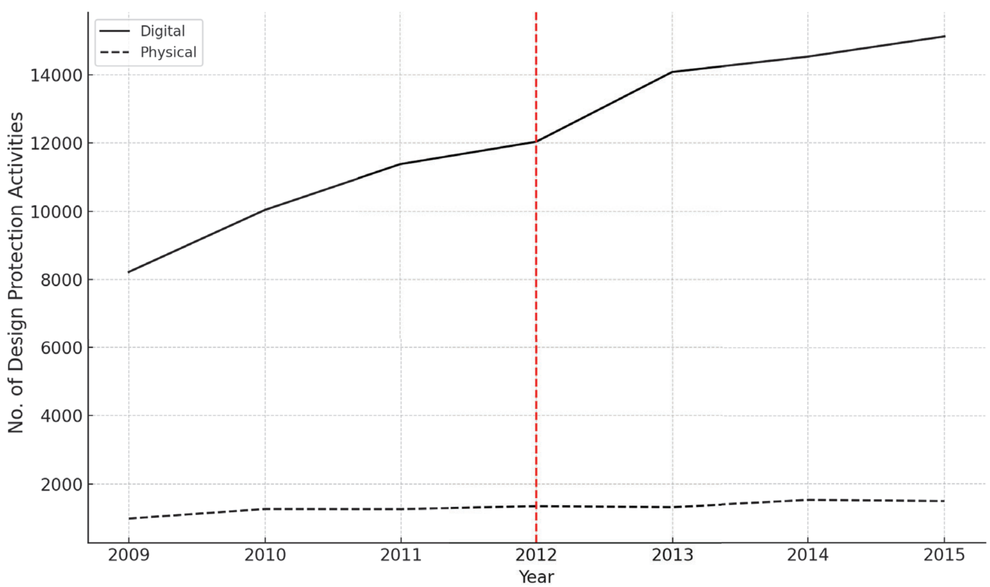
has a mean of 0.5, consistent with our balanced sampling strategy between digital and physical subclasses.

Table 1: Summary Statistics (21,553 Subclass-Year Observations)

Variable	Mean	Std. Dev.	Min	Max
No. of Protection	4.47	19.47	0	935
No. of Transfer	1.43	3.83	0	180
No. of License	0.01	0.05	0	3
Digital (Dummy=1)	0.50	0.50	0	1
Year	2012	2	2009	2015

Figure 3 plots the annual count of design protection activities in digital and physical subclasses from 2009 to 2015. The vertical red line marks the 2012 *Apple v. Samsung* verdict. While protection activities in physical subclasses remain relatively flat over time, digital subclasses exhibit an upward trend, especially after 2012. This divergence in protection activities is consistent with our theoretical prediction: a rise in legal certainty should disproportionately stimulate the protection of digital designs.

Figure 3: Annual Count of Digital and Physical Design Protection



Notes: The solid line shows total design applications in digital subclasses. The dashed line represents applications in matched physical subclasses. The red vertical line denotes the 2012 *Apple v. Samsung* jury verdict. The sample is based on a balanced panel of 21,553 subclass–year observations (2009–2015).

The aggregate trends in Figure 3 are mirrored by the behavior of market intermediaries. RPX Corporation, a defensive patent aggregator that acquires portfolios to neutralize litigation exposure for its members, provides a revealing case. Figure D.2 in Online Appendix D shows that RPX's acquisition of digital design patents increased markedly in the post-verdict period relative to physical designs. Before 2012, RPX acquired digital and physical design patents at comparable rates. After the verdict, acquisitions of digital designs accelerated sharply while physical design acquisitions grew more modestly. This pattern suggests that sophisticated market participants—those whose valuations must be precise enough to sustain a business model—perceived digital designs as increasingly valuable and tradable assets following the legal clarification. RPX's revealed preferences thus corroborate the aggregate protection trends: legal certainty transformed digital designs from uncertain claims into assets worth acquiring.

4.2 Impact of Legal Certainty on Design Protection

We now formally test our predictions. To begin with, Prediction 1 states that increased legal certainty would raise the protection of digital designs. Table 2 reports the estimates. The coefficient on the interaction term *Digital* $\times$ *Post* is positive and statistically significant ($\beta = 0.09$, $p < 0.01$). Given a baseline mean of 4.47, the 0.09 log-point increase corresponds to roughly 0.42 additional design protections per subclass–year. This result is consistent with the model's prediction that legal certainty raises the expected value of protection and lowers protection thresholds.

Table 2: Effect of Legal Certainty on Design Protection

	(1) Protection
Digital	0.63***
	(0.02)
Post	0.01
	(0.01)
Digital $\times$ Post	0.09***
	(0.02)
Pair FE	Yes
N	21,553
R^2	0.38

Notes: The dependent variable is the log of the number of design protection activities at the subclass–year level (zeros adjusted prior to logging). All regressions absorb matched subclass–pair fixed effects, with standard errors clustered at the subclass level. Sample comprises 21,553 subclass–year observations from 2009–2015. *** $p < 0.01$.

We further explore whether the increased design protection activities reflect new design creation or simply the protection of existing designs. Anecdotal evidence from our interviews suggests that it may reflect the former rather than the latter. As Interviewee R1 explained, when protection was uncertain, "you're not going to be as innovative." Without a clear path to safeguarding digital designs, the safest strategy was to "stick with what's worked before." After the verdict, however, the message to in-house designers changed: "if you come up with something innovative, we can actually protect it [...] it's a positive factor that allows us to continue striving to be innovative in this space." This anecdotal evidence supports the idea that post-verdict surge in filings was driven largely by new design creation.

Lastly, we examine whether the post-verdict increase in protection is concentrated among designs that were actually commercialized. Table F.1 reports the triple-difference specification. The coefficient on the three-way interaction (*Digital* × *Post* × *Commercialized*) is positive and statistically significant, indicating that the legal shift disproportionately increased protection of commercialized designs. This finding aligns with the interpretation that legal certainty made protection more valuable precisely for designs intended for market use, reinforcing our argument that the ruling lowered protection thresholds by raising expected payoffs from commercialization.[11]

4.3 Effect on Appropriation Strategy

We now formally test Prediction 2. We posit that increased legal certainty would shift appropriation strategies away from licensing and toward design patent transfer. Column (1) Table 3 shows the results for design patent transfer while Column (2) of the same table shows the outcome for licensing.

Table 3: Effect of Legal Certainty on Transfers and Licensing

	(1) Transfer	(2) License
Digital	0.40***	0.00
	(0.02)	(0.00)
Post	0.03***	-0.00*
	(0.01)	(0.00)
Digital × Post	0.08***	0.00
	(0.01)	(0.00)
Pair FE	Yes	Yes
N	21,553	21,553
R^2	0.41	0.07

Notes: The dependent variable is the log of design patent transfers (Column 1) and licenses (Column 2) at the subclass–year level (zeros adjusted prior to logging). All regressions absorb matched subclass–pair fixed effects, with standard errors clustered at the subclass level. Sample comprises 21,553 subclass–year observations from 2009–2015. *** $p < 0.01$, * $p < 0.1$.

Column (1) indicates a significant increase in transfer for digital designs post-2012 ($\beta = 0.08$, $p < 0.01$). By contrast, Column (2) shows no significant change in licensing activity. The results are consistent with the interpretation that legal certainty made digital designs more attractive for design patent transfer and that licensing remained rare.

While the transfer results provide clear evidence for Prediction 2, the absence of any measurable effect on licensing requires additional discussion. Licensing remains rare and unaffected. This aligns with our

[11] We identify commercialized designs using the *IPRoduct* database, which links design patents to marketed products, and then we subsequently link these products to Amazon listings.

model's prediction and its extension on non-exclusive licensing (see Online Appendix A.5.1) and with our interviews.[12]

Taken together, we show that legal certainty increased the attractiveness of transfers, while licensing remained unattractive. The rarity of licensing in our data itself may be informative. It underscores that the appropriation strategy for digital designs is *not* pursued through licensing.

4.4 Role of Design Space Density

So far, we have shown that greater legal certainty led to a rise in digital design protection activity and that transfers became the dominant appropriation mode relative to licenses. We now turn to Predictions 3a and 3b by examining heterogeneous treatment effects across design spaces of varying density. To operationalize this, we split subclasses by the median pre-2012 design space similarity density (DSSD) introduced by Amoncio et al. (2025). DSSD could be thought of how many visually similar designs are available in a given subclass. Hence, in high-density subclasses, there are many visually similar alternatives, while in low-density subclasses, there are fewer design alternatives and easier to distinguish.

[12] Practitioners described licensing design patents as both conceptually and reputationally unattractive. One attorney noted that digital designs are "the public face of the company," making them inseparable from brand identity (Interviewee R1, Interviewee R2). Another explained bluntly that "you don't even see much licensing of designs because it's like licensing your face [...] it's just too much of your front face" (Interviewee C1). Others stressed enforcement challenges: because user interfaces can be modified incrementally, "it is very easy to design around" a claimed digital design, making it "extremely difficult to police" potential licensees (Interviewee T1). Such accounts highlight why licensing is not simply absent from the data by chance but is actively avoided in practice.

Table 4: Heterogeneity Analyses: DSSD and Transfers

	(1) Low DSSD	(2) High DSSD	(3) Full Sample
Digital	0.08***	0.31***	0.09***
	(0.01)	(0.03)	(0.02)
Post	0.01	0.07***	0.01
	(0.01)	(0.02)	(0.01)
Digital × Post	0.02	0.07***	0.02
	(0.02)	(0.03)	(0.01)
DSSD (median=1)			0.48***
			(0.02)
Digital × DSSD			0.22***
			(0.03)
Post × DSSD			0.07***
			(0.02)
Digital × Post × DSSD			0.05*
			(0.03)
Pair FE	Yes	Yes	Yes
N	10,773	10,780	21,553
R^2	0.31	0.49	0.48

Notes: The dependent variable is the log of design patent transfers at the subclass–year level (zeros adjusted prior to logging). Columns (1) and (2) show results separately for low and high density subclasses; Column (3) includes the full sample with a median split on pre-2012 design-space similarity density. All regressions include subclass–pair fixed effects, with standard errors clustered at the subclass level. *** $p < 0.01$.

Columns (1) and (2) of Table 4 present separate regressions for low- and high-density subclasses. Only the high DSSD show a positive post-2012 treatment effect with a magnitude of $\beta = 0.07$, significant at 0.01 level. This level difference is consistent with Prediction 3a: transfers are relatively more common in dense design spaces, where monitoring remains costly.

Column (3) reports the full-sample regression with an interaction for high-density subclasses. The positive Digital × Post × High-DSSD coefficient indicates that the post-2012 transfer increase is larger in dense subclasses, consistent with Prediction 3b. Together, the results confirm that density shapes both the baseline level and the responsiveness of transfer activity to institutional change.

Table F.2 provides complementary evidence for licenses. The split-sample results show no systematic post-2012 increase in licensing activity and the triple interaction is small and statistically indistinguishable from zero. This null finding is consistent with Predictions 3a and 3b, which imply that dense design spaces push appropriation toward transfers rather than licenses and that improved legal certainty does little to alter this licensing pattern.

4.5 Robustness Tests

We conduct a series of robustness tests that impose increasingly stringent identification requirements to assess the validity of our empirical strategy. First, to ensure that the estimated treatment effect is not confounded by subclass-specific dynamics or common shocks, we augment the baseline specification with time-varying controls, i.e., average pendency (Harhoff and Wagner, 2009). Average pendency is the average number of days between application and grant. We additionally included year and pair × year fixed effects to take into account the unobserved exogenous technological change in the observation period. Results in Table 5 show that the coefficient of interest remains positive and statistically significant for protection and transfers, with no effect on licensing.

Table 5: Robustness CheckL: OLS

	(1) Protection	(2) Transfer	(3) License
Digital	0.48***	0.30***	0.00
	(0.03)	(0.02)	(0.00)
Digital × Post	0.06***	0.06***	0.00
	(0.02)	(0.01)	(0.00)
Pendency	0.00***	0.00***	0.00
	(0.00)	(0.00)	(0.00)
Pair FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Pair × Year FE	Yes	Yes	Yes
N	21,546	21,546	21,546
R^2	0.59	0.62	0.52

Notes: The dependent variables are the log number of design patent protection (Column 1), transfer (Column 2), and licensing (Column 3) activities at the subclass–year level. All regressions absorb matched subclass pair, year, and subclass pair-year fixed effects, with standard errors clustered at the subclass level. The sample comprises 21,546 subclass–year observations from 2009–2015. Pendency is the average number of days between application and grant. *** $p < 0.01$.

Second, to account for the count nature of our dependent variables and the frequent presence of zeros, we estimate Poisson pseudo–maximum likelihood models. Similar to the previous analyses, to account for the unobserved exogenous technological change in the observation period, we include not only subclass pair and year fixed effect but also pair × year fixed effects. Table 6 shows consistent results. The interaction between digital subclasses and the post is positive and statistically significant for both protection ($\beta = 0.35$, $p < 0.01$) and transfers ($\beta = 0.12$, $p < 0.05$), but remains small and insignificant for licensing ($\beta = 0.91$, $p > 0.1$).

Table 6: Robustness Check: Poisson

	(1) Protection	(2) Transfer	(3) License
Digital	1.73***	0.88***	0.17
	(0.10)	(0.05)	(0.28)
Digital × Post	0.35***	0.12**	0.91
	(0.11)	(0.05)	(0.59)
Pendency	0.00***	0.00***	0.00
	(0.00)	(0.00)	(0.00)
Pair FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Pair × Year FE	Yes	Yes	Yes
N	7,996	12,144	78
Log pseudolikelihood	-29,823.41	-19,996.70	-69.42

Notes: The dependent variables are the number of design protections (Column 1), transfers (Column 2), and licenses (Column 3) at the subclass–year level. All regressions are estimated using Poisson pseudo–maximum likelihood with matched subclass pair–year fixed effects, and standard errors clustered at the subclass level. Subclasses must exhibit variation in the respective outcome to be included in the estimation, which explains the differences in sample size across columns. *** $p < 0.01$, ** $p < 0.05$.

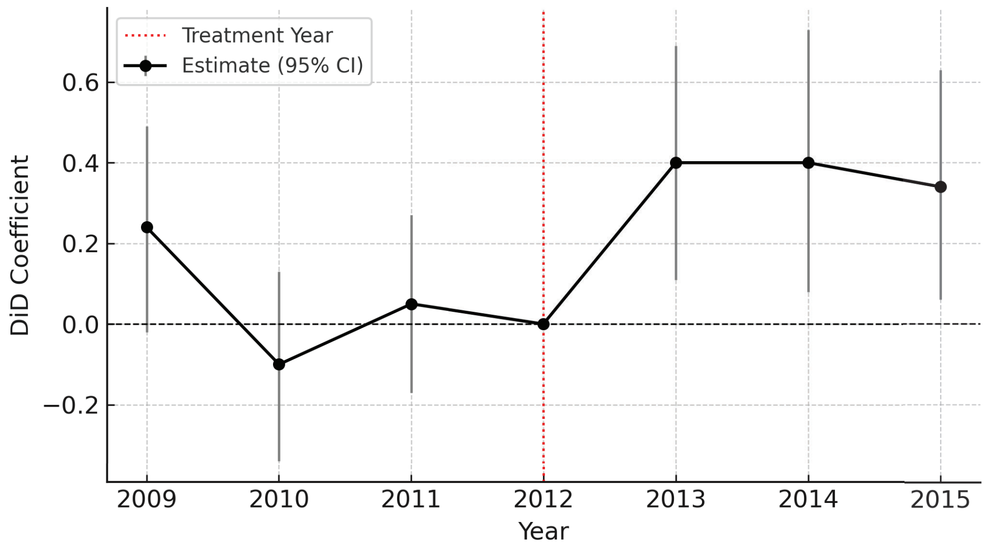
Lastly, we consider substitution as a potential threat to identification. Substitution could happen where improved digital design certainty might reduce interest in physical design protection and could theoretically bias estimated effects upward, we observe no empirical decline in physical filings. On the contrary, filings in physical categories remain growing (see Figure 3). Moreover, from prior literature (Borner et al., 2023), given that digital designs are often bundled with hardware (phones, wearables, appliances),[13] increased legal certainty on digital designs would increases the joint return to design protection, reflecting complementarity. As a result, our estimates could be viewed as lower-bound.

4.6 Validity Analyses: Event Study and Placebo Tests

Finally, we assess the validity of our identification strategy using an event-study specification and a placebo test. Figure 4 plots the dynamic treatment effects for digital design protection—the main outcome in our analysis. The coefficients before 2012 are statistically indistinguishable from zero, lending support to the parallel-trends assumption. The positive and significant effects appear only after 2012, consistent with the interpretation that the *Apple v. Samsung* verdict, which increased legal certainty, triggered greater protection of digital designs.

[13] A practitioner highlights that devices are getting “smarter” with physical designs getting digital interfaces (Interviewee B1)

Figure 4: Event Study: Effect of Legal Certainty on Digital Design Protection



Notes: Estimates plot year-specific DiD coefficients for digital subclasses, relative to 2012 (red vertical line). Error bars show 95% confidence intervals clustered at the subclass level. Coefficients are obtained from Poisson regressions on a balanced panel of 21,553 subclass–year observations (2009–2015), using a matched difference-in-differences specification with subclass-pair, year, and pair×year fixed effects. Outcomes are measured as number design patent protection activities.

Because transfer and licensing outcomes are sparse and highly zero-inflated, event-study estimation for these variables is not informative and therefore omitted; their pre-trend stability is indirectly confirmed by the placebo analysis. We do so by assigning a fictitious treatment year of 2011. Table 7 shows that the interaction term Digital × Placebo is statistically insignificant across all outcomes. With these results, we confirm that the observed post-2012 effects are not driven by pre-existing trends.

Table 7: Placebo Tests

	(1) Protection	(2) Transfer	(3) License
Digital	1.80***	0.99***	-0.07
	(0.11)	(0.07)	(0.40)
Digital × Placebo	0.02	0.07	1.01
	(0.11)	(0.09)	(1.31)
Pendency	0.00***	0.00***	0.00*
	(0.00)	(0.00)	(0.00)
Pair FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Pair × Year FE	Yes	Yes	Yes
N	5,448	6,819	108
Log pseudolikelihood	-21,052.43	-10,998.09	-51.79

Notes: The dependent variables are the number of design protections (Column 1), transfers (Column 2), and licenses (Column 3) at the subclass–year level. All regressions are estimated by Poisson pseudo–maximum likelihood with subclass pair, year, and pair × year fixed effects, and standard errors clustered at the subclass level. The sample is restricted to the pre-period (2009–2011). *** $p < 0.01$, * $p < 0.1$.

5 Discussion and Conclusion

Legal uncertainty long surrounded the protection of digital designs—animations, icons, and layouts—casting doubt on their eligibility for design patent protection and on the enforceability of those rights. The 2012 *Apple v. Samsung* verdict provides an exogenous shock that clarifies both protectability and enforceability, allowing us to examine how greater legal certainty shapes protection and appropriation. Building on a transaction–cost model, we argue that legal certainty reduces due-diligence costs far more than monitoring costs. Using a matched difference-in-differences approach on US design patents (2009–2015), we document three effects: protection of digital designs rose by roughly 9% relative to matched physical subclasses; appropriation shifted away from licensing and toward transfers; and this shift was most pronounced in dense design spaces.

This study advances the literature in two distinct and novel ways. Our first contribution extends the transaction cost theory. Prior work assumes that increasing legal certainty would reduce all sources of transaction friction equally (Arora and Fosfuri, 2003; Gans and Stern, 2003). We show instead that legal certainty lowers due diligence costs far more than monitoring costs. This asymmetry matters. When monitoring costs remain high, legal certainty increases protection but shifts appropriation away from licensing and toward transfers. By emphasizing uneven cost reductions, our study extends the scope of transaction cost theory to settings where legal and institutional changes alter the balance across different stages of the transaction.

Our second contribution is to extend the markets-for-technology literature. Much of this work highlights licensing as the dominant appropriation mode once rights are clarified and enforceable (Arora et al., 2001; Gans and Stern, 2003). We demonstrate that this logic does not hold uniformly across IP types. For digital designs, where ongoing monitoring is costly and infringement boundaries remain blurry, transfers rather than licenses become the preferred form of exchange. This contrast underscores that the structure of markets-for-technology depends not only on the existence of well-defined rights but also on the characteristics of the underlying asset.

Our findings also carry policy implications. Clarifying protectability and enforceability is a necessary condition for stimulating digital design activity: our estimates show a nine percent increase in protection, and anecdotal evidence suggest that these design patents were tied to commercializable products. Yet this alone is not sufficient to ensure diffusion. Because monitoring costs remain high, licensing did not expand; instead, appropriation shifted toward transfers.

Two implications follow. First, legal certainty can successfully encourage investment in design innovation and enhance the liquidity of design markets by making transfers more feasible. Second, while diffusion is a central policy goal in technology markets, its relevance for design is more limited—designs are often independently created and do not always benefit from reuse. In our setting, monitoring frictions make even non-exclusive licensing unattractive, helping explain why licensing remained rare. This outcome may not signal a policy shortfall, but it suggests that diffusion through licensing is unlikely without targeted measures (e.g., collective enforcement or industry clearinghouses). Only in cases where user welfare depends on consistency, such as interface standards or dominant designs, would reforms to lower frictions meaningfully expand design licensing.

Two limitations warrant acknowledgment. First, our analysis captures only recorded transfers; unrecorded or informal in-house licenses may not be reflected, although industry interviews suggest that such licensing is uncommon for digital designs. Second, our study focuses on the effects of legal certainty within the US context; exploring how these dynamics play out in jurisdictions with different enforcement regimes or in emerging areas like AI-assisted interfaces could offer valuable perspectives. As technological areas continues to influence design processes, understanding how legal frameworks adapt to protect AI-assisted designs becomes increasingly important with regard to the incentives this provides to create new designs and how much firms will adopt AI technology in design creation.

In summary, improved legal certainty enhances protection of digital design assets and reshapes appropriation, favoring rights transfers over licensing by altering the balance between due diligence and monitoring costs. Beyond technical contributions to the theory, our findings highlight that policies can produce asset-specific shifts in appropriation strategies. Looking ahead, extending this inquiry to AI-assisted and other fast-moving digital domains can deepen our understanding of how policies shape innovation when value is made visible "under the glass."

References

Aguiar, L. and Waldfogel, J. (2018). Quality predictability and the welfare benefits from new products: Evidence from the digitization of recorded music. *Journal of Political Economy*, 126(2):492–524.

Amoncio, E., Chan, T., and Storz, C. (2025). Using computer vision to measure design similarity: An application to design rights. *Research Policy*, 54(9):105309.

Arora, A. and Ceccagnoli, M. (2006). Patent protection, complementary assets, and firms' incentives for technology licensing. *Management science*, 52(2):293–308.

Arora, A. and Fosfuri, A. (2003). Licensing the market for technology. *Journal of Economic Behavior & Organization*, 52(2):277–295.

Arora, A., Fosfuri, A., and Gambardella, A. (2001). Markets for technology: The economics of innovation and corporate strategy. *MIT Press*.

Arts, S., Cassiman, B., and Gomez, J. C. (2018). Text matching to measure patent similarity. *Strategic Management Journal*, 39(1):62–84.

Aydin Ozden, S. and Khashabi, P. (2023). Patent remedies and technology licensing: Evidence from a supreme court decision. *Strategic Management Journal*, 44(9):2311–2338.

Borner, K., Berends, H., Deken, F., and Feldberg, F. (2023). Another pathway to complementarity: How users and intermediaries identify and create new combinations in innovation ecosystems. *Research Policy*, 52(7):104788.

Boudreau, K. J., Jeppesen, L. B., and Miric, M. (2022). Profiting from digital innovation: Patents, copyright and performance. *Research Policy*, 51(5):104477.

Chan, T. H., Mihm, J., and Sosa, M. E. (2018). On styles in product design: An analysis of us design patents. *Management Science*, 64(3):1230–1249.

Cockburn, I. M. and MacGarvie, M. J. (2011). Entry and patenting in the software industry. *Management science*, 57(5):915–933.

Contigiani, A., Hsu, D. H., and Barankay, I. (2018). Trade secrets and innovation: Evidence from the "inevitable disclosure" doctrine. *Strategic Management Journal*, 39(11):2921–2942.

Dell'Era, C. and Verganti, R. (2007). Strategies of innovation and imitation of product languages: The case of alessi and its imitators. *Research Policy*, 36(3):463–483.

Fosfuri, A. (2006). The licensing dilemma: understanding the determinants of the rate of technology licensing. *Strategic Management Journal*, 27(12):1141–1158.

Gaessler, F., Harhoff, D., Sorg, S., and von Graevenitz, G. (2025). Patents, freedom to operate, and follow-on innovation: evidence from post-grant opposition. *Management Science*, 71(2):1315–1334.

Gans, J. S., Hsu, D. H., and Stern, S. (2008). The impact of uncertain intellectual property rights on the market for ideas: Evidence from patent grant delays. *Management science*, 54(5):982–997.

Gans, J. S. and Stern, S. (2003). The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. *Research policy*, 32(2):333–350.

Graham, S. J., Marco, A. C., and Myers, A. F. (2018). Patent transactions in the marketplace: Lessons from the uspto patent assignment dataset. *Journal of Economics & Management Strategy*, 27(3):343–371.

Hall, B. H. and Ziedonis, R. H. (2001). The patent paradox revisited: an empirical study of patenting in the us semiconductor industry, 1979-1995. *rand Journal of Economics*, pages 101–128.

Harhoff, D. and Wagner, S. (2009). The duration of patent examination at the european patent office. *Management Science*, 55(12):1969–1984.

Hegde, D. and Luo, H. (2018). Patent publication and the market for ideas. *Management Science*, 64(2):652–672.

Jones, A. and Vascellaro, J. (2012). Apple v. samsung: The patent trial of the century. *Wall Street Journal*. Accessed: 2025-09-03.

Kallinikos, J., Aaltonen, A., and Marton, A. (2013). The ambivalent ontology of digital artifacts. *MIS Quarterly*, 37(2):357–370.

Mezzanotti, F. (2021). Roadblock to innovation: The role of patent litigation in corporate r&d. *Management Science*, 67(12):7362–7390.

Miller, C. D. and Wang, R. D. (2024). Product digitization and differentiation strategy change: Evidence from the book publishing industry. *Strategic Management Journal*, 45(7):1241–1272.

Moser, P., Ohmstedt, J., and Rhode, P. W. (2018). Patent citations—an analysis of quality differences and citing practices in hybrid corn. *Management Science*, 64(4):1926–1940.

Mullally, K. C. (2009). Legal (un) certainty, legal process, and patent law. *Loy. LAL Rev.*, 43:1109.

Nagaraj, A. (2018). Does copyright affect reuse? evidence from google books and wikipedia. *Management Science*, 64(7):3091–3107.

Pisano, G. P. and Teece, D. J. (2007). How to capture value from innovation: Shaping intellectual property and industry architecture. *California management review*, 50(1):278–296.

Posen, H. E., Ross, J.-M., Wu, B., Benigni, S., and Cao, Z. (2023). Reconceptualizing imitation: Implications for dynamic capabilities, innovation, and competitive advantage. *Academy of Management Annals*, 17(1):74–112.

Stigler, R. (2014). Ooey gui: The messy protection of graphical user interfaces. *Nw. J. Tech. & Intell. Prop.*, 12:215.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, 15(6):285–305.

USPTO (2023). Supplemental guidance for examination of design patent applications related to computer-generated electronic images, including computer-generated icons and graphical user interfaces.

Williamson, O. E. (1985). The economic institutions of capitalism. *New York*.

Yoo, Y., Boland Jr, R. J., Lyytinen, K., and Majchrzak, A. (2012). Organizing for innovation in the digitized world. *Organization science*, 23(5):1398–1408.

Online Appendix A: Formal Model

A.1 Model Setup and Timeline

Consider a firm owning a digital design with stand-alone market value $v \sim F(v)$ on $[0, \bar{v}]$. The firm faces two sequential decisions:

Period 0: Protection decision (protect or not protect).

Period 1: If protected, appropriation decision (transfer or license).

Legal certainty $\theta \in [0, 1]$ indexes the legal environment (0 = complete uncertainty; 1 = complete certainty). Enforcement value scales with legal certainty:

$$\Delta(\theta) = \theta\bar{\Delta}, \quad \bar{\Delta} > 0. \tag{1}$$

A.2 Main Model

A.2.1 Protection Decision

If *not protected*, the design faces imitation loss $m \geq 0$, yielding

$$\pi^{NP} = v - m. \tag{2}$$

If *protected* at cost $c > 0$, payoff depends on the appropriation choice in Period 1.

A.2.2 Appropriation Decision

A.2.2.1 Transfer

The buyer pays $\beta(\theta)\Delta(\theta)$, where $\beta(\theta) \in (0, 1]$, $\beta'(\theta) > 0$. Due diligence costs are $\tau(\theta)$ with $\tau'(\theta) < 0$.

$$R^T(\theta) = \beta(\theta)\Delta(\theta) - \tau(\theta), \tag{3}$$

$$\pi^T(\theta) = v - c + R^T(\theta). \tag{4}$$

A.2.2.2 Licensing

Royalties equal $\alpha(\theta)\Delta(\theta)$, with $\alpha(\theta) \in (0, 1)$, $\alpha'(\theta) > 0$, $\alpha(\theta) < \beta(\theta)$. Monitoring costs $M(\theta)$ and rent dissipation $RD > 0$ apply.

$$R^L(\theta) = \alpha(\theta)\Delta(\theta) - M(\theta) - RD, \tag{5}$$

$$\pi^L(\theta) = v - c + R^L(\theta). \tag{6}$$

A.2.2.3 Choice

Appropriation mode is determined by the net revenue margin:

$$\Delta R(\theta) \equiv R^T(\theta) - R^L(\theta) \;\geq\; 0. \tag{7}$$

A.2.3 Key Mechanism: Asymmetric Cost Reduction

The central feature of the model is that legal certainty affects and frictions differently:

$$\tau'(\theta) < 0, \qquad |M'(\theta)| \approx 0. \tag{8}$$

Legal certainty substantially reduces due diligence costs (valuation and contracting), while monitoring costs remain largely unchanged due to ongoing enforcement difficulties.

A.2.4 Equilibrium Analysis

A.2.4.1 Protection Effect

Define the protection threshold:

$$\bar{\Delta}_P(\theta) = \min\left\{ \frac{c - m + \tau(\theta)}{\beta(\theta)},\ \frac{c - m + M(\theta) + RD}{\alpha(\theta)} \right\}. \tag{9}$$

Proposition 1 (Protection increases with legal certainty)**.** $\bar{\Delta}_P'(\theta) < 0$*: higher* θ *reduces the threshold for protection.*

A.2.4.2 Appropriation Mode Shift

Define the cutoff:

$$\bar{\Delta}_T(\theta) = \frac{\tau(\theta) - M(\theta) - RD}{\beta(\theta) - \alpha(\theta)}. \tag{10}$$

Proposition 2 (Transfers become more attractive with θ)**.** $\bar{\Delta}_T'(\theta) < 0$*: higher* θ *lowers the transfer threshold.*

A.3 Testable Predictions (Core)

Prediction 1 (Protection)**.** *Higher legal certainty increases the probability of protection:*

$$\Pr[Protect|\theta_1] > \Pr[Protect|\theta_0], \quad \theta_1 > \theta_0.$$

Prediction 2 (Transfer)**.** *Conditional on protection, higher legal certainty increases the relative probability of transfer:*

$$\frac{\Pr[Transfer|Protect, \theta_1]}{\Pr[License|Protect, \theta_1]} > \frac{\Pr[Transfer|Protect, \theta_0]}{\Pr[License|Protect, \theta_0]}.$$

A.4 Extensions

A.4.1 Design-Space Density

We now enrich the model by allowing design-space density d to affect costs.

Infringement–detection complementarity. Suppose infringements arrive at rate $\lambda(d)$ with $\lambda'(d) > 0$, and detection probability is $p(\theta)$ with $p'(\theta) > 0$. Monitoring costs take the form:

$$M(\theta, d) = \kappa\lambda(d)\,[1 - p(\theta)].$$

Then $M_d > 0$, $M_\theta < 0$, and $M_{\theta d} < 0$, implying that monitoring costs grow with density and fall slowly with certainty.

Clearance search. Due diligence may also depend on d, but less strongly. If clearance requires scanning $N(d)$ prior designs, with cost $\kappa_\tau \log(1 + N(d))$, then $\tau_d > 0$ but small relative to M_d.

Prediction 3 (Level Effect)**.** *Transfers will be relatively more likely than licenses in high-density design spaces, independent of legal certainty.*

Prediction 4 (Interaction Effect)**.** *The shift toward transfers following higher legal certainty will be stronger in high-density design spaces than in low-density spaces.*

A.5 Further Extensions

A.5.1 Non-Exclusive Licensing

Licensors may issue multiple parallel licenses. With $n \geq 1$ licensees, the net licensing revenue is

$$R_n^L(\theta) = n\alpha(\theta)\Delta(\theta) - nM(\theta) - RD(n),$$

where $RD(n)$ captures downstream rent dissipation that rises in n due to intensified product-market competition.

Lemma 1 (Scope and monitoring)**.** *If monitoring costs scale linearly in the number of licensees, then*

$$R^T(\theta) - R_n^L(\theta) \;\geq\; R^T(\theta) - R_1^L(\theta) \quad \forall n \geq 1.$$

This result shows that expanding the number of licensees weakly worsens the licensing margin when monitoring is costly, reinforcing the transfer advantage.

A.5.2 Learning About Value v

The model so far assumes firms know v before protection. In reality, v may be uncertain . Suppose firms draw v from prior G with mean μ and can pay cost $k > 0$ to learn v before protecting.

Learning is optimal if

$$k \leq \mathbb{E}\big[\max\{\pi^T(v,\theta), \pi^L(v,\theta)\} - \pi^{NP}(v)\big] - \max\{\pi^T(\mu,\theta), \pi^L(\mu,\theta)\} + \pi^{NP}(\mu).$$

If $\Delta(\theta, v) = \theta\delta v$, the value of learning rises in θ, implying legal certainty strengthens investment in valuation and protection for high-v designs.

A.5.3 Mean–Variance Refinement

Suppose enforcement outcomes are stochastic X, with $\mathbb{E}[X] = \mu_\Delta(\theta)$ and $\text{Var}(X) = \sigma_\Delta^2(\theta)$, where $\sigma'_\Delta(\theta) < 0$.

If buyers and licensees apply convex risk penalties, the surplus split $\beta(\theta), \alpha(\theta)$ increases in $\mu_\Delta(\theta)$ and decreases in $\sigma_\Delta^2(\theta)$.

Asset sales are typically more sensitive to tail risk than pay-as-you-go royalties, so reducing variance amplifies β relative to α, reinforcing the transfer shift as θ rises.

A.5.4 Post-Transfer Own Use

In practice, sellers sometimes retain partial own-use rights through license-back provisions or carve-outs. Let $\phi \in [0, 1]$ denote the fraction of stand-alone value v that the seller keeps after transferring the design.

$$\pi^T(\theta; \phi) = \phi v - c + \beta(\theta)\Delta(\theta) - \tau(\theta).$$

The protection threshold under transfer becomes

$$\bar{\Delta}_P^T(\theta; \phi) = \frac{c - m + \tau(\theta) + (1 - \phi)v}{\beta(\theta)}.$$

Own-use retention shifts the level of protection incentives but does not alter the relative attractiveness of transfer versus licensing, since both margins still depend on the same difference $\Delta R(\theta)$.

Online Appendix B. Expert Interviews

We documents the individuals interviewed for this study, their professional affiliations, roles, and the rationale for their selection. Each interviewee is referenced in the text using an anonymized identifier. All interviews were conducted with informed consent between 2023 and 2024, primarily via videoconference, and lasted approximately 60-90 minutes.

Table B.1: Interviewees

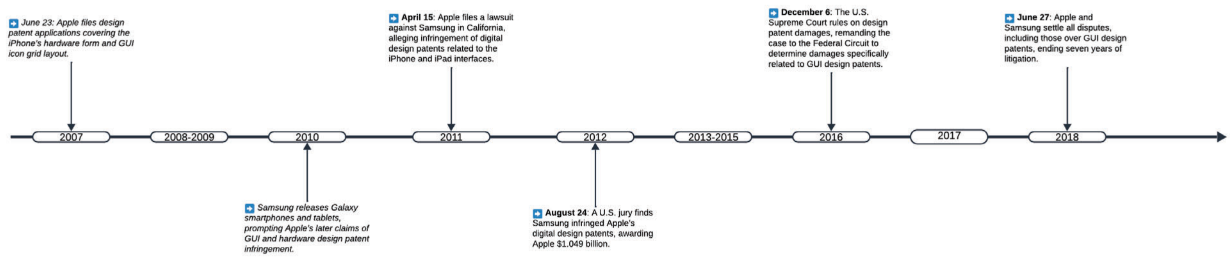
ID	Affiliation	Role
E1	Finnegan LLP	Legal expert
R1	Banner & Witcoff	Legal expert
R2	Banner & Witcoff	Legal expert
C1	McAndrews, Held & Malloy	Legal expert
T1	Sterne Kessler Goldstein & Fox	Legal expert
R3	Aristocrat	Practitioner
P1	WIPO	Policymaker
P2	WIPO	Policymaker

Interviewees were selected to cover the main professional domains involved in design protection and enforcement. Legal experts (E1, R1, R2, C1, T1) were included for their recognized expertise in design patent litigation, prosecution, and counseling, especially in the context of the US. Practitioners (R3) were selected to represent the perspective of corporate decision-making on design rights. Policymakers (P1, P2) were included to provide insights into the international policies of design law and administration. This purposive sampling ensured a balanced set of perspectives across law firms, corporate practice, and international institutions.

Online Appendix C: *Apple v. Samsung*

We provide a concise timeline of the *Apple v. Samsung* litigation saga, focusing on how the case clarified the protectability and enforceability of digital designs under US design patent law. We emphasize milestones relevant to digital designs and condense issues related to damages, which are not the focus of our study. Figure 1 guides the discussion of the timeline.

Figure C.1: Timeline of *Apple v. Samsung* Litigation Saga



Notes: Timeline of *Apple v. Samsung* litigation focusing on digital design patents, from initial filings to settlement. The figure highlights key events clarifying the protectability and enforceability of digital design under US patent law.

C.1 Background (2007–2010)

Apple introduced the iPhone in 2007, a product that combined distinctive hardware form with a novel digital interface. Rounded corners, bezel proportions, and an icon grid defined the "look" of the product. Apple protected not the phone's physical appearance but also on digital designs such as the grid of icons (e.g., US Patent D604305).

By 2010, Samsung released Galaxy smartphones and tablets. Apple claimed these products infringed their design patents, including digital designs. The stage was thus set for the first major litigation to test the scope of protection for digital designs.

C.2 Lawsuit Filed (2011)

In April 2011, Apple filed suit in the Northern District of California alleging that Samsung "slavishly copied" its smartphone and tablet designs. Key design patents included the D604305. Apple's decision to press digital design claims was novel, since courts had previously considered physical design patents but had not clearly resolved the status of purely digital ornamental features.

C.3 Jury Verdict on Digital Designs (2012)

In August 2012, a jury found that Samsung infringed Apple's digital design. The verdict confirmed that design patents covering digital ornamental features were protectable and enforceable. This was the decisive moment. Digital designs were recognized as protectable subject matter under US law. Firms could now file and enforce digital design patents with confidence that they were not limited to physical form factors.

C.4 Appeals and Partial Reversals (2013–2015)

Samsung appealed to the verdict. While higher courts struck down Apple's trade dress claims (finding them functional or insufficiently distinctive), they upheld the validity of the design patents, including those covering digital designs. Thus, protectability of digital designs remained intact.

C.5 Supreme Court Review: Enforceability and Damages (2016)

The dispute reached the US Supreme Court in 2016. The issue was not whether digital design patents were valid, but how to calculate damages for infringement. Under 35 USC 289, an infringer is liable for the "total profits" from the "article of manufacture." The question was whether the relevant article was the entire smartphone or only the infringing component (e.g., the screen interface).

In December 2016, the Court unanimously held that damages need not equal the total profits from the whole product. The relevant article could be a component. Importantly, the Court left the design patent infringement findings untouched. Thus, enforceability was confirmed, but its monetary reach was limited to the value of the infringing component.

C.6 Settlement (2018)

On remand, damages were recalculated, and in May 2018 a jury awarded Apple $539 million. Shortly after, Apple and Samsung settled, ending seven years of litigation. While the final figures received media attention, the broader legal significance lies elsewhere: the case established that digital designs are both protectable and enforceable under US design patent law, with enforceability tied to proportional remedies.

Online Appendix D: Appropriation Strategy Outcomes

We construct our sample of design patent transactions from the USPTO Patent Assignment Dataset, which records all ownership changes following patent grants. Building on Graham et al. (2018), our primary objective is to isolate arms-length transfers of ownership between organizations. At the same time, we would like to exclude administrative, employment-related, or financial filings that do not reflect genuine market exchanges.

D.1 Initial Filtering Criteria

Starting with the full set of assignment records, we construct the sample imposing three inclusion and exclusion requirements. First, we retain only transactions executed between 2009 and 2015 pertaining to design patents. Second, we exclude employment-related assignments. The USPTO flags transfers from inventors to employers at the time of initial filing, and we drop all records coded as employer assignments to focus on post-grant market transactions rather than internal transfers of ownership from inventors to their firms. Third, we restrict our sample to firm-to-firm transactions. We observe that some transactions, while not flagged by the USPTO as employment-related, nevertheless involve transfers from designers affiliated with the assignee. Using name-based heuristics, we identify and remove transactions in which either the assignor or assignee appears to be an individual (e.g., names formatted as "Last, First" or containing personal suffixes such as "Jr." or "Ph.D."). This approach yields a conservative lower-bound estimate of market transactions.

D.2 Initial Transaction Classification

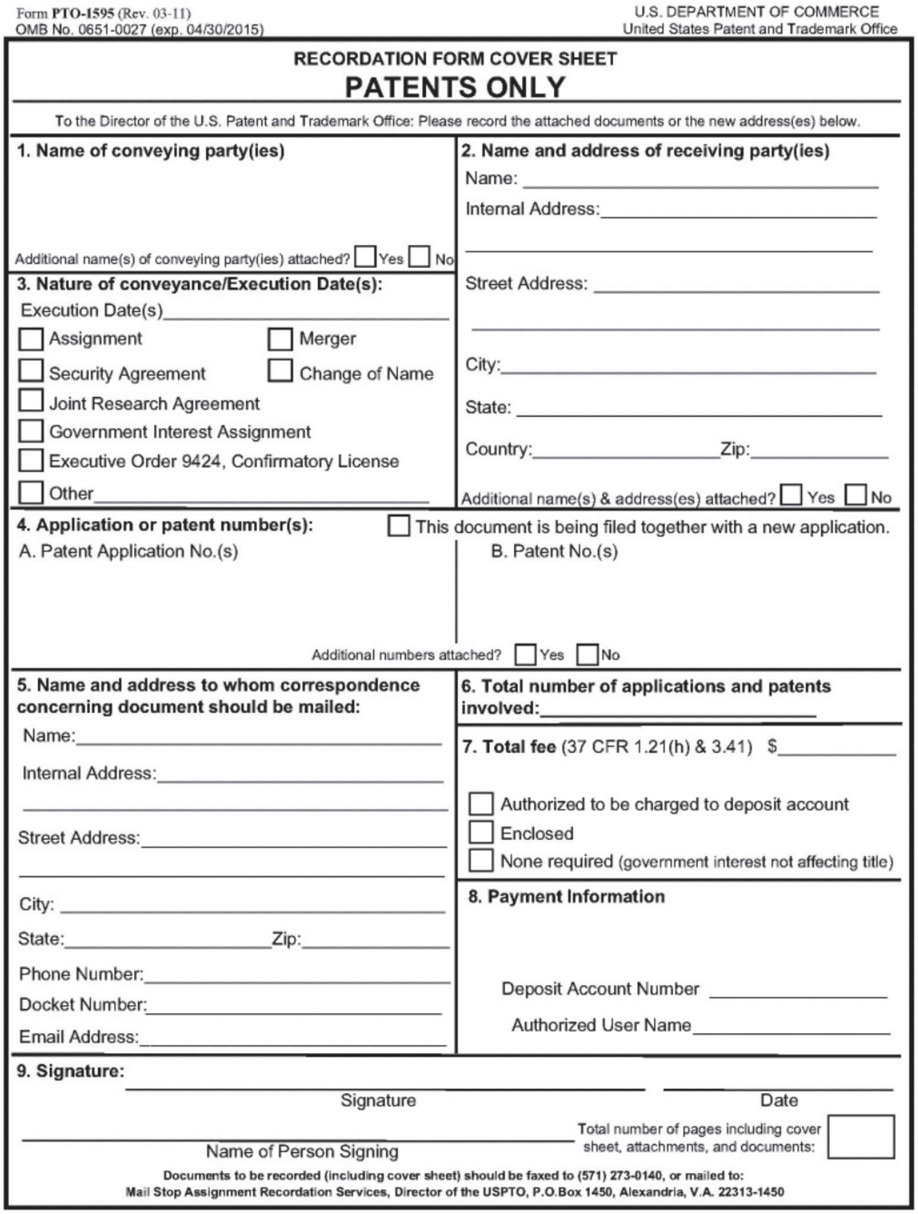
The USPTO assigns each transaction a conveyance category. Table D.1 presents the frequency distribution of these categories in our filtered sample. Figure D.1 gives an example of the document use to record these conveyances.

Table D.1: Summary Statistics of Conveyance Categories (N=327,875)

Category	**Frequency**
Assignment	32,526
Correction	22,659
Government	179
Merger	6,197
Missing	359
Name Change	14,627
Other	251
Release	98,815
Security	152,262

We exclude name changes and corrections, as these represent administrative processes rather than economic exchanges. We also exclude transactions with missing conveyance types, as the nature of these transactions cannot be verified. Since licensing is not an explicit category, we examine the conveyance text to identify and classify licensing agreements. This means that we reclassify transactions from their original category (e.g., other, government) to licensing.

Figure D.1: Illustrative Example of Recordation Form Sheet for Patents


Form PTO-1595 (Rev. 03-11)
OMB No. 0651-0027 (exp. 04/30/2015)

U.S. DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

RECORDATION FORM COVER SHEET

PATENTS ONLY

To the Director of the U.S. Patent and Trademark Office: Please record the attached documents or the new address(es) below.

1. Name of conveying party(ies)

Additional name(s) of conveying party(ies) attached? ☐ Yes ☐ No

2. Name and address of receiving party(ies)

Name: ____

Internal Address: ____

Street Address: ____

City: ____

State: ____

Country: ____ Zip: ____

Additional name(s) & address(es) attached? ☐ Yes ☐ No

3. Nature of conveyance/Execution Date(s):

Execution Date(s) ____

☐ Assignment ☐ Merger

☐ Security Agreement ☐ Change of Name

☐ Joint Research Agreement

☐ Government Interest Assignment

☐ Executive Order 9424, Confirmatory License

☐ Other ____

4. Application or patent number(s): ☐ This document is being filed together with a new application.

A. Patent Application No.(s)

B. Patent No.(s)

Additional numbers attached? ☐ Yes ☐ No

5. Name and address to whom correspondence concerning document should be mailed:

Name: ____

Internal Address: ____

Street Address: ____

City: ____

State: ____ Zip: ____

Phone Number: ____

Docket Number: ____

Email Address: ____

6. Total number of applications and patents involved: ____

7. Total fee (37 CFR 1.21(h) & 3.41) $____

☐ Authorized to be charged to deposit account

☐ Enclosed

☐ None required (government interest not affecting title)

8. Payment Information

Deposit Account Number ____

Authorized User Name ____

9. Signature:

Signature

Date

Name of Person Signing

Total number of pages including cover sheet, attachments, and documents:

Documents to be recorded (including cover sheet) should be faxed to (571) 273-0140, or mailed to: Mail Stop Assignment Recordation Services, Director of the USPTO, P.O.Box 1450, Alexandria, V.A. 22313-1450

D.3 Identifying Arms-Length Transactions

The primary challenge in constructing our sample is distinguishing genuine arms-length market transactions from transfers between related entities. While we excluded employer-employee transactions in the initial filtering exercise, manual inspection reveals that many transactions occur between parties within the same organizational structure (e.g., parent-subsidiary relationships) or between entities that have merged. This is especially true for transactions categorized under "Assignment". Security transactions, for example, are relatively easy to detect given that the firms involved are from distinct industrial backgrounds (e.g., one is a bank and the other is an ordinary firm).

Hence, to ensure we capture only arms-length transactions, we implement the following refinement procedures. First, we standardize firm names to identify potential related-party transactions. Specifically, we remove legal suffixes (e.g., Inc., LLC, Ltd.), normalize abbreviations, and reconcile variant spellings. We then assign a unique numerical identifier to each distinct standardized firm name. This allows us to identify unique pairings of firms that have transaction histories.

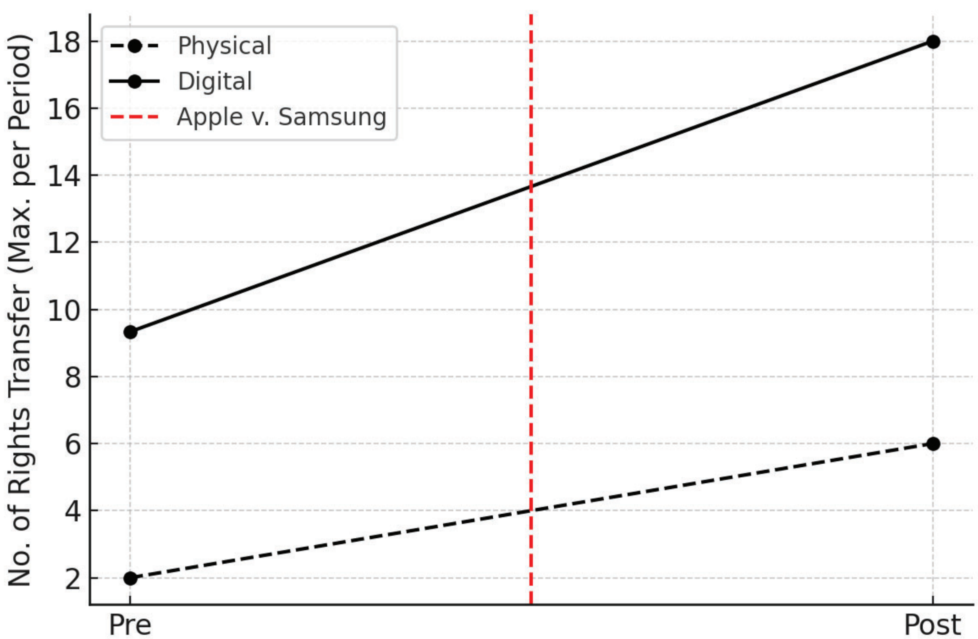
From the cleaned unique pairs of firm IDs, we check whether organizational relationships may exist between entities with different names. To verify organizational independence, we employ a web-search-assisted validation procedure using DeepResearch in ChatGPT-4o. The model retrieves authoritative evidence from SEC filings, company investor relations pages, and merger announcements to classify entity pairs. Each pair receives one of three labels: SAM (same entities), SEP (separate entities), or UNS (uncertain).

In our final sample, we only retain those pairs that are labeled "SEP" (separate entities). We exclude those firms belonging to the same corporate group (labeled as "SAM"), those firms that merged during or prior to the sample period, those entities that separated from a common parent company during the sample period, and those firms for which organizational independence could not be ascertained (labeled as "UNS"). From more than 32,000 records under the assignment category with 4,875 unique firm pairs involved, we validated 11,878 records from 2,477 firm pairs.

D.4 Illustrative Example: Case of RPX

To illustrate how design patent transfers operate in practice, we highlight the case of RPX Corporation. Founded in 2008, RPX is a defensive patent aggregator that acquires patent portfolios from operating companies and non-practicing entities to mitigate litigation risks for its members. Rather than asserting these patents, RPX's model centers on neutralizing exposure through centralized ownership and coordinated management of intellectual property assets.

Figure D.2: Case of RPX's Rights Transfer



In our data, RPX emerges as a notable assignee of design patents, receiving transfers from firms across industries. Following *Apple v. Samsung*, companies in digital sectors faced a sharper need to manage valuation and enforcement risks tied to user interface designs. As shown in Figure D.2, RPX became a major receiver of design patent transfers in the post-verdict period, particularly from firms specializing in digital interfaces.

RPX's role underscores how *Apple v. Samsung* expanded the tradability of digital design rights. Once courts confirmed their protectability and enforceability, firms could value these assets with greater confidence and transact them through specialized intermediaries. RPX exemplifies this broader institutional response: entities that absorb enforcement risk and facilitate the circulation of intellectual property in emerging design markets.

This case reinforces our core argument. By lowering due-diligence costs, legal certainty transformed design patents from uncertain claims into marketable assets that circulate through secondary exchanges. The post-2012 rise in recorded transfers to RPX thus marks not just an increase in trading volume but a structural shift in how firms appropriate and manage design-related value.

Online Appendix E: Matching Digital and Physical Subclasses

Identifying causal effects of digital design innovation requires comparing digital designs to appropriate physical counterfactuals—but this is inherently difficult for three reasons. First, the boundary between digital and physical designs has become increasingly blurred. A display screen showing an interface could be classified as either physical hardware or digital software depending on subtle distinctions in functionality and claims language. Second, even when digital designs are identified, finding comparable physical designs is complicated by the multidimensional nature of design similarity—designs can be similar visually (how they look), functionally (what they do), or both. Simply matching on appearance might compare a digital calculator interface to decorative physical patterns, while matching on function alone might compare visually disparate designs. Third, technological evolution means that digital and physical designs may operate in different technological contexts even when serving similar purposes, potentially confounding any comparison.

Our identification strategy addresses these challenges through a multi-layered approach that leverages both regulatory guidance and network structure. First, we use the USPTO's 2023 supplemental guidance to precisely identify digital designs based on their status as "integral and active components" of computer operation, using specific textual markers that distinguish true digital interfaces from mere display hardware. Second, we exploit the citation network structure at the subclass level, which inherently captures both visual and functional similarity. Following Chan et al. (2018), who demonstrate that citation patterns reveal visual similarity between designs, we calculate similarity scores between subclasses based on their citation behavior. Crucially, because USPTO subclasses are organized by functional purpose, our subclass-level matching automatically incorporates functional equivalence—ensuring we compare digital keyboards to physical keyboards, not to arbitrary physical designs. This approach elegantly solves the multidimensional matching problem: the citation patterns capture visual similarity while the subclass structure ensures functional correspondence, with pair fixed effects absorbing any residual heterogeneity in match quality.

E.1 Technical Implementation

Step 1: Digital Design Classification. We first identify digital subclasses within the USPTO design patent database. Following the 2023 USPTO supplemental guidance, we parse the title and claims text of all design patents to flag those containing keywords indicating digital interfaces: "graphical user interface," "user interface," "interactive display," "animated icon," and "virtual button." Subclasses where the majority of patents contain these keywords are classified as digital ($Digital = 1$), while all others constitute the pool of potential physical controls ($Digital = 0$).

Step 2: Citation Network Construction. We construct a directed citation network where nodes represent USPTO subclasses and edges represent citation relationships between them. Each edge is weighted by the frequency of citations from patents in one subclass to patents in another. This network captures how designers and examiners perceive relationships between different design categories through their citation behavior.

Step 3: Similarity Calculation. For each pair of subclasses, we compute similarity using two complementary measures:

(a) *Direct citation coupling:* Each outbound citation from a focal subclass is weighted by the inverse of its total out-degree, ensuring that subclasses citing many others do not artificially inflate similarity scores.

(b) *Bibliographic coupling:* We calculate the Jaccard coefficient of shared citations, i.e.,

$$\mathrm{BC}_{ij} = \frac{|\,\mathcal{R}_i \cap \mathcal{R}_j\,|}{|\,\mathcal{R}_i \cup \mathcal{R}_j\,|}.$$

The final similarity score S_{ij} combines both measures, yielding values between 0 (no similarity) and 1 (perfect similarity).

Step 4: Uniqueness-Constrained Matching. To ensure clean identification, we implement a greedy matching algorithm that pairs each digital subclass with its most similar physical counterpart while preserving uniqueness:

1. Digital subclasses are sorted by their maximum S_{ij} values.
2. Each digital subclass is matched to the highest-similarity physical subclass not already assigned. This one-to-one matching prevents any physical subclass from serving as a control for multiple treatment units.

This procedure yields a matched set where each digital subclass is paired with its most visually and functionally similar physical counterpart, providing credible counterfactuals for causal identification.

E.2 Illustrative Example: Digital Keyboard Interfaces and Physical Keyboards

To demonstrate how our matching procedure identifies meaningful digital–physical pairs, consider the pairing of USPC subclass **D14/488** with **D14/138**. Subclass D14/488 encompasses digital designs for virtual keyboards displayed on touchscreens, tablets, and other interactive displays. Through our citation-based similarity analysis, this digital subclass achieves its highest similarity score ($S_{ij} = 0.67$) with subclass D14/138, which covers the ornamental design of physical computer keyboards.

Figure E.1: Illustrative Example of Digital and Physical Keyboard Designs

Notes: The left panel illustrates a digital design (touchscreen keyboard interface, USPC D14/488), and the right panel shows its matched physical counterpart (computer keyboard layout, USPC D14/138). Both share the same QWERTY grid structure and functional role of enabling text input, though rendered on different substrates (glass versus plastic). This figure is provided purely as an illustrative example of the digital–physical subclass matching procedure.

This pairing illustrates the multidimensional correspondence our identification strategy captures. *Visually*, both subclasses center on the familiar QWERTY key arrangement—rows of alphanumeric keys in a standardized grid layout that has persisted across the transition from physical to digital input methods. Examiners and designers recognize this visual continuity, as evidenced by the substantial citation overlap between these subclasses: patents in D14/488 frequently cite physical keyboard designs as prior art, while subsequent innovations cite both digital and physical keyboards as related designs.

Functionally, both subclasses serve the identical purpose of text input, despite their different substrates. The USPTO's classification system groups them within the broader category of data processing equipment (D14), acknowledging their shared utility. This functional alignment is crucial for our identification strategy—we are comparing digital innovations in text input interfaces with their most relevant physical counterparts, not with arbitrary physical designs that might share superficial visual elements.

Online Appendix F: Supplementary Tables

Table F.1: Design Protection Activities and Commercialized Designs

	(1) Protection
Digital × Post	0.09***
	(0.02)
Digital × Post × Commercialized	0.31*
	(0.18)
Pair-Year FE	Yes
N	21,553
R^2	0.42

Notes: The dependent variable is the log number of design patents protected (granted) at the subclass–year level. All regressions absorb matched subclass–pair fixed effects, with standard errors clustered at the subclass level. Sample comprises 21,553 subclass–year observations from 2009–2015. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table F.2: Heterogeneity Analyses: DSSD and Licenses

	(1) Low DSSD	(2) High DSSD	(3) Full Sample
Digital	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)
Post Apple v. Samsung	-0.00	-0.00	-0.00*
	(0.00)	(0.00)	(0.00)
Digital × Post	0.00*	0.00	0.00*
	(0.00)	(0.00)	(0.00)
DSSD (median=1)			0.00**
			(0.00)
Digital × DSSD			-0.00
			(0.00)
Digital × Post × DSSD			-0.00
			(0.00)
Pair FE	Yes	Yes	Yes
N	10,773	10,780	21,553
R^2	0.11	0.10	0.07

Notes: The dependent variable is the log number of design patent licenses at the subclass–year level. Columns (1) and (2) split the sample by pre-2012 design-space similarity density (DSSD) at the median; column (3) uses the full sample with DSSD interactions. All regressions absorb matched subclass–pair fixed effects; standard errors are clustered at the subclass level. ** $p < 0.05$, * $p < 0.1$.

Cover: WIPO Design