The Application of Economic Models in the Courtroom: A Failed Promise?

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Abstract

Scientific models are frequently used as sources of evidence in legal proceedings. A prominent example is the use of economic models by expert witnesses in competition cases, that is, legal disputes involving alleged violations of antitrust laws. In these cases, economic experts apply theoretical models and econometric techniques to provide quantitative insights about specific markets. Judges then assess the reliability and strength of this model-based evidence when making their decisions. However, despite its widespread use, economic models often fail to significantly influence judicial outcomes, undermining their intended role in the courtroom. This paper argues that disregarding model-based evidence has serious consequences, as weaker and less reliable evidence often fills the void, potentially reducing the quality of judicial decisions. To uncover the reasons behind this phenomenon, I will explore the methodological challenges of using economic models in courts in two ways. First, I argue that the judicial assessment of economic models differs from other instances of model use studied in philosophy of science. Second, I contend that institutional and epistemological factors contribute to the challenges of using economic models in court. Specifically, economic models have a large "attack surface," making them vulnerable to challenges in adversarial settings. Ironically, this vulnerability allows less reliable forms of evidence, which are simpler and harder to challenge, to gain prominence in judicial decisions.

Keywords: model application, legal proceedings, competition, economic models, evidence

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1 Introduction

Scientific models are routinely employed in various social and institutional contexts, often accompanied by high expectations of enhancing reasoning and strengthening the evidential basis for decision-making. Notable examples recently explored by philosophers of science include the use of economic models in central banks and auction design, model ensembles in climate science, and natural hazard models in probabilistic risk assessment (e.g., Gluck 2023; Jhun 2023; Parker 2010, 2011; Roussos, Bradley, and Frigg 2021; van Basshuysen 2023; Winsberg and Harvard 2024; Zanetti 2024). A common lesson emerging from these studies is that using scientific models outside academic and research-based settings introduces a range of epistemic and practical challenges. One major challenge is how to aggregate input from multiple scientific models when making policy decisions amidst model uncertainty (Jhun 2023; Roussos, Bradley, and Frigg 2021; Zanetti 2024). Another challenge arises from the urgency of decision-making in what is often referred to as the "fast science" context (Friedman and Šešelja 2023; Northcott 2022; Van Basshuysen and White 2021; Winsberg, Brennan, and Surprenant 2020; Stegenga, forthcoming).

Incidentally, most philosophical analyses to date have focused on the use of models within the scientific community, particularly in cases of peer disagreement over the assessment of evidential strength in support of a hypothesis, or in policy contexts where scientific models inform decisions that guide public policy. However, a third, often overlooked domain exists where scientific models play a crucial and high-stakes role: the courtroom.[1] This article seeks to expand the existing literature by critically examining how expert witnesses use scientific models to shape judicial outcomes. I argue that this legal context raises distinctive philosophical and practical challenges, and I advance two main claims. First, excluding model-based evidence from legal proceedings can compromise the quality of judicial decision-making by leaving fact-finders with a weaker evidentiary base.[2] Second, I contend that such evidence is often excluded not because it lacks relevance or reliability, but because, as I will explain in more detail later, it has what I call a broader *attack surface* – that is, it is more exposed to criticism and dispute in the adversarial setting of the courtroom.

To support these two claims, I will focus on the practice of using economic models by expert witnesses in US legal proceedings involving alleged violations of antitrust or competition laws by firms (hereafter referred to as "competition cases"). In this context, models are employed as sources of evidence intended to influence a court's verdict. Economic experts typically construct empirical models by combining theoretical modeling with econometric techniques

1. To be sure, philosophers have examined how courts should evaluate and manage scientific evidence in judicial proceedings (e.g., Beecher-Monas 2009; Dwyer 2008; Gerken 2022; Haack 2015; Jasanoff 1997; Martini 2015; Miller 2016; Satta 2022; Sikorski 2022). However, this article takes a unique approach by concentrating on the role of scientific modeling in judicial proceedings, a topic that has not been extensively addressed in the existing research.

2. "Fact-finder" refers to the individual or entity responsible for assessing the facts of the case – the judge in a bench trial or the jury in a jury trial, depending on the type of case.

and apply them to generate quantitative results about particular markets under scrutiny. Judges, in turn, assess the strength and reliability of this model-based evidence when reaching their verdict.

Despite their widespread use, however, economic models often fail to influence judicial decision-making, thereby undermining the rationale for their introduction into courts of law. To illustrate this, in Section 3, I will survey US case law and the current debate among antitrust scholars to demonstrate that instances in which model-based evidence becomes irrelevant are not negligible. The dismissal of model-based evidence is not without consequences. Indeed, I will show that model-based evidence presented in legal proceedings tends to be overshadowed by weaker, less reliable evidence (Section 4). As a result, I argue that discarding model-based evidence may harm the quality of judicial decisions, as decisions made by fact-finders are grounded in a less reliable evidentiary base.

The study of the practice of using economic models in the courtroom reveals interesting methodological challenges that economists face. I will situate this case study within philosophy of science in two ways. First, I will show how this practice differs from other uses of multiple models that have already been studied in philosophy of science (Section 5). Second, I will highlight a form of model usage that may have been underappreciated in philosophy of science. I argue that the methodological challenges faced by economic modeling in the courtroom arise from the combination of the institutional setting and the epistemological characteristics of economic models. In particular, I contend that courts may discard model-based evidence because it has a large "attack surface"; that is, model-based evidence is particularly susceptible to challenge in an adversarial setting (Section 6).

Before proceeding with the main content of this article, a few disclaimers are in order. First, my focus in this article is not on the systemic influence of economic thought on the legal system, but rather on specific ways in which economic models impacts court verdicts in competition cases. Second, I will set aside the long-standing debate on the goals of competition policy and proceed on the assumption that courts enforcing antitrust laws aim to protect competition and consumers – whatever that may entail in specific circumstances (see, e.g., Esposito 2022; Giocoli 2024; Martin 2007). Finally, given my focus on US legal system, the terms "antitrust", "competition law", and "competition policy" will be used interchangeably.[3] Also, I follow the common practice in US legal scholarship and use "courts" and "judges" as synonyms.

2 Model-based evidence in competition cases

Our case study concerns the use of economic models in competition cases, that is, legal disputes concerning alleged violations of antitrust laws, such as monopolistic practices, anti-competitive

3. Antitrust law was introduced in North America at the end of the nineteenth century to prevent anti-competitive behavior and promote market competition. In Europe and other jurisdictions, antitrust law is referred to as competition law.

agreements, and abuse of market dominance, among others. In these cases, economists are often hired as expert witnesses to construct models of counterfactual scenarios, that is, of what would have occurred in the absence of the anticompetitive conduct.[4] Antitrust practitioners usually refer to this counterfactual scenario as the "but-for" world to indicate the world that one should expect to exist *but for* the alleged anticompetitive behavior. Ideally, the comparison between the actual world and the but-for world demonstrates the effect of the antitrust violation.

An important example of but-for modeling is merger simulation (also referred to as a "merger simulation models"), a technique that involves the parametrization of game-theoretic models of oligopolistic markets to simulate how prices in the relevant market would change if a merger were permitted. Merger simulation models combine theoretical and empirical approaches through the following four-step procedure (for further details, see Budzinski and Ruhmer 2010; Budzinski and Noskova 2022; Werden, Froeb, and Scheffman 2004). First, the type of competition in the simulated market is defined by selecting an appropriate oligopoly model, with Bertrand and Cournot competition models being the most common choices. Second, the most suitable functional form for the market demand system is chosen. Third, the demand systems are calibrated using pre-merger data. Finally, the full simulation is performed, incorporating the previous steps to predict the post-merger market situation.

Merger simulation models are commonly used in merger reviews, which are court-based assessments determining whether a merger between two or more firms violates antitrust laws. These reviews are becoming an increasingly significant area of antitrust and competition law on both sides of the Atlantic. The results of merger simulations play a key role in guiding judicial decision-making in both US and European courts, especially in cases brought by competition authorities like the Federal Trade Commission and the European Commission.

Merger simulation models are just one example of the many cases in which economic models are used as sources of evidence (see *infra* Section 6 for further analysis on the epistemology of merger simulation models). As a working definition, I call *model-based evidence* any item or piece of information derived from scientific models that can influence what one is justified in believing about a particular state of affairs.[5] For instance, if a merger simulation model predicts that a proposed merger will result in a 5 percent price increase, this prediction becomes part of the model-based evidence presented in the case. Other examples from various scientific fields are also possible. For example, probabilistic models used in DNA analysis estimate the likelihood that DNA found at a crime scene matches a suspect's, often providing crucial evidence in criminal trials.[6]

4. On the role of economists as expert witnesses, see the classic articles by Mandel (1999) and Posner (1999) and the recent contributions by Maas and Svorenčík (2017), Chassonnery-Zaigouche (2020), Giocoli (2020), and Peruzzi (2023).

5. There is significant debate within the philosophy of science about what constitutes evidence (for an overview, see Kelly 2016 and Ho 2021). That said, my definition of model-based evidence follows the standard conception of evidence as something that can make a difference to what one is justified in believing (see Kelly 2016).

6. It is important to distinguish model-based evidence from other types of evidence that can also play a significant role in legal proceedings. Legal texts often categorize evidence based on the role it plays in supporting

3 The neutralization of model-based evidence

A notable phenomenon observed by competition scholars and legal authorities is that, despite their widespread use, model-based evidence is often "neutralized" during legal proceedings, diminishing or even nullifying its impact on court verdicts. To better understand this, let us examine in more detail the institutional context in which model-based evidence is presented and evaluated.

In the Anglo-American common law system, which is the focus of my analysis, disputes are resolved through the adversarial system, where parties present their cases in a public forum before independent judges.[7] Each party hires its own lawyers and, potentially, scientific experts to present a partisan view of both the law and the facts. The goal of the adversarial system is, in principle, to reveal the procedural "truth" through the clash of opposing, self-interested views, presented on equal footing.[8] In such an adversarial context, it is standard practice for the plaintiff's expert to present a model's results, while the defendant responds with detailed critiques of nearly all the plaintiff's assumptions, sometimes even offering an alternative model. As a result, judges frequently encounter multiple, and often conflicting, models – making this the norm rather than the exception. The key phenomenon I want to highlight is that when faced with competing models or differing assumptions, judges frequently avoid taking a definitive position, effectively neutralizing both perspectives. In this way, model-based evidence is disregarded and ultimately plays no role in the court's verdict.

A concrete litigated case can help illustrate this phenomenon of the neutralization of model-based evidence. One relevant example is the 2020 Peabody case, in which the Federal Trade Commission (FTC) sought to block a proposed joint venture between two coal mining companies, Peabody Energy and Arch Resources, arguing that it would severely harm competition in a region supplying 40 percent of America's coal.[9] The court had to make a decision on the hypothesis that the merger would significantly reduce competition, thereby violating antitrust laws. To reach such a decision, the court also needed to assess, alongside other types of evidence, the model-based evidence presented by the expert witnesses of the opposing parties.

The FTC presented the expert opinion of Dr. Nicholas Hill, who worked for the leading economic consulting group Bates White. The court was initially swayed by the market definition presented by the FTC's economic expert, who effectively argued for a narrow relevant

or challenging arguments. *Factual evidence* refers to direct observations or testimonies that can be verified, such as witness statements about a company's practices or sales records showing pricing strategies. *Documentary evidence* includes written or recorded materials supporting a claim, such as contracts, emails, or reports detailing communications regarding pricing agreements or market strategies.

7. The adversarial system contrasts with the inquisitorial system used in many European countries, where the judge plays a more active role in directing the case, making inquiries, calling and examining witnesses, and generally determining the matters the court will decide.

8. Gordon Tullock famously criticized the common law system on this very point, arguing that the clash of self-interested parties is both informationally inefficient and socially wasteful. See Tullock (2004, 2005a, 2005b), and discussion in Albertazzi, Ploner, and Vaccari (2024), Shughart (2018), and Zywicki (2008).

9. *FTC v. Peabody Energy Corp.*, 492 F. Supp. 3D 865 (E.d. Mo. 2020). ("Peabody").

market consisting of coal sourced from the Powder River Basin.[10]

With the relevant antitrust market established, the FTC needed to provide evidence that the merger would generate anticompetitive effects. As a first step, the plaintiff's expert highlighted a significant change in the Herfindahl–Hirschman Index (HHI) post-merger. The Herfindahl-Hirschman Index (HHI) is a common measure of market concentration that varies from 0 to 10000. It is calculated squaring the market share of each firm competing in the market and then summing the resulting number. Dr. Hill calculated that the two companies had a combined market share of 68 percent as measured by production volumes. Moreover, he computed the HHI using 2019 mine production data and found that the merger would increase the HHI by 2258 points to 4965.[11]

Eventually, to provide further evidence to support its case, the FTC's expert employed a merger simulation based on the Cournot model, a standard workhorse model from industrial economics that describes an oligopoly market where firms produce a homogeneous product at constant marginal costs and compete by choosing the quantity of output they produce. Accordingly, the plaintiff's expert modeled the market as one in which a few coal mining companies (including the two merging companies, Peabody Energy and Arch Resources) compete with each other, offering similar products and having similar cost structures.[12] Applying the Cournot model using available data on prices, quantity, and demand substitution patterns, the plaintiff's expert argued that if the merger were allowed, it would cause "significantly higher prices for SPRB [Southern Powder River Basin] coal over the next ten years, causing total harm with a net present value of over $1 billion." (*ibid.*, 906). The plaintiff argued that the model results constituted solid evidence that "the parties' [. . .] claimed marginal cost efficiencies" would not prevent the joint venture from "substantially reducing competition, raising prices, and harming consumers." (*ivi*).

The defendants, with the help of their own economic experts, attacked the application of the Cournot model by the plaintiff's expert witness. The main allegation was that Dr. Hill's model did not incorporate dynamic risks. Their argument was that, given the growth of renewables in recent years, the coal industry would likely face a rapid decline in demand as consumers switch to renewable energy. An economic model that does not include such considerations, the defendants argued, is bound to overestimate the harm caused by the merger. Broadly, their critique was that the plaintiff's model did not reflect the actual properties of the coal industry under examination, and therefore could not provide solid evidence that should influence the

10. The Powder River Basin is a geologic structural basin in southeast Montana and northeast Wyoming. Roughly speaking, the smaller the market, the easier it is for the plaintiff to demonstrate potential anticompetitive effects of certain business conduct. As such, persuading the judge of a narrow market definition is a strong starting point for winning a competition case.

11. The HHI is currently used as a barometer for potential anticompetitive effects of mergers in the European Commission's Guidelines on the Assessment of Horizontal Mergers and the US Horizontal Merger Guidelines. In Section 4 *infra*, I shall further discuss market concentration measures (which I will label "index-based evidence") in contrast to model-based evidence.

12. For a textbook treatment of the Cournot model, see Tirole (1988).

court's decision.

The court discussed the plaintiff's merger simulation model and the critiques raised by the defendant over several pages, including suggestions from the defendant's expert for variations in the plaintiff's model that resulted in opposing price predictions. However, in its written verdict, the court decisively stated that it did not take a position on the model-based evidence, that is, the evidence resulting from the application of economic models – in this case, to predict the merger's effect on prices. "This Court," we read, "need not decisively sift through various models and theories." (*ibid.*, 907) Thus, model-based evidence did not play a role in the court's verdict; it was irrelevant as it did not alter the judge's hypothesis about the competitiveness of the merger.

Peabody is not an isolated case; similar expressions regarding the irrelevance of the evidence produced by economic models can be found in various cases litigated before US federal courts. For instance, in *Tronox* (2018), after evaluating the empirical models proposed by competing experts, Judge McFadden remarked:

> While the Court found them [empirical models] ultimately consistent with the other evidence presented by the plaintiff's economic expert, his [model-based] analysis was not dispositive on either the relevant market or the likelihood that the merger will increase market concentration.[13]

The court's reluctance in *Tronox* reflects a broader trend in antitrust litigation, where judges often avoid choosing between the economic models presented by the plaintiff and the criticisms raised by the defense. In fact, the courts in both *Peabody* and *Tronox* explicitly continued a legal precedent established in *Sysco* (2013), which determined that courts should not decide which economic model is most appropriate when ruling on a competition case.[14]

The tendency of antitrust courts to overlook model-based evidence has not gone unnoticed by legal scholars, legislators, and economists. Indeed, a debate has emerged regarding the appropriateness of using economic models in court to provide scientific evidence. Central to this debate is the recognition that applying economic models in the courtroom involves clear costs, which should ideally be outweighed by corresponding benefits (e.g., Bernstein and Lasker 2015; Haw Allensworth 2012; Posner 1999).

These costs are multifaceted. First, there are significant monetary costs associated with expert witnesses, who are often highly compensated. Second, there are costs in terms of cognitive and time resources. Generalist judges, and even more so jurors, often lack formal education in

13. *FTC v. Tronox Ltd.*, 332 F.Supp. 3d 187 (D.D.C. 2018).

14. *FTC v. Sysco Corp.*, 113 F.Supp. 3d 1. ("Sysco"). For another example of the irrelevance of model-based evidence in court verdicts, see the opinion issued by Judge Victor Marrero in *New York v. Deutsche Telekom AG*, 439 F. Supp. 3d 179 (S.D.N.Y. 2020). There, he argued that the parties' efforts were reduced to "imprecise and somewhat suspect aids: competing [sic] crystal balls" (188). "The parties' costly and conflicting [...] economic [...] models," he wrote, "along with the incompatible visions of the competitive future their experts' shades-of-gray forecasts portrayed, essentially canceled each other out as helpful evidence the Court could comfortably endorse as decidedly affirming one side rather than the other" (*ibid.*, 187).

economics.[15] As a result, it might be difficult for them to adequately assess the economic models presented in court – why should we expect courts to be capable of properly evaluating these models in the first place? Such assessments, assuming they are feasible, are extremely costly in terms of both time and cognitive resources. Third, concerns arise about the neutrality and independence of these witnesses.[16] The so-called commissioning bias manifests in two ways: first, experts may subconsciously align with the interests of the client paying their fees (Haack 2014; Walton 2008); and second, generalist judges may be unduly influenced by partisan expert testimony.

In light of this, do the benefits of using economic models outweigh the costs of their application? On the one hand, when model-based evidence becomes irrelevant, it seems that the costs of using economic models outweigh the benefits. Jonathan Kanter, who served as Assistant Attorney General at the Department of Justice Antitrust Division during the Biden administration, has expressed radical skepticism toward the use of economic models in legal proceedings:

> We spend millions arguing about models of the economy and how conduct will hypothetically shift outcomes to the fourth decimal point up or down. Plaintiffs and defendants offer experts to present quantitative models. More often than not, courts reject both competing models and do not believe either side.[17]

On the other hand, some economists argue that the benefits of using economic models generally outweigh the costs. For instance, Berkeley economist Carl Shapiro has made a compelling case for the positive impact that economics has had on antitrust decisions:

> Economics provides an indispensable way to sift through a mountain of evidence to better understand the likely economic effects of various business practices in comparison with some suitable counterfactual. Economics is not "pro-defense" or "pro-plaintiff." Properly used, economics instructs us *what to look for* in a given case to assess effects. (Shapiro 2021a, 39)

"Economics," he continues, "is a neutral tool that helps us understand the economic effects of various business practices." (*ivi.*) The idea is that when effectively applied by experts, economics provides tools to help decision-makers understand the impacts of firms' conduct

15. Judicial struggles with scientific evidence are well-documented (see Hans and Saks (2018), Koehler (2018), and references therein). One potential solution is increasing the use of court-appointed experts to mediate conflicts between opposing expert testimonies (see Lopatka 2016; Posner 1999; Sidak 2013; Rubinfeld and Cecil 2018; Peruzzi 2023).

16. The accusation that expert witnesses are merely 'hired guns' is a common refrain in the media. For example, consider this article from ProPublica: https://www.propublica.org/article/these-professors-make-more-than-thousand-bucks-hour-peddling-mega-mergers.

17. Keynote at the University of Chicago Stigler Center, Chicago, IL, Thursday, April 21, 2022 "Antitrust Enforcement: The Road to Recovery." Transcript of the speech available here: https://www.justice.gov/opa/speech/assistant-attorney-general-jonathan-kanter-delivers-keynote-university-chicago-stigler.

across various markets. Shapiro acknowledges that many factors beyond economic reasoning, such as how courts allocate burdens of proof and establish legal standards, routinely influence judicial decision-making. Nevertheless, in his optimistic view, economic models – and, by extension, the economist *qua* economic expert – have the potential to assist the court in making correct decisions: convicting guilty firms while acquitting innocent ones. Beyond Shapiro, many other prominent economists have recently contributed to the internal debate within the discipline on the advantages and risks of using economic models in the courtroom (e.g., Carlton and Israel 2021; Katz 2021; Salop 2021; Shapiro 2021a, 2021b).[18]

Settling the ongoing debate among antitrust practitioners and competition economists is beyond the scope of this article. My aim here is to highlight that the case law discussed, along with the ongoing debate over the use of economic models in antitrust litigation, provides strong reasons to believe that these models often fail to meaningfully influence court verdicts. If economic models do not significantly impact judicial decision-making, their continued use becomes difficult to justify, particularly given the increased financial and cognitive burdens placed on judges and jurors.

Although one might argue that this is a good reason to simply stop using models altogether, in the next section, I will argue that ignoring model-based evidence can also be harmful to judicial decisions.

4 The problem of ignoring model-based evidence

The examples presented earlier suggest that evidence from economic models is often irrelevant in court rulings, particularly in competition cases. One might ask why this is a problem at all – why do courts even need model-based evidence? Some might even go further and argue that the neutralization of model-based evidence is not a flaw, but a feature of the adversarial system. According to this view, the mutual neutralization of competing models during a trial reveals a "truth": that model-based evidence is irrelevant for resolving the specific case at hand.

Contrary to this view, I argue that courts should resist discarding model-based evidence, as the consequences of doing so are far from benign. Without model-based evidence, court decisions can become significantly flawed, as the remaining evidence driving the verdict is often weaker and less reliable. My concern is not that model-based evidence is irrelevant *per se*, but that when it is sidelined, less reliable evidence takes its place, ultimately influencing judicial decisions in a possible detrimental way.

To see a concrete example, consider again *Peabody*, in which the court decided to discard model-based evidence after facing a battle of experts. In the same opinion, the court chose to block the merger primarily based on the plaintiff's demonstration of an increase in market share after the merger. More specifically, the court argued that "the FTC's HHI analysis created

18. For further insights on the various roles that forensic economics, especially industrial economics, can play in the enforcement of competition law, see Schinkel (2008).

a 'presumption [...] that [the Joint Venture] will substantially lessen competition by 'showing that the JV [Joint Venture] will result in significant market share and an undue increase in concentration' in the SPRB [Southern Powder River Basin] coal market." (*907*) This pattern can also be observed in many other recent judicial opinions on antitrust violations, where model-based evidence is set aside, and other forms of evidence appear to be the decisive factors behind the court's decision (Budzinski and Noskova 2022; Rafkin and Kuykendall 2021).

To understand what happens in those legal cases where model-based evidence becomes irrelevant, I propose to distinguish between *model-based evidence* and what I will refer to, for lack of a better term, as *index-based evidence*.

I have already defined model-based evidence as any evidence derived from economic models, primarily through the structural estimation of industrial economics models. Index-based evidence differs from model-based evidence along three key dimensions: 1) reliance on scientific models, 2) complexity, and 3) internal reliability. In particular, index-based evidence does not rely on scientific models, is simpler than evidence produced by a model, and is less internally reliable than evidence produced by a scientific model.[19]

First, index-based evidence does not rely on scientific models but, as the name implies, on simple arithmetic indices. A key example is the use of market concentration measures, which are derived from observable data such as market shares. For instance, the n-firm concentration ratio shows the combined market share of the largest n firms.[20] Another example, which we have already encountered, is the Herfindahl-Hirschman Index (HHI). These measures are based on the assumption that markets with fewer firms are less competitive. This assumption stems from the idea that competition flourishes when there are many buyers and sellers, making it harder for any single firm to control prices.[21] Thus, markets dominated by a few large firms are often interpreted as exhibiting reduced competition.

Second, index-based evidence is generally simpler than model-based evidence, as it usually relies on basic arithmetic calculations that are easy to compute and understand, even for non-experts. For example, the Herfindahl-Hirschman Index (HHI), one of the most commonly used market concentration measures, is a normalized index that can be calculated once market shares

19. The distinction between model-based and index-based evidence does not exhaust the kinds of evidence that scientific experts might employ in principle. For example, economists routinely accept other types of evidence, such as randomized controlled trials (RCTs), quasi-experimental empirical research, and laboratory experiments, in their academic work. However, I do not explicitly consider these types of evidence here, as they are generally not yet central in the context of legal proceedings (Einav and Levin 2010).

20. For example, in a market where the three largest firms, A, B, and C, hold market shares of 50 percent, 30 percent, and 10 percent respectively, the 3-firm concentration ratio would be 90 percent (i.e., 50 percent + 30 percent + 10 percent).

21. I should note at the outset that indexes are not created in a theoretical vacuum – they typically rest on underlying theoretical assumptions, and developing them is not necessarily a model-free exercise. For instance, the GDP deflator can be derived using the Keynesian aggregate demand function. More complex indexes, such as the Chicago Fed's National Activity Index or the Atlanta Fed's GDPNow, rely on both theoretical and empirical models to combine multiple indicators or generate filtered estimates (see, e.g., Boumans 2004, 2015 for an analysis of the relationship between modeling and indexing in economics). The type of indexes I refer to here, however, are based on informal models or simple hypotheses – such as "the more firms, the more competition" – which differ from the fully-fledged economic models that are used to generate what I call model-based evidence.

are known. In contrast, model-based evidence requires the use of complex economic models and statistical techniques to generate results that can be used as evidence, making this kind of evidence more sophisticated and less accessible to laymen such as judges and jurors.

Third, model-based evidence is generally regarded as more internally reliable within the relevant scientific community than other kinds of evidence. Economists typically agree that inferences drawn from model-based evidence are more trustworthy than those based on index-based evidence. In particular, although concentration measures are relatively simple to calculate and understand, economists broadly agree that a basic calculation of market concentration based on indices does not yield reliable conclusions about market competitiveness. This is because high concentration can also result from competitive market dynamics, rather than from anticompetitive behavior or reduced competition.

To make a classic example, Harold Demsetz (1973, 1982) famously introduced the concept of "concentration through competition," arguing that concentration is not necessarily a sign of reduced competitiveness but can instead reflect successful entrepreneurial efforts. He noted that "if rivals seek better ways to satisfy buyers or to produce a product, and if one or a few succeed in such endeavors, then the reward for their entrepreneurial effort is likely to be some (short-term) monopoly power, and this may be associated with increased industrial concentration" (1973, 3). Demsetz's critique is part of the common background knowledge among contemporary economists, who generally view market concentration as, at best, a rough indicator of anticompetitive behavior. As a result, economists agree that index-based evidence should not be relied upon in isolation for court verdicts in competition cases (e.g. Berry, Gaynor, and Morton 2019; Carlton and Israel 2021; Fisher 2008; Syverson 2019).[22] And yet, in many competition cases, what becomes relevant is *precisely* such index-based evidence.

Given the distinction between model-based and index-based evidence, it becomes clear why overlooking model-based evidence may have harmful consequences for the quality of judicial decisions. Courts should base their judgments on available evidence, giving appropriate weight to each piece according to its reliability. Dismissing model-based evidence means courts overlook a more reliable source of information, leading to less accurate and potentially unjust outcomes, which undermines the fairness of judicial decision-making. In short, disregarding more reliable evidence may worsen the judicial outcome.

It is important to note that the problem of dismissing model-based evidence runs even deeper than simply harming judicial decision-making. In fact, even if courts were always to reach the correct verdict (convicting guilty firms and acquitting innocent ones) the epistemological implications of discarding model-based evidence would still remain. This is true for two

22. It is important to note that the distinction between model-based and index-based evidence simplifies a more complex spectrum. In practice, evidence varies in the degree to which it relies on a theoretical framework, with some types of evidence drawing more heavily on scientific models than others. However, for the purposes of this article, this dichotomy will serve as a useful working framework. What is crucial for my argument is merely that contemporary economics suggests that index-based evidence, when considered in isolation, is unreliable for assessing competition and should not be the sole basis for competition policy decisions.

key reasons. First, courts that rely solely on index-based evidence fail to reflect the current state of economic research, which increasingly sees such evidence as unreliable for drawing meaningful conclusions about market competition. As I said, leading competition economists have consistently raised this concern. For instance, Franklin Fisher warns that "it is a mistake—and sometimes a major error—to concentrate only on market share in an analysis of monopoly or market power. Market share measures, even when properly done, provide only a crude guide. They ought not to be treated as a 'bright-line test.'" (2008, 139) Similarly, Dennis Carlton and Mark Israel argue that "using thresholds based on the level of HHI to determine the level of competition is questionable at best." (2021, 218)

Second, disregarding model-based evidence would violate a highly plausible principle of evidence evaluation: that the weight given to different types of evidence should be proportional to their reliability. To see why this principle is reasonable, consider an analogy from forensic science: we would hardly accept a court systematically ignoring DNA analysis in favor of fingerprint analysis, given that DNA evidence is generally considered far more reliable. Yet, in antitrust litigation, courts often do something similar by favoring index-based evidence over model-based evidence, despite the latter being better aligned with modern economic theory.

The considerations raised in the last two sections lead us to a broader question: why do economic models, despite their theoretical advantages, struggle to gain traction in legal settings? To answer this question, I will examine the methodological challenges of using economic models in court from two perspectives. First, I will argue that the way courts assess economic models differs significantly from how models are evaluated in other scientific contexts, as studied in the philosophy of science. Second, I will explore the institutional and epistemological factors that make economic models particularly vulnerable in legal settings.

5 Averaging, robustness analysis, and de-idealization

On the surface, the model assessment that the judge must undertake bears resemblance to other instances of model usage studied in the philosophy of science. Recent scholarship, for example, has focused on the use of (multiple) scientific models for policy guidance (e.g., Aydinonat 2018; Grüne-Yanoff and Marchionni 2018; Morrison 2011; Parker 2010, 2011; Roussos, Bradley, and Frigg 2021; Zanetti 2024). One might thus look to these analyses for potential remedies to make scientific models more relevant for court rulings.

In the model averaging approach, for instance, judges could be required to average conflicting model-based evidence instead of discarding it altogether. For example, if the plaintiff's model predicts a 10 percent price increase and the defense's model predicts 2 percent, the judge could conclude that the overall model-based evidence suggests a 6 percent increase.[23] An approach based on robustness analysis might instead suggest that judges focus on model

23. More sophisticated methods for model averaging exist, but the core idea of leveraging model ensembles in the face of uncertainty remains the same (Roussos, Bradley, and Frigg 2021; Zanetti 2024).

results that are consistent across expert testimonies from both parties.[24] For example, if both the plaintiff's and defendant's experts agree that prices will rise but differ on the magnitude of the increase, the judge could accept the statement "prices will rise" as model-based evidence and revise their belief accordingly.

Although these proposals are conceptually valuable, they present two major challenges. First, they are designed with policy guidance in mind, yet litigation differs from policy-making. As such, they somewhat conflict with the adversarial nature of the legal system. In a trial, the goal is not to average conflicting evidence or identify common elements between expert testimonies, as might occur in other policy contexts. Instead, models are presented with the aim of convincing the judge of a particular state of affairs in order to win the case. Second, these proposals assume that both parties will present competing scientific models. However, in many legal cases, it is *only* the plaintiff's expert who introduces a model, while the defendant's expert critiques it without offering an alternative one. In such situations, there is no basis for averaging or identifying a robust result.

A different proposal, supported by recent discussions in the philosophy of science, is to employ various de-idealization techniques to make models more realistic with respect to the particular target systems they are applied. This approach rests on the premise that in order to persuade judges to base their verdicts on model-based evidence, scientific models must accurately capture the key aspects of the relevant target system. In fact, this suggestion is often raised by legal scholars and economists themselves as a way to improve the performance of economic models in courts (e.g., Coate and Fischer 2012; Hovenkamp 2005; Rafkin and Kuykendall 2021). I have a straightforward objection to this proposal: although it is true that, under certain conditions, economists may expand the applicability of their models by removing unrealistic assumptions (for relevant examples, see Lehtinen 2022 and Peruzzi and Cevolani 2022), it is widely recognized that these so-called "de-idealization strategies" face both pragmatic and conceptual challenges (Cassini 2021; Knuuttila and Morgan 2019; Quack 2024). Moreover, in the courtroom, the scope for de-idealization is further limited by the need for experts to simplify their models to ensure they are comprehensible to judges and jurors.

To be sure, these proposals could help make scientific models more central to court verdicts and, potentially, improve judicial decision-making. However, it is clear that they are primarily designed for use in purely scientific contexts – such as when scientists disagree with one another – or in policy settings, where scientific evidence informs policy decisions. For this reason, they cannot directly address the two problems that, as I will argue in the next section, undermine the use of economic models in the courtroom: the "dangerous" combination of the institutional setting in which the models are constructed and applied, namely the courtroom, and some basic facts about the epistemology of economic models.

24. The epistemic value of robustness analysis varies among authors. See, for instance, Lisciandra and Korbmacher (2021), Kuorikoski, Lehtinen, and Marchionni (2010), Lloyd (2015), Odenbaugh and Alexandrova (2011), and Woodward (2006).

6 Economic models in the adversarial setting

The picture that arose from the previous sections casts a rather grim light on the optimism surrounding the use of economic models into the courtroom. In practice, the kind of economic models employed in competition cases often lack the strength to provide decisive evidence for adjudicating legal disputes. What remains are simpler, but less reliable, market concentration metrics that nonetheless frequently succeed in persuading judges to lean one way or another in relation to the plaintiff's claims.

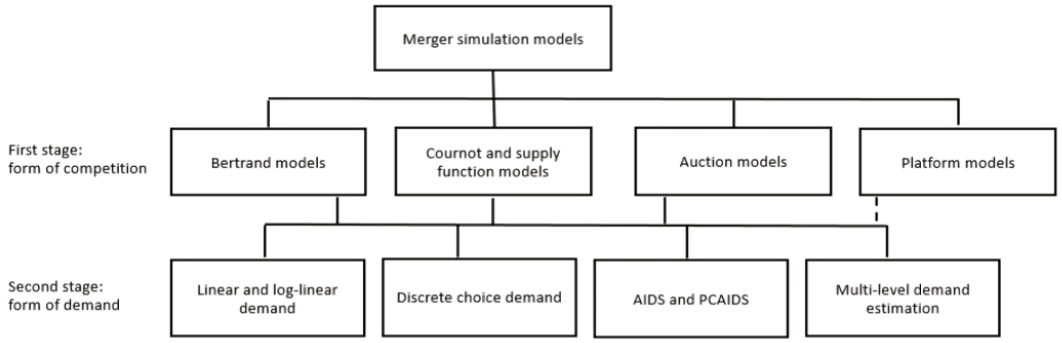
In some sense, this should not come as a surprise to philosophers of economics, who have long highlighted the challenges surrounding the use of economic models for explanatory, predictive, or policy-related purposes (e.g., Aydinonat 2018; Hoover 2023; Jhun 2021; Mäki 2018; Rodrik 2015). The key difference here lies in the institutional setting, which exacerbates these challenges: economic models, being already fragile objects, are further exposed to these vulnerabilities in the adversarial environment of the courtroom (Giocoli 2020; Peruzzi 2023).

To explain why economic models are particularly fragile or vulnerable when used as sources of evidence in legal proceedings, I introduce the notion of an *attack surface.* More specifically, I argue that model-based evidence has a large attack surface, that is, it is especially susceptible to criticism from the opposing side in an adversarial setting. This vulnerability arises because economic models used in courtrooms are empirical models with an exceptionally high degree of freedom. By degrees of freedom, I refer to the set of modeling choices available to the modeler. This high degree of freedom provides ample room for critique and even enables the construction of competing models, the evaluation of which often exceeds the expertise of even the most well-intentioned judges.[25]

Let us take a closer look at how economic models are routinely applied in competition cases. These models are primarily used either to represent counterfactual scenarios or, in merger reviews, as predictive tools. Consider, for instance, a merger simulation model employed by an expert witness to predict the price effects of a merger between two companies. Upon reflection, this is an enormously complex task with many degrees of freedom, as acknowledged by economists and practitioners (see, e.g., Budzinski and Ruhmer 2010; Budzinski and Noskova 2022; Miller and Sheu 2021; Panhans and Taragin 2023).

A merger simulation model relies on two key ingredients: a theoretical model that represents the nature of competition in a given market and a demand system that captures consumer purchasing behavior. In every such model, two fundamental choices must be made: (i) selecting an appropriate theoretical model to describe the competitive dynamics and (ii) specifying a functional form for the demand system, which determines how consumers substitute between

25. The explanation for the neutralization of model-based evidence provided here, which centers on the notion of attack surface, is not in conflict with other explanations that highlight the judge's lack of economic expertise. On the contrary, it should be seen as complementary, as the two factors reinforce each other: model-based evidence, which already has a large attack surface, is bound to appear even more inscrutable the less economic expertise the judge possesses. In such a context, the incentives to rely on index-based evidence and avoid engaging with more complex models are considerable.



Source: modified from Oliver Budzinski & Isabel Ruhmer, *Merger simulation in competition policy: A survey*, 6 J. COMPETITION L. ECON. 277, 283 (2010).

Figure 1: Merger simulation models. Source: Budzinski and Noskova (2022).

products (see Figure 1).

Even if the theoretical model accurately represents market conditions, the challenge remains of obtaining reliable data to estimate or calibrate its parameters. More critically, difficulties often arise in specifying the functional form of the demand system. Simpler functional forms impose stronger assumptions about product substitution, requiring less data and making the results easier for judges to interpret. Conversely, more complex functional forms reduce unrealistic assumptions but demand more data and are harder to analyze (Asker and Nocke 2021; Budzinski and Ruhmer 2010; Miller and Sheu 2021) As a result, modelers face a multitude of choices, each of which is contestable, opening a spot for attack from opposing experts.

The point is not that economists lack good reasons for selecting a specific competition model or functional form for demand systems. On the contrary, these choices are typically well-justified (e.g., in the Peabody case, coal is homogeneous, making Cournot competition appropriate, whereas in markets with differentiated goods, a Bertrand model is more suitable). However, model selection often depends on qualitative market features that are easily contested by the opposing side. As a consequence, the degrees of freedom inherent in modeling increase the potential for attack: this is why economic models have a large attack surface.

A comparison with index-based evidence is useful here. Although less reliable, index-based evidence is simpler and has a smaller attack surface. This is because, once market boundaries are defined, market concentration measures are merely arithmetic calculations. As a result, they are harder to criticize and attack than model-based evidence.

The *Peabody* case illustrates this distinction well. Index-based evidence was contested by the defendants, who argued that "this Court cannot simply assume, based on the FTC's showing of 'increased concentration in a narrowly defined market,' that the JV [Joint Venture] will have anticompetitive effects" (*ibid.*, p. 905). However, once the Court accepted the relevant market definition, calculating market shares and HHI variations became a straightforward computational exercise, involving no theoretical debate. Consequently, the defendants had little room

to challenge the HHI itself, as it was effectively a mechanical outcome based on agreed market parameters – primarily market size and output production. Notably, the Court emphasized that "tellingly, Defendants' experts do not contest the accuracy of Dr. Hill's calculations of market share or market concentration" (*ibid.*, p. 903), without acknowledging that challenging the calculation itself would have been nearly impossible.

Before concluding, I would like to address the possible objection that the notion of attack surface is merely a metaphor used to describe the properties of different types of evidence. Although further philosophical work is needed to fully articulate the concept, a few clarifying remarks are in order to better define its scope and highlight its practical implications. At least two interpretations of attack surface can be distinguished. The first is an *operational* interpretation, which views the attack surface as a feature of how a given piece of evidence is produced. For instance, the more modeling choices are available, and thus open to challenge by the opposing party, the broader the attack surface. In this sense, as discussed earlier, model-based evidence typically has a wider attack surface than index-based evidence, precisely because more discretionary choices are involved in its production.

The second interpretation highlights the *rhetorical* dimension of attack surface. Regardless of the intrinsic strength or reliability of the evidence, some forms of evidence may appear more vulnerable to rhetorical challenge from the judge's perspective. This rhetorical susceptibility is crucial, as in adversarial legal settings, it is often rhetorical persuasion – rather than evidential reliability – that determines which arguments ultimately prevail in court. It is thus a notable feature of the attack surface concept that it encompasses both operational and rhetorical aspects, each of which plays a crucial role in the use of scientific evidence in legal proceedings. Indeed, it is these two aspects that help explain why, in practice, model-based evidence is often set aside in favor of index-based evidence.

7 Concluding remarks

Philosophers and historians of science are increasingly interested in the epistemic and practical problems involved in the usage of scientific models in non-academic contexts. Crucially, the application of scientific models in legal proceedings has been severely neglected. As I have argued in this article, the use of economic models in courts of law faces specific challenges that raise doubts about their effectiveness and usefulness in legal proceedings. This is because, despite their widespread use, economic models often fail to significantly influence judicial decisions, which undermines the rationale for introducing them into the courtroom. More concerning is the dismissal of model-based evidence, which carries substantial consequences: when such evidence is disregarded, weaker, less reliable forms of evidence often take its place, potentially lowering the quality of judicial decisions.

To explore the reasons behind this phenomenon, I examined the methodological challenges of using economic models in court in two key ways. First, I argued that, despite apparent

similarities, the judicial assessment of model-based evidence differs from other instances of model usage discussed in the philosophy of science. Second, I suggested that the challenges faced by economic modeling in the courtroom stem from a combination of institutional factors and the epistemological nature of economic models. Specifically, I contended that courts may dismiss model-based evidence due to its larger attack surface, making it particularly vulnerable to challenges in an adversarial environment. Ironically, because they are simpler and have a smaller attack surface, other forms of evidence – while less reliable – may take precedence in judicial decisions.

This article represents an initial step toward understanding how scientific models are, and perhaps should be, employed in court proceedings. However, much work remains for philosophers of science in this area. The next step would be to explore whether the present analysis is specific to economic models or whether it applies more broadly. Other scientific models, such as forensic models (e.g., ballistic or bloodstain pattern analysis), psychological models (e.g., risk assessments or mental state evaluations), and financial models (e.g., estimating damages in patent or fraud cases), are also used in the courtroom. Future research could focus on whether fields with stronger consensus on reliable methods of evidence gathering – such as DNA or fingerprint analysis – are less prone to the neutralization of expert testimony.

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