Beyond the But-For World

Weak-necessity causal reasoning for model-based counterfactuals in law and economics

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Table of Contents

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Abstract

Under current standards for scientific evidence defined under *Daubert*, antitrust models are frequently excluded from legal consideration, but not always for reasons that make them genuinely unreliable. This paper clarifies why antitrust models face difficulties when subjected to methodological scrutiny: the employment of model-based counterfactual arguments under an epistemically defective 'but-for' structure of causation. Assessing the relevance and reliability of an antitrust model is a matter of assessing the validity and applicability of the causal claim it makes, not the degree to which the modeling methodology is considered scientific. A more flexible causal framework, the weak-necessity structure of causation, is suggested as a means of developing and evaluating model-based counterfactuals. This framework allows for modeling of overdetermined-causation situations, or situations in which the outcome of interest can be attributed to two or more causes. Since antitrust cases typically involve overdetermined causation, the weak-necessity framework allows them to be modeled in a more precise and intuitive way.

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I. Introduction: an old lament

In a 2013 column for the New York Times, Harvard economist Raj Chetty wrote of economics: "There's an old lament about my profession: if you ask three economists a question, you'll get three different answers" (Chetty, 2013). This is a perennial criticism of economics. For any given issue, one can find a well-trained economist to formulate a good-faith economic argument for any position on the matter. It seems like economists are sometimes even rewarded for their disagreements—in 2013, to the shock of the wider scientific community, the Nobel Memorial Prize in Economic Science was awarded jointly to two economists whose views on financial markets appeared mutually incompatible. Scandal! That economists are unable to establish consensus threatens to undermine the credibility of the entire practice. Critics ask, is economics even a science?

The question of whether economics counts as a *real* science has been beaten to all but death. Here is a more pragmatic question: beyond the credibility of the profession, what is at stake when economists fail to agree?

An answer to this begins with the question, in what settings do the opinions of economists have influence over outcomes in the real world? One important setting is in the court of law. Lawyers frequently retain the services of professional economists as expert witnesses, borrowing their expertise—and expert reputation—as a way of fortifying their cases. Economists are employed in all branches of law to estimate damages, prove wage discrimination, and model counterfactual scenarios. Antitrust law is one branch that is especially intimate with economics. After all, the very existence of antitrust litigation is justified largely by the economic theories of monopoly and competition. Given the adversarial nature of the United States legal system, it should not be surprising that economist expert witnesses frequently submit conflicting models as

scientific evidence to the court. Most antitrust cases involve two economists on directly opposing sides of an issue. The problem is, whereas the theoretical academic economist can propose unorthodox models for the sake of intellectual inquiry or the mere joy of academic debate, the economist expert witness is at least partially responsible for the outcome of a legal case and the legal precedent it sets.

It is therefore imperative that the economic testimonies presented for legal consideration are good ones. But of course, this means nothing without answers to the following three questions: (1) What is good economics? (2) Who is the arbiter of what economics is good? (3) How does this arbiter decide?

These are not new questions; the law has tried many a time to answer them. A 1923 case, *Frye v. United States*, determined an expert testimony is admissible only if it represents an opinion "generally accepted" within a scientific community (Giocoli, 2020, p. 206). The obvious limitations of this rule, most obviously the lack of scientific consensus in many areas that might reasonably become relevant in a legal context, were addressed in 1993 with *Daubert v. Merrell Dow Pharmaceuticals*. *Daubert* appointed trial court judges the "gatekeepers" of scientific evidence, tasking them to prevent methodologically unsound, "junk science" from being presented in court. *Daubert* weakened the "general acceptability" criterion of *Frye* and improved upon it by providing five criteria upon which a trial court should judge the reliability and relevance of the methodology involved in an expert testimony. Following its introduction, *Daubert* was modified and expanded several times in a series of court decisions between 1993 and 1999. In its present form, the *Daubert* standards involve consideration of these five factors: (1) Whether the technique or theory in question can be, and has been tested; (2) Whether it has been subjected to publication and peer review; (3) Its known or potential error rate; (4) The

existence and maintenance of standards controlling its operation; and (5) Whether it has attracted widespread acceptance within a relevant scientific community (*Daubert*, 1995).

Daubert was intended as an all-purpose framework for methodological evaluation across all scientific disciplines. It has been subject to substantial criticism: it is accused of being less than useful for evaluating economics and other social sciences. Antitrust economists face particular difficulties (Giocoli, 2020; Langenfeld & Alexander, 2010). My focus will be to understand the difficulties that economic models face when evaluated under the all-purpose *Daubert* standards and suggest practical alternatives to *Daubert*.

I have two objectives. First, I clarify why antitrust models face such serious difficulties when subjected to methodological scrutiny and argue that lessons from antitrust modeling can be extrapolated to other areas of economics. Antitrust economists often employ model-based counterfactual arguments under a 'but-for' or strong-necessity structure of causation. I expose the structural features common to these kinds of arguments that make them vulnerable to methodological criticism. I then suggest an alternative causal framework, the weak necessity structure of causation, as a means of developing and evaluating model-based counterfactuals.

To start, I will make two assumptions that serve as a background for the discussion that follows: first, I set aside general concerns about the worth of counterfactual arguments; second, I set aside general concerns about the validity of expert testimonies.

I.i. Assumption on the worth of counterfactual arguments

One of the most important ambitions of economic science is generating narratives about counterfactual worlds—worlds that do not exist. Any causal claim, *X causes Y*, carries with it an implicit counterfactual claim—an argument for that state of the world which would occur in the

absence of the proposed cause. But of course, no one has genuine access to a counterfactual world. Among an infinite number of imaginable possible worlds, there seems to be no clear way to determine which of them is the uniquely correct counterfactual. If we can never be certain that we have identified the uniquely correct counterfactual, then are counterfactual claims useless? Are they, as George DeMartino says, "irreducibly fictitious" (2021, p. 253)?

I will assume that *counterfactual modeling has real use in economics*. Even as economists lack the ability to achieve perfect certainty in identifying a uniquely true counterfactual world, they can still glean useful information through the process of paring down an infinite set of possible worlds to the set of those that are most plausible. Hypothesizing what *would* or *could* happen in the counterfactual is the basis of all mechanism design. Before William Harvey published his theory of blood circulation in 1628, Galenic theory—the theory that the body converts food into blood, then consumes the blood for energy—had prevailed since 129 AD (Friedland, 2009). Galen's theory was wrong about several key things, but it provided useful guidance on features of the blood that it correctly captured. There is no real meaning to labeling a model entirely fictitious or entirely true; the value of a model exists in its contribution to understanding a mechanism. It would be foolish to abandon the task of understanding a causal relationship simply because we are afraid that our guess is wrong.

My interest is in evaluating and distinguishing between plausible models. Which of the infinite and uncountable are the truly possible worlds? Among those, which should provide the narrative in reference to which legal decisions are made? These are the questions I intend to address.

I.ii. Assumption on the validity of expert testimonies

I now address the recurrent concern that expert scientific witnesses are likely to be partisans, "hired guns," rather than offering the court honest, scientific, evidence (Posner, 1999, p. 93; Lee, 1988; Haack, 2015, p. 41). Suspicion is natural; how can we trust the testimony of an expert whose paycheck depends on how well his findings support his employer's case? Who is to stop the witness from "hiding behind an impenetrable wall of esoteric knowledge"? Certainly, we do not expect this of non-expert judges and jurors. Therefore, the economist "has both motive and means of slanting the truth in favor of the client" (Posner, 1999, p. 93).

Commentary on this issue is abundant. I will summarize a few relevant arguments in defense of economist expert testimony. First, most expert economists have a reputation to defend. Those with records of academic publication are unlikely to contradict their past work on the stand, at the risk of inviting "devastating cross-examination" (Posner, 1999, p. 94). Second, expert witnesses have an incentive to give persuasive testimony, and an incomprehensible testimony is unlikely to be persuasive (Posner, 1999, p. 96). Third, the use of an expert economist is useful, and we should prefer the potential for scientific evidence, even if risky, over the alternative: total uncertainty (Shapiro, 2021, p. 39).

The third of these arguments is the position I adopt here. I will assume that *expert testimonies are widely used and will continue to be in the absence of compelling alternative forms of evidence*. Thus, what is necessary is a practical approach to evaluate expert testimonies, which is what I offer here.

II. Why do economic models struggle in court?

II.i. *Daubert* and its trouble with models

The *Daubert* standards offer a quick-and-dirty tool for a non-expert judge to figure out whether a testimony and its conclusion are scientifically valid. It is quick in the sense that it is intended as a practical tool for the non-expert judge rather than a comprehensive system for methodology evaluation. It is dirty in the sense that it is always applied ad hoc; no combination of *Daubert* failures guarantees an exclusion. The input to the tool is, notably, a "technique or theory" rather than the finding itself. This means judges have to be the arbiters of which methodologies are "acceptable" in order for the conclusions drawn from studies that derive from said methodologies to be considered reliable, and hence useful. This might work in disciplines with a general sense of accepted protocol such as those with standardized laboratory tests, but, as antitrust economist Gregory Werden has pointed out, "economics has no well-established standards governing the selection and application of particular models and methods" (Werden, 2008, p. 815). In economics, the design of inventive and purpose-made models is usually at least part of the point. This means that verifying the validity of economic methods is an especially complicated task.

Economic testimony is routinely deemed inadmissible via *Daubert* challenge. *Daubert* challenges are raised disproportionately more often against experts in economics and finance compared to those in other fields (Giocoli, 2020, p. 212). What forms the basis of these challenges? Here is a characteristic example. In the 2009 case *Kentucky Speedway v. National Association of Stock Car Auto Racing,* an expert's testimony adapted an existing, widely used method known as the Small but Significant and Non-transitory Increase in Price (SSNIP) test for market definition. Though the method was common for antitrust cases, the testimony was

rejected because the modification, "his own version," was one that "had not been tested; has not been subjected to peer review and publication; there are no standards controlling it; and there is no showing that it enjoys general acceptance within the scientific community. Further, it was produced solely for this litigation." In this case, the court was suspicious that the expert "used his own version" of a standard test (Langenfeld & Alexander, 2010, p. 24). This rejection is significant because it seems to reveal that courts object to a common practice in economics: the modification of existing models to better suit one's purposes. It is alarming that the rejection is based solely on the relative novelty of the method, rather than any substantial criticism of the applicability of the modified test to the situation at hand.

The problem here is not really that the court has exercised an abundance of caution in determining whether the expert's findings were admissible. Rather, the problem is that the court's caution is directed toward the appearance of what is unconventional or unfamiliar. A reasonable argument may be made to justify a similar level of suspicion toward, say, a novel lab-on-a-chip method[1] for identifying diseases by testing a very small amount of blood in a compact device. Such an argument can take many forms, but the structure is likely to be as follows: the diagnosis of a disease of interest has historically been done via a well-accepted method, call this method O for "old." Suppose O, being an established method, is credible under *Daubert*, meaning that (1) it has been tested, (2) its use has been documented and its results subject to peer review, (3) its margin of error is documented, (4) the procedure for properly conducting the test is well-defined, and (5) the test is widely accepted. Now suppose a new test, N, has been developed to test for the same disease. N is so new that it has not had a chance to be extensively

[1]These are the same claims made by Theranos, a health technology company famously dissolved in 2018 after its technology was found to produce inaccurate results and its founder was convicted of four counts of fraud.

tested or published, and norms for its use have not yet been established. Its advantage is that its creators claim that it has a smaller margin of error than O, but this claim has not been validated by others. The marginal benefit that N offers is the promise of greater accuracy, but the court is likely to favor the much lower risk that O carries over an unvalidated promise of improved accuracy. The situation has an important trait that differentiates it from an economics situation: the quality of the test itself directly determines the quality of its findings.

In economics, the quality of the method is, unlike in the blood testing example, not the determinant of whether a result is credible. It is not meaningful to say that an economist's testimony is credible on the basis that it employs an Ordinary Least Squares (OLS) regression; the concern should be whether the economist has correctly modeled the situation in advance of asking his computer to run the regression according to his specifications. Here is an example to make this concrete: in a 2022 paper, Miller et al. criticizes the regression of price against the Herfindahl-Hirschman Index (HHI), a measure of market power, to support an argument that greater market power caused the price level for a given market to rise. Miller rejected this argument by pointing out that both price and HHI are equilibrium outcomes determined by the determinants of supply and demand. This is to say, price and HHI share common causes, but neither causally influences the other. A regression on these variables is misleading because it discovers a strong correlation between them even in the absence of a genuine causal relationship. The argument that Miller criticizes is precisely the kind that ought to be excluded from legal consideration—it makes the basic mistake of treating correlation as causation. Whether the method used to derive the result, OLS regression, is good or bad should not be the object of focus if one's goal is to determine the reliability and relevance of the testimony.

But *Daubert* gives little guidance on how judges may go about distinguishing well-applied from poorly-applied analyses. In many cases, judges are not equipped with the expertise needed to become, ostensibly, a peer reviewer for a professional economist. In some cases, decisions about the acceptability of economist expert testimonies do not make any particular reference to the *Daubert* standards, and instead rule on an inconsistent, case-by-case basis (Bronsteen & Varma, 2001, p. 15). In other cases, judges may improperly admit poor testimonies into legal consideration and justify the admission by superficial references to *Daubert*. For instance, in *Ohio ex rel. Montgomery v. Louis Trauth Dairy*, a district court judge admitted into consideration two competing regression analyses on price data by the justification that "[e]conometric and regression analyses are generally considered reliable disciplines .... [R]egression analysis is testable, generally accepted and reproducible" (*Ohio*). In this decision, the standards of *Daubert* are explicitly cited, but this reasoning offers no reassurance as to the quality of the two testimonies.

This reveals a first, basic reason why *Daubert* should not give any judge, jury, or economist solace about the appropriateness of economic evidence that makes it into the courtroom. It equivocates, loosely referring to techniques, theories, and models all as methodologies, and gives the false impression that all methodologies can be handled in roughly the same way. *Daubert* is most useful in evaluating techniques—lists of detailed instructions—where the concern is with the formal mechanics of the procedure rather than, for instance, how well the procedure is executed. In many non-laboratory sciences, economics especially, the technique is not in dispute—it is the validity of the technique's *application* with which we must concern ourselves. Often, this means that the technique must be correctly applied in the context of a valid *model*.

I concentrate primarily on economic models, rather than techniques or general theories, because their validity hinges on their coherence with the design principle, which cannot be evaluated by a tool as myopic as *Daubert*. Successful models typically require the correct application of statistical tools such as OLS regression as well as more basic templates of economic analysis. These modeling templates—supply and demand, monopoly and oligopoly—are not considered perpetually valid after their successful application in some models; they must be applied appropriately in every instance of their use. This type of ad-hoc, context-dependent modeling is most economists' primary tool of reasoning, but as I have shown, *Daubert* lacks the capacity to properly evaluate it. Hence, there is an obvious need for a systematic framework to evaluate economists' model-based arguments.

II.ii. Antitrust: a representative example of model-based counterfactual arguments

Nicola Giocoli has previously described antitrust as uniquely vulnerable among fields of economics to methodological challenges under *Daubert*, on the basis of having a fundamentally incompatible "methodological blueprint" (Giocoli, 2020, p. 214). I treat antitrust not as a special case among economic disciplines, but rather a representative case that makes obvious the issues that all expert witnesses in the social sciences face. Antitrust cases often employ a structure of argument I refer to as a *model-based counterfactual*, where the economist presents an economic model representing what would have happened in the counterfactual world. Here, I will sketch the general structure of these arguments and show that while antitrust cases provide many prominent examples of model-based counterfactuals, the structure of reasoning is widely used in economics.

For a claim such as *firm A engaged in anticompetitive business practices*, there is typically no direct evidence. That is, investigation into antitrust claims do not generally yield tapes of cigar-smoking executives covertly planning to monopolize the market and harm competitors. This means that any antitrust allegation must be supported by a counterfactual argument, an argument that (1) the state of things would be different, perhaps better, if that firm had not engaged in those behaviors, and (2) one can identify the differences between the real and counterfactual worlds.

An antitrust economist on the plaintiff's side—an economist who aims to build a case arguing that an entity has exhibited anticompetitive behaviors—needs to provide evidence to this effect: Firm A engaged in a set of allegedly anticompetitive behaviors, Σ, which together *caused* the actual outcome Y_A. In their absence, the outcome *would have been* the hypothetical Y_H. For the plaintiff, outcome Y_A is inferior to outcome Y_H, and thus the difference between outcomes, call this $\rho(Y_A, Y_H)$ for some metric ρ, is the *harm* done by firm A. The expression $\rho(Y_A, Y_H)$ measures distance between states of the world along a relevant parameter. The economist's tasks are to expose a causal relationship substantiated by data and develop a clear picture of what *would have* happened, absent a set of conditions, institutional arrangements, or habitual behaviors that did in fact hold. In other words, the plaintiff's economist must construct and depict a but-for world—the state that would have obtained, just if A had not done Σ.

Often in economics, the states Y_A and Y_H are described in dollar terms, to reflect differences in prices or profits. In these cases, one could represent the difference between outcomes, $\rho(Y_A, Y_H)$, as $|Y_A - Y_H|$, the absolute value of the difference between outcomes, in dollar terms. This structure is implicit in many antitrust cases. In those contexts, Y_A captures the actual price for which some good has sold, and Y_H represents the counterfactual price for which

the good sells under competitive conditions. In other contests, Y_A might capture a firm's actual revenue, computed by multiplying an actual price, P_A by the actual quantity sold, Q_A, while Y_H captures the firm's hypothetical revenue at competitive prices, computed by multiplying a hypothetical competitive price P_H by the actual quantity sold, P_A. This gives a way to represent damages, D, as a difference of revenues: $|Y_A – Y_H| = |P_AQ_A – P_HQ_A|$ (Abele, 2011, p. 854).

Labor economists make similarly-structured arguments when serving as expert witnesses in employment discrimination cases, and their arguments are often challenged via *Daubert*. Here is one example: in 2023, a plaintiff brought to the District Court of Colorado allegations of gender discrimination her former employer, Jackson National Life Insurance Company. Labor economist Patricia Pacey served as an expert witness in the case. Pacey used salary data from the company to compute the plaintiff's hypothetical earnings "but for the disparate treatment" (Equal Employment Opportunity Commission v. Jackson National Life Insurance Company, 2023, p. 5). In this case, the outcome Y_H was represented as what the plaintiff would have earned in the counterfactual situation where discrimination did not cause the plaintiff to be passed over for promotions and pay raises that were awarded to her colleagues. The outcome Y_A was her actual earnings. The difference between the two outcomes accounted for the damages suffered by the plaintiff.

This suffices to show that the structure of counterfactual argument identified here is common in legal cases employing economist expert witnesses, and a framework to address it will be useful in contexts not limited to antitrust.

II.iii. The role of causation in law and economics

The problems that economic models face in legal contexts have previously been framed in several ways. Giocoli describes them as arising from incompatibilities between the criteria for valid science posed in *Daubert* and the realities of economic science (see Giocoli 2020). Susan Haack has criticized the very notion of science that *Daubert* employs, arguing that *Daubert* builds upon a poorly conceived mixture of Karl Popper's Falsificationist and Carl Hempel's Inductivist philosophies of science—two philosophies generally seen as incompatible (see Haack, 2005, p. S67). Haack goes further, arguing that even if the *Daubert* standards referenced a consistent philosophy of science, they would still be inadequate for evaluating expert testimonies—there are basic philosophical problems with equating the reliability of evidence with its scientific validity. Haack writes, "There can be no criterion discriminating scientific, and hence reliable, testimony from the unscientific and unreliable; for not all, and not only, scientific evidence is reliable" (Haack, 2005, p. S66-S67). Hanns Abele has framed the issue in yet another way, suggesting that the root of the issue is in law and economics employing incompatible notions of causation (Abele et al., 2011, p. 847).

Like Abele, I will frame the issue as arising from law and economics employing unworkable causal frameworks. The focus on causation is justified in virtue of its ubiquity in model-based economic arguments. As I have discussed, the central structure of argument of many issues that call on economist expert witnesses is that of a model-based counterfactual. It is not hard to place causation within these counterfactual arguments. Following Kevin Hoover and James Woodward, I adopt the view that the sort of counterfactual analysis used in economic models is based in presumed causal knowledge (Hoover, 2001; Woodward, 2003). That is, in the counterfactual claim, *if conditions* Σ *had not obtained,* Y_H *would have happened instead of* Y_A,

there is an implicit assumption that Σ causes Y_A.[2] Though the ideas of cause and counterfactual are intimately linked, turning to focus on causation facilitates access to existing legal frameworks of causation.

My framing of the issue resembles Abele's in its focus on causation, but it will differ in two substantial ways. First, I modify the narrative: the issues I have discussed emerge not from incompatibilities between law and economics but rather those between two disciplines within law, tort and antitrust. Second, I focus not on methodological differences between the law and economics but rather on substantive differences in the types of causal relations involved in tort and antitrust cases.

II.iv. Antitrust's imports from tort law: the but-for framework of causation

Most concerns about causation in the legal space first appeared in tort law, in cases where a plaintiff seeks to prove that the defendant's actions caused harm. In general, tort law deals in two kinds of causation, actual (also known as "factual," "cause-in-fact," or "but-for" causation) and legal (also known as "proximate" or "material" causation). Actual causation is causation rooted in the facts of the case. Legal causation is a legal concept only; it is the notion of causation sufficient to support legal liability. Sometimes, actual causes are not considered legal causes; the law does not hold all actors responsible if some actors played peripheral or improbable roles (Hartnett, 2017, p. 2301).

My concern is with actual causation—this is the form of causation an expert witness is tasked with proving. In tort cases, the plaintiff must establish a "substantial connection" between

[2] To be precise, counterfactuals involving *intervention* are causal; other counterfactuals may not be causal (Woodward, 2003, p. 45). In general, economic models deal exclusively with counterfactuals involving intervention.

the wrongdoing and the injury. The standard way to do so is to verify a causal link under a 'but-for' notion of causation. The but-for test checks for whether harm would have occurred in the absence of some action or omission (Abele et al., 2011, p. 849; David et al., 2005, p. 216). In short, "its purpose is to eliminate from consideration factually irrelevant causes. . . If the but-for test is not met then the injury would have occurred regardless of the act or omission in question" (Chisholm). In tort law, it is usually relatively clear what this entails; one must, for instance, convince the court of a claim such as, *if defendant A had not run the red light, A would not have crashed his car into B's car, and B would not have suffered a concussion*.

There are many similarities between tort and antitrust cases. As in tort cases, the primary objective for plaintiffs in a private antitrust case is to prove that the defendant's anticompetitive actions caused the plaintiff to suffer damages (Abele et al., 2011, p. 847). Furthermore, tort and antitrust plaintiffs often employ similarly-structured causal arguments.

Here, I present a 2015 antitrust case for discussion. Since 1979, French pharmaceutical company Sanofi had 100% monopoly power in the market for a meningitis vaccine known as Menactra, as well as dominant market share in several other pediatric vaccine markets (*Castro*). In 2009, Swiss market entrant Novartis, which did not supply other pediatric vaccines, introduced a competing vaccine, Menveo. Sanofi responded by raising the prices of all its vaccines and inventing an offer in which Menactra was sold in a "loyalty bundle" with Sanofi's other pediatric vaccine offerings, where each item in the bundle was sold at the original, lower prices. Customers who did not purchase a sufficient percentage of the bundled vaccines paid the higher prices. In a 2015 case known as *Castro v. Sanofi Pasteur Inc*., three pediatric physicians brought a class action suit against Sanofi's loyalty bundle, which they alleged was an anticompetitive behavior that had caused the price of vaccines to increase. The plaintiffs hired

renowned antitrust economist Einer Elhauge to serve as an expert witness providing economic evidence that Sanofi's bundling had in fact caused vaccine prices to increase. Elhauge's argument was based on a well-known economic model, a Bertrand model with differentiated products. He argued that his model represented what would have happened in the absence of Sanofi's anticompetitive bundling practices. Elhauge sought to convince the court that his model accurately captured the events of a counterfactual world, the one that would have been actualized *but for* Sanofi's actions (Peruzzi, 2021, p. 343-344). The defendants in *Castro v. Sanofi Pasteur* hired their own expert economist to challenge Elhauge's model. They argued that Elhauge's Bertrand model with differentiated goods did not accurately represent the correct counterfactual and filed a claim to exclude Elhauge's testimony from legal consideration via a *Daubert* challenge. Ultimately, the challenge was dismissed, and Elhauge's model was presented in court.

Castro v. Sanofi Pasteur Inc., involves an argument along the lines of, *if Sanofi had not created a "loyalty bundle" of their pediatric vaccines, overall vaccine prices would not have increased, and physicians would have had less difficulty accessing vaccines for children.* Most significantly, they both often involve a strategy in which a world under "natural" conditions is compared with another world under "artificial" conditions. In the tort example, the world under natural conditions is that in which all traffic rules were obeyed, and A had not run a red light, while the world of artificial conditions is the one in which the red light was run. This strategy has been a staple of antitrust litigation since the very first legal case to involve an economist expert witness: *United States v. United States Steel Co*. (1920). There, the plaintiff's expert economist, Francis Walker, compared the prices of steel observed under the alleged monopoly conditions ("artificial" conditions) with those of a counterfactual world with ideally competitive economic conditions—a but-for world (Elzinga, 2022, p. S525).

The apparent parallel between tort and antitrust cases may be the reason for traditional tort law's obvious influence in contemporary antitrust law. The two areas of law share an interest in a key system: the one comprising two worlds, one actual and one counterfactual, separated by a distinct action—what I will call the separating condition. But it remains to explain why, even with similar structures of argument, it seems to be more difficult to come up with a convincing argument for an antitrust plaintiff than a typical torts plaintiff.

II.v. Two ways to distinguish tort from antitrust: causal distance & clarity of the counterfactual

The basic differences between the two types of cases are made clear via an example. Consider two cases: first, the case in which the act by person A of running a red light is said to have caused B's concussion; and second, the antitrust case in which a prominent pharmaceutical company is accused of using its monopoly power to bundle pediatric vaccines and hence restrain trade, leading to an increase in pediatric vaccine prices. Differences emerge along two important dimensions: what I will call *causal distance* and *clarity of the counterfactual*.

First, I define *causal distance*. In general, the separating condition and outcome of interest are linked by a series of factors, those being causally relevant actions, omissions, or circumstances. Call these *intermediate causal factors*. The number of intermediate causal factors that can be placed between a separating condition and the outcome of interest provides a rough metric of how direct the relationship is between them. That the metric is rough—e.g., different observers may count greater or fewer intermediate causal factors—is not particularly important for my purposes. I simply want to provide a unit by which to measure a type of distance that

signals the number of theoretical possibilities for alternative explanations of an outcome of interest, subject to some bounding conditions.

The definition of distance I have provided is nebulous and informal, and its usefulness may rightfully be questioned. If the measure of causal distance is bound to have margins of error depending on how many factors the observer counts as relevant, is it even a metric? Is distance even an appropriate metaphor for understanding chains of causation? Is it sensible to take distance as an unweighted sum of intermediate causal factors, if multiple factors may act simultaneously and if the factors seem to hold different amounts of significance? To address these concerns, I clarify that this notion of distance is a heuristic tool, for demonstration purposes, not a formal metric. It is useful to make the point that some causes are somehow farther away than others. Here is a somewhat trite example to demonstrate: the French philosopher Blaise Pascal wrote, not entirely seriously, "Cleopatra's nose: had it been shorter, the whole aspect of the world would have been altered" (Pascal, 1669, pub. 1958). Had Cleopatra's nose been shorter, it would not have met the Roman beauty ideal of a long nose, and neither Mark Antony nor Octavian would have fallen for her, and the power struggle between them would never have occurred, Octavian would have never become emperor of the Roman world. So on and so forth. Few in their right minds would seriously make the argument that the length of Cleopatra's nose has caused the modern world to take its current form; it is too arbitrary. This example reveals a simple principle: causal distance is a function of the start and end points the modeler attempts to link. It is often that longer causal distance is correlated with a more tenuous connection and a more difficult argument. One could concede that there is nothing inherently different about tort cases and antitrust cases; it simply happens that in tort cases, the

events that people often choose to link are closer than those in antitrust. Still, this is an important difference between the two kinds of cases.

To give a concrete example of causal distance, consider the traffic tort case. There, the separating condition is party A running a red light and the outcome of interest is party B's concussion. Few intermediate causal factors distance the separating condition from the outcome of interest. Factors of interest include the presence or absence of well-known traffic laws, the presence or absence of intoxication while driving in either individual, and the presence or absence of slippery roads that may have led A to unintentionally lose control of his vehicle. By contrast, the antitrust case involves substantially more intermediate causal factors, and hence longer causal distance. Consider the separating condition to be Sanofi bundling its pediatric vaccines and the outcome of interest the rise in prices of pediatric vaccines. Then, intermediate causal factors must include all reasons that could cause pediatric vaccine prices to rise, including any shortages in vaccine ingredients or exogenous increases in demand for certain pediatric vaccines. The significance of causal distance here is to make the general point that tort cases often involve separating conditions much closer to the outcome of interest than do antitrust cases.

Second, I define *clarity of the counterfactual.* This idea demonstrates differences in access to a coherent vision of what a counterfactual world looks like. In the car accident case, it is not hard to imagine the state in which traffic laws had been obeyed, a red light had not been run, and B was not injured in a car accident. This is the way things *usually* are, a sensible and accessible "state of nature." Access to the counterfactual is a central principle of traditional tort law.

> The essential purpose and most basic principle of tort law is that the plaintiff must be placed in the position he or she would have been in absent the defendant's negligence (the "original position"). However, the plaintiff is not to be placed in a position *better* than his or her original one. It is therefore necessary not only to determine the plaintiff's position after the tort but also to assess what the "original position" would have been. It is the difference between these positions, the "original position" and the "injured position", which is the plaintiff's loss.
>
> *Athey*, 1996, p. 235

Significant emphasis is placed on the idea of an "original" position, which relies on the intuitive idea of what is *typically* true of the world, or what is the case more often than not.

This idea is often used by antitrust economists. In *United States v. United States Steel Co.*, the plaintiff's expert economist, Jeremiah Walker, painted this picture: in the state of nature, United States Steel would not have a monopoly in the steel industry, and the steel industry would have competitive economic conditions. In reality, "artificial" conditions have obtained, and United States Steel has used its monopoly power to suppress competition. As a result, steel prices have increased. Despite the appearance of a neat parallel, there is a crucial difference: genuinely competitive economic conditions seldom occur in reality. Whereas the typical tort case compares the anomaly to a typical reality, the antitrust economist employing this strategy compares typical reality to an anomalous ideal. The theoretical economist is accustomed to upholding abstract, idealized concepts like perfect economic competition as the standard, against which common occurrences like concentrated market share are anomalous deviations. These conventions make strategies like Walker's in the steel case seem permissible and even logical.

But the incongruence I have pointed out poses significant problems for the antitrust economist. Since the world taken to represent the state of nature, competitive economic conditions, is not often actually observed, there is very limited access to a coherent image of what things hold in that world. There is little experiential reference point for actual markets that are close to perfect competition, and thus it is difficult to imagine what is entailed by a competitive steel market. The textbook model of perfect competition is not a genuine point of reference for the real world. In practice, this means that the antitrust economist faces difficulty proving causation under the tradition of but-for causation adopted in tort law.

The persistence of *Daubert* challenges toward antitrust models may also be understood using the notions of distance and clarity. First, antitrust models are largely untestable because of a lack of access to the counterfactual conditions; one cannot easily experiment under conditions of perfect economic competition in an industry that is monopolized in reality. This is precisely the reason why the counterfactual model needed to be constructed in the first place. Second, a margin of error for a model of a counterfactual amounts to a measure of how far off the model's predictions are from how the counterfactual world actually is—again, this is not directly accessible. Third, peer review is hindered by long causal distance in antitrust cases—economists are likely to come up with greater numbers of distinct and competing models simply owing to the larger number of possibilities to consider. Fourth, it is hard to define what widely-agreed-upon standards antitrust models should be subject to. Even if an economist abides by a generally-agreed-upon set of steps for designing a model, there is no framework general enough to be applicable to every modeling situation while also being specific enough to ensure that every model created under its instruction is valid. Fifth, given that each antitrust model must be purpose-made for a particular separating condition and a particular outcome of interest, it is

difficult to ensure that any one model gains widespread acceptance among the scientific community.

II.vi. Justifying a new causal framework

The two issues I have noted, causal distance and clarity of counterfactual, manifest both in issues with the application of the systems of but-for causation native to tort law and in application of *Daubert* standards for scientific validity. Even in tort law, but-for causation is not sufficient in all cases and fails particularly when causes are too complex or removed from their outcomes (David et al., 2005; Stapleton, 2015). Legal scholar Richard Wright gives special attention to overdetermined causation cases—"cases in which two or more factors each would have been sufficient to produce the injury, so that none of them was a necessary condition for the injury"—as ones in which the failure of but-for is especially spectacular (Wright, 1985, p. 1740). Overdetermined causation comes in a few forms. There are two named types: (1) preemptive causation and (2) duplicative causation. Preemptive causation is the case where agents A and B each offer P a poisoned cup, and P drinks from B's cup before A's. Hence, B causes P to die, but if B had not poisoned the cup, P would have died by drinking from C's cup. Since the outcome, P dying, would happen regardless of whether B poisoned the cup, the but-for test would report that B did not cause P's death. Duplicative causation describes the case in which two people, A and B, independently and simultaneously set fire to P's house. P's house is burned down, and each fire would alone have been sufficient to destroy the house. Again, since the house would burn down whether or not any one of A or B decided to set the fire, the but-for test would find that neither individual caused P's house to be destroyed (Wright, 1985, p. 1776). A third type is the one describing an entangled mess of distinct and simultaneous causes. Here is an example by

legal scholars Arno Becht and Frank Miller, slightly modified[3]: consider the case in which a plaintiff sits on a poorly-constructed wall. The defendant crashes his push reel lawn mower into the wall, which collapses, leading to the plaintiff's injury. The plaintiff would not have been injured if he had not sat on a poorly-constructed wall, and it would not have collapsed if the defendant had not crashed his mower into it. The plaintiff argues that the defendant's crashing the mower was the cause for the collapse and subsequent injury. The defendant argues that the plaintiff was negligent in sitting on a poorly-constructed wall. Both plaintiff and defendant have identified but-for causes for the injury, but neither of the causes are alone sufficient to produce injury. In both arguments, the but-for world is the same, in terms of the injury: it is a state of the world in which the plaintiff is not injured. The difficulty comes from the real and counterfactual (but-for) worlds being separated by the incidence of more than one discrete action—causation is overdetermined. In the previously used terminology, overdetermined causation means that the separating condition is actually an entangled bundle of actions, environmental factors, and institutional structures.

Anticompetitive practices are almost never composed of singular actions, which is to say they almost always involve overdetermined causation. For instance, the decision to bundle vaccines so as to assert market dominance over a market entrant can cause harm only if the market is in a state that permits such a behavior. But the state of the market is the product of a complex interaction between legal conventions and economic practice. Moreover, the state of the market often produces monopoly situations, as is common with the granting of patents. The actions of the pharmaceutical company are no more a cause for the undesired rise in prices than

[3] The original case involved a car crashing into the wall. To avoid raising any potentially distracting reflexes to the effect of, "any wall, no matter how well-built, would collapse after having a car crash into it," I have replaced the car with a lawn mower, which presumably has less destructive power than the average car.

are the combination of existing institutional norms and legal standards. As I have already discussed, the practice of simply choosing a state of the world to represent the natural state of things *a priori* (in antitrust, competitive economic conditions) is epistemically defective. Discarding this thought framework creates difficulty. The framework of but-for causation provides no guidance on how to disentangle and prioritize certain causes over others. But-for causation is insufficient to address many cases in tort law, and in antitrust it often leads to contrived narrative twisting in order to manufacture an "artificial" state of the world to compare with the real one.

It is necessary to adopt a causal framework that relieves but-for causation from the burden of handling cases whose distance is too great and clarity too low and offers an alternative to *Daubert* when assessing the validity of an expert economist. Next, I propose a causal framework that will function in place of but-for causation across law and economics.

III. A framework for causation across law and economics

Previous attempts to address the issues of that model-based counterfactuals face in legal settings have involved suggestions that courts look for "economically sound" evidence for causation rather than fumble with fuzzy legal criteria for causation (Hartnett, 2017, p. 2323). For example, Hartnett suggests "independently analyzing causation under procedural, economic requirements of causation evidence" (2017, p. 2324). Suggestions like these appeal to the issue that law and economics often operate with incompatible notions of causation. The suggestion to unify law and economics under a shared notion of causation would be a good one if the field of economics had a widely-agreed-upon theory of causation. Unfortunately, no such theory exists. Here, I will suggest one that may serve the purpose.

III.i. Weak necessity: Wright's NESS

The but-for cause is also known as a *sine qua non* cause, or a strong necessary condition. It is strong because its definition is strict. X is a cause if and only if the outcome of interest would not occur in its absence; i.e., X must be a necessary condition for the outcome. Not every outcome has a single necessary condition, and so not every outcome can be said to have a but-for cause. This creates trouble in situations where a cause must be assigned to a particular outcome. A natural step is thus to seek out a causal account that preserves the intuitive appeal of but-for but weakens the strict requirement for a necessary condition.

Legal theorist Richard Wright argues for a weak necessity account of causation and claims that causes under this account can be identified by his "necessary element of a sufficient set" (NESS) test. Under this theory,

> A particular condition was a cause of (condition contributing to) a specific consequence if and only if it was a necessary element of a set of antecedent actual conditions that was sufficient for the occurrence of the consequence. (Note that the phrase "a set" permits a plurality of sufficient sets.)
>
> Wright, 1985, p. 1790

I will note that Wright's account is not the first of its kind. It draws strongly from Hart and Honoré's 1959 account of a "causally relevant factor," which was itself first articulated by economist-philosopher David Hume. Wright's NESS is also very similar to J.L. Mackie's 1965 account of an INUS (Insufficient, Non-redundant member of a set of Unnecessary but Sufficient conditions) condition (Wright, 2011, p. 2). I will use elements of both Wright's NESS and Mackie's INUS. The two accounts are not identical, but the elements I extract from each are consistent with one another.

NESS and similar weak-necessity accounts are deeply pragmatic. One advantage is in its deft handling of situations of long *causal distance*. A modeler attempting to prove that Cleopatra's long nose caused the entire state of the modern world under a NESS account will struggle to assemble a sufficient set, let alone identify a coherent set of NESS conditions.

To make clear how NESS works, we return to the duplicate fires example. The *sufficient set* can be understood as the set of all conditions, actions, and institutional structures that together ensure the outcome. In the case of duplicate fires, the sufficient set includes arsonist A's setting a fire, the physical presence of A at P's home, the presence of oxygen in the atmosphere, the presence of inflammable materials inside the home, and so on. This set will also contain all of the facts relevant to the occurrence of the fire. Perhaps A entered P's home in order to rob it.

That fact would belong in the sufficient set. Another, similar sufficient set could be identified for B's role in P's home burning down—sufficient sets need not be unique for an outcome. Among the elements of a sufficient set, some are not necessary. For example, if arsonist A entered P's home in order to rob it, and then opportunistically spilled gasoline and lit a fire, the robbery is not a necessary element in the set of conditions sufficient for the house to have burned down. So, the attempt at robbery is not a cause for the destroyed house. However, A needed to be physically present in the home in order to have burned it down, and this happens to have been achieved via his intent to rob the house. A's physical presence is a necessary element. The necessary elements of the sufficient set are each deemed a *cause* of the outcome of interest. This is to say, the presence of oxygen in the atmosphere caused the burning down of P's home, just as A's pouring gasoline and lighting a fire is.

The key contribution of NESS is, whereas the but-for account finds neither arsonist's actions to have caused the destruction of the house, the NESS test finds that each arsonist, considered individually, caused the house to burn down. Applied to law, this has the use of reconciling the mechanical calculation of a cause with the commonsense notion of 'is responsible for.' This solves the problem of having a formal test like but-for report that A did not cause P's house to burn down, despite A having poured the gasoline and started the fire.

A new problem may be raised at this point, which is that the NESS account reveals many things that can be construed as causes. A NESS condition is, as Kevin Hoover writes of Mackie's very similar INUS conditions, "not the complete cause of its effect" (Hoover, 1994, p. 66). In general, the court of law is not interested in holding atmospheric oxygen responsible for the burning of a house. This is to say, not all causes have equal import. How do we prioritize NESS

conditions? Next, I will incorporate Mackie's theory of the causal field to the NESS account presented thus far.

III.ii. Mackie's causal field

To provide stronger guidance as to how the weak necessity account of causation can prioritize multiple causes, I will introduce Mackie's idea of a causal field. The discussion of causal fields occurs within Mackie's framework of INUS conditions. As I have said, INUS and NESS are not the same. However, their differences do not lie in the portions I have selected to present. So, in what follows, assume that INUS conditions are also NESS conditions. Kevin Hoover has previously described the causal field in this way:

> In general, we are interested in some INUS conditions but wish not to pay direct attention to others. Both Federal Reserve policy and the institutional structure of Wall Street may be INUS conditions of the term structure of interest rates; but a bond trader is directly interested in Fed policy and generally relegates institutional structure to what Mackie calls the 'causal field'. The causal field is simply the set of INUS conditions, which either do not change or which serve as boundary conditions for the problem at hand. To say that a causal relation is invariant to interventions of control leaves unstated the caveat, 'within a particular causal field'.
>
> Hoover, 1994, p. 66

The causal field is best understood as the background, or setting, of the specific causal relationship under scrutiny. In many causal analyses, the field can be taken for granted, rather than precisely stated. Precisely stating the causal field, however, has the use of giving boundary conditions for the number of possible counterfactual scenarios. Per Mackie, the field "may be

definite enough for us to be able to say that certain facts or possibilities are irrelevant to the particular causal problem under consideration, because they would constitute a shift from the intended field from the intended field to a different one" (Mackie, 1985, p. 250). This idea solves two key problems. First, it addresses the philosophical concern that it is impossible to identify a genuine sufficient set, without including as a cause the whole prior state of the universe. It is difficult to identify a sufficient set of causes against the range of all possibilities in the universe, but much more tractable to identify a sufficient set against a well-specified causal field. Second, it precludes the emergence of a 'butterfly effect' from a small change in the events, and thus prevents the explosion of a causal question into the intractable problem of comparing uncountably infinite number of possible counterfactual scenarios.

A theory of causation presented in an antitrust case should tell a complete story of how it was that cause led to effect. The completeness of the story requires specifying the sufficient set, the necessary elements of the sufficient set (NESS causes), and the causal field. The precise statement of a causal field is particularly useful in the antitrust economist's work.

What level of specificity gives an appropriate causal field? This is a pertinent question because, as Jane Stapleton writes, "the law describes the particular phenomenon of interest in as fine grained a way in respect of time and place as the known facts allow" (Stapleton, 2015, 723). Consider the following situation:

> On Sunday Agent 1 contaminates a desert traveller's only water keg with an odourless poison which would kill within 24 hours of ingestion; an hour later an unrelated Agent 2 drains the contaminated liquid from the keg; on the following Friday at noon the traveller dies of thirst.
>
> Stapleton, 2015, p. 723-724

In the law, the event of interest is not merely the traveler's death, or the traveler's death by thirst, but rather the traveler's death by thirst on Friday at noon. Does this mean that models of the situation should capture every environmental parameter capable of being measured in that desert on that Friday at noon? Not necessarily. For my purposes, the problem is a practical one more than a philosophical one. One need not be dogmatic about this; the modeler is expected to fine-tune the model to the extent that is practical and useful for the situation at hand. The parameters that can be appropriately relegated to the causal field are ones that *must* be held constant over all envisioned counterfactual scenarios. The model's causal field need not specify that temperature of the desert was 99 degrees Fahrenheit, but it does need to specify that the temperature was high enough that the traveler dies of thirst within five days of being deprived of water.

Modelers using the but-for account of causation are likely to encounter the issue of an unclear counterfactual. The causal field provides an advantage of weak-necessity accounts in this regard: it serves as backdrop to the entire set of possible counterfactual scenarios with a set of fixed parameters.

The traditional antitrust economist's strategy of discussing an ideal, competitive but-for world against the "artificial" anti-competitive real world is, as I have said, epistemically defective. It requires the economist to contort the narrative in a way that justifies categorizing some actions as "artificial" interventions to the market and to simply decide that the seldom-realized ideal of competitive economy is what would have happened without the allegedly anticompetitive actions. The model relies on the intuition of a "natural" state of the world. Reframing the causal framework in terms of NESS conditions and a causal field reduces this reliance on an unfounded intuition. Suppose for instance that an antitrust economist has specified

the following set of conditions as a sufficient set for the outcome: the anticompetitive actions under scrutiny, the market share of the firm under scrutiny, and the long-standing economic institutions, conventions, and structures of the United States. These conventions and structures can hold the seemingly contradictory positions of championing the ideal of competitive market conditions while also containing ways for the firms in its domain to capture large shares of the market and execute what are later construed as anticompetitive behaviors. The plaintiff's economist who takes competitive conditions as a baseline state of nature makes the implicit claim that institutional structures that uphold and enable competitive economic conditions should be relegated to the causal field, while drawing the institutional structures that enable individual firms to capture large shares of the market out of the field and into an active role.

Of course, this means that disagreement about which NESS conditions are natural and which are artificial amounts to disagreements about which of these conditions belong in active causal roles as opposed to in the causal field. These disagreements may be factual, i.e., two economists dispute the relevance of a particular parameter in determining the outcome, or normative, i.e., a disagreement about whether a particular structure should be in place. Whether the institutional structures that establish competitive market conditions—laws, doctrines of economists, political rhetoric—belong in the causal field is ultimately a normative question. The decision of whether to uphold the normalcy of such institutions, and to seal it into legal precedent, is left for the judge. The economist is responsible only for all that comes prior to that: providing a complete account of factual causation and selecting an appropriate model by which to demonstrate the events in a plausible counterfactual.

III.iii. Weak necessity and structural causal models

Weak necessity accounts of causation like NESS and INUS are compatible with structural models that form the basis of modern econometric theory (Baldwin, 2003, p. 28). I will briefly elaborate this compatibility. Judea Pearl defines an equation of the form $y = \beta x + \varepsilon$ as *structural* if it can be interpreted in a particular way. This interpretation is presented by Richard Baldwin as follows: "In an ideal experiment where we intervene to fix X to x and any other set Z of variables (not containing X or Y) to z, the value of Y is given by $\beta x + \varepsilon$, where ε is not a function of the settings X = x and Z = z" (Baldwin, 2003, p. 27). A system of equations in which each equation represents a particular mechanism that determines the value of a single (dependent) variable is a *structural causal model* (Pearl, 2000, p. 27).

Pearl and Joseph Halpern have demonstrated use of the weak necessity account in a structural model of the duplicate fires example introduced in the previous section. In short, their model entails a number of variables whose values, when manipulated, index through the set of possible outcomes within the specified causal field. These include U, an exogenous binary variable that captures the motivation and state of mind of the arsonists ($U_{1,2} = 1$ if and only if both agents intend to set a fire); ML_1 and ML_2, endogenous binary variables that capture whether each agent lights the match; and B, an endogenous variable that indicates whether the house burns down. The causal field is represented in this model as parameters whose values are relevant in determining the behavior of each equation, but that do not change.

More than one structural model of the weak necessity account of causation has been formalized (see Baldwin, 2003). This suffices to show that Wright's NESS account should have obvious appeal for economists, for many of whom the tools of econometrics have become bread and butter.

III.iv. Weak necessity for evaluating model-based counterfactual arguments

Thus far, I have proposed Wright's NESS account paired with Mackie's causal field as a way of uniting law and economics under a shared notion of causation and prioritizing some causes over others. I will now explain how the causal framework provides a method of systematically evaluating model-based counterfactuals presented at court.

The plaintiff's expert economist is usually tasked with (1) proving factual causation and then (2) selecting a model by which to model the events of a counterfactual world. Proving factual causation is determining that the defendant caused, in factual terms, the outcome of interest. In short, this amounts to proving that the defendant has produced at least one NESS condition that is not in the causal field. Selecting an appropriate model requires adapting an economic model that shares a causal field with the model's target.

The first task, proving factual causation, is the less complicated one to verify. If the causal claim implicit in the counterfactual model is not explicit, the judge may want to make this explicit. The weak-necessity account provides a template for retroactively constructing an implicit causal claim: the judge seeks the factual details in a situation that form the sufficient set, NESS conditions (a subset of the sufficient set), and the causal field (a subset of the set of NESS conditions). Provided that the economist has provided a compelling sufficient set and the judge finds no obvious absurdities in the choice of NESS conditions relegated to the causal field, the task of proving causation is complete. In short, the first step in assessing the validity of a counterfactual model is to determine the validity of the causal claim implicit in the model. The framework of weak necessity is a helpful device for structuring this evaluation.

Showing that a model is appropriate for the situation at hand involves explicitly spelling out, for both the selected model and the model target, a complete causal account: the sufficient

set which ensures the outcome of interest, the NESS conditions, and the causal field. Together, these specifications should formulate a complete—though not necessarily unique—narrative of how proposed cause produces the outcome of interest. Let us underscore that uniqueness is not required. The causal field, if properly specified, provides boundary conditions on the possible counterfactual worlds that may emerge from a causal claim. The conditions of the causal field hold across all possible ways in which a situation may unfold, of which there are more than one. The idea is not that an economist should know precisely how the counterfactual occurs, but rather that certain known parameters should be able to bound the number of possibilities to a finite number. The applicability of the model to the target situation can be assessed by formally comparing the causal story implicit in the economist's account of factual causation with that of the proposed economic model. The key question is not whether the assumptions behind each causal story match but whether the stories share a common causal field, such that the model can be said to describe the model target.

For the second task, it may be helpful to introduce another evaluation framework to supplement the weak-necessity causal structure. Edoardo Peruzzi has previously proposed structuring the analysis of a model's relevance and reliability by a two-tier system: weak and strong applicability. He argues that the economist employing a model-based argument typically makes two implicit claims: a *weak applicability claim,* or a claim that their model M is weakly applicable to the target situation T "because there is evidence $E_1, \ldots, E_n$ that some critical assumptions of M are approximately shared by T," and a *strong applicability claim,* or a claim that their model M is strongly applicable to the target situation T because "there is evidence $E'_1, \ldots, E'_m$ that M' describes or predicts some quantitative features of the target to some degree" (Peruzzi, 2023, p. 341-342). By incorporating the causal framework into the analysis of

a model's applicability, we give greater precision to the nature of the "critical assumptions" that the model shares with the target system. The criterion of weak applicability encapsulates the requirement that an appropriate causal field be specified. This means that an economist who wishes to employ a well-known theoretical economic model (for example, the Bertrand model with differentiated goods, as in *Castro v. Sanofi*) in his argument should present the model with clarity about the active causal mechanism and an argument that the theoretical model is compatible with the proposed causal field in the situation being modeled. If the model proves unable to accommodate the desired causal field for the relevant situation, then the claim of weak applicability fails. By default, strong applicability also fails to hold.

It is always possible that in an adversarial legal system such as that of the United States, the opposing side is likely to disagree. They may put forward an opposing model that denies the proposed cause or proposes an alternative NESS condition as playing the primary causal role. If this is the case, this alternative model can be deconstructed and evaluated in precisely the same two-stage process.

The process outlined here may not be trivial. It would be especially complicated if the expert economists do not provide explicit insights into, for instance, the causal claims upon which their counterfactual models are built. However, the current processes by which judges evaluate models can also be non-trivial, on top of being non-standard and lacking a clear sense of procedure. Moreover, for a judge to properly fulfill her gatekeeping role for expert testimonies, it is imperative that she have a clear insight into the underlying causal mechanism for any model presented to her. I am suggesting a structured way that assists in gaining this insight.

IV. Applying the framework

I now give some examples to demonstrate how the framework previously described might work in practice. Three cases are considered: first, I revisit the differentiated Bertrand model of *Castro v. Sanofi*; second, I discuss how causal structure may be exposed from a regression analysis; third, I provide a situation in which deconstructing a regression model may fail to give the judge useful insight into its usefulness.

IV.i. Assessing applicability for a theoretical model

Recall that in the case *Castro v. Sanofi* introduced earlier, the plaintiff's economist Einer Elhauge was tasked with justifying a causal relationship between Sanofi's creation of a loyalty bundle and the subsequent observation of higher prices in the market for pediatric meningitis vaccines. Elhauge applied a differentiated Bertrand competition model to calculate what meningitis vaccine prices would have been without the bundle. The defendant hired their own economist, David Kaplan, who disputed Elhauge's use of the Bertrand model and raised a number of criticisms against it, though did not provide a complete model of his own. Here, I will demonstrate how the weak-necessity causal framework can be used to deconstruct the arguments for each side. As Peruzzi has discussed, Elhauge succeeded in convincing the judge that the Bertrand model was applicable to the situation, and the *Daubert* challenge was presented in court (Peruzzi, 2023, p. 343).

The causal narrative Elhauge puts forth involves a sufficient set for the price increase, of which the necessary elements include: (1) Sanofi's creation of a loyalty bundle, (2) Sanofi's substantial market share in several vaccine markets, (3) Novartis's entry to the meningococcal vaccine market. Other NESS conditions may be (4) the set of institutional structures that enable

Sanofi to establish and maintain its market share in several vaccine markets, (5) the institutional structures that enable Novartis to enter the market, and (6) the legal norms that establish competition as an ideal state for the market. According to the NESS framework, all of these factors are considered causes for the price increase; all are necessary elements of a sufficient set. However, some elements—conditions 4, 5, and 6—may be relegated to the causal field; they either do not change or are assumed to be true in all considered iterations of the counterfactual world. For the purposes of providing a case for factual causation, Elhauge has succeeded—he shows that Sanofi's creation of a loyalty bundle is at least a necessary element of a set of conditions sufficient for the outcome of interest. In his testimony, Elhauge makes an even stronger argument than this; he claims that the bundle is a but-for cause, i.e., that the bundle fulfills a strong necessity requirement. This stronger requirement fulfills the general precedent of but-for reasoning in many antitrust cases, but it is much harder to prove and faces more criticism.

Elhauge is also tasked with identifying some precise qualities of the counterfactual world that would have obtained, had Sanofi not created the bundle. To do so, he argues that the Bertrand model with differentiated products can correctly represent that world. The differentiated Bertrand model is generally applicable in describing duopolies where each firm supplies a good that is similar but distinct from the other. Elhauge gave three reasons why the differentiated Bertrand model was appropriate. First, the market was differentiated—Menactra and Menveo were meaningfully different, though substitutable. Second, the market was Bertrand; firms competed in the market by setting prices, not quantity. Third, the market was characterized by competition, not coordination (*Castro*, 2015).

Kaplan criticized several elements of this argument. In particular, Kaplan pointed to alternative possibilities for what could have caused vaccine prices to rise and argued that certain

assumptions of the Bertrand model were not matched by reality. The weak necessity framework can handle these concerns in a systematic way. The framework does not require a judge to consider whether every aspect of the target situation matches the assumptions of the model. It may be that the model makes assumptions that cannot be perfectly true of the target situation. For instance, the model in question assumes, like many economic models, that each agent possesses perfect information. Evidently, this is not likely to be true in the world. It may also be that the model does not capture the mechanisms of every NESS condition identified in the target situation. For instance, Kaplan argued that Elhauge's Bertrand model neglected to account for the role that a market entrant may have in raising market prices, as in the case of a generic entry into a pharmaceutical market (*Castro*, 2015). The judge should treat suggestions of alternative causes as incomplete causal arguments. Often, a suggestion that the true cause of the outcome of interest was actually X can be phrased as its own causal account. This can be evaluated independently of the previously proposed model; the existence of an alternative causal model does not undermine the plausibility of the previous model.

Elhauge argued that the increase in vaccine prices was primarily caused by Sanofi's loyalty bundle. Kaplan denies that the rise in vaccine prices was caused by the bundle; he argues that it might have been a result of Novartis' entry to the market—entry of a generic competitor can increase the brand competitor's prices in markets where there is a segmentation of customer types into price-sensitive and price-insensitive. Though Kaplan does not provide a complete causal account, it is possible to complete the causal story implicit in his criticism. In essence, this criticism is Kaplan proposing that the rise in prices might have been caused another factor—the entry of Novartis into the market. This argument poses a problem under the but-for account of causation because it denies the existing causal connection between the loyalty bundle and the

prices and attempts to replace it with an alternative but-for cause. However, this criticism is not actually problematic under a weak necessity framework, because the framework admits that there may be more than one equally plausible sufficient set for the outcome, each comprising several causes. Kaplan could have built a causal model with the theory that the new market entry was a NESS condition for vaccine prices to rise, or alternatively have argued that Elhauge was wrong to identify the bundle as a NESS condition. Otherwise, simply raising an alternative factor as a cause is unlikely to pose a problem under a framework of weak necessity. This principle, flexibility with regard to possibilities for the primary cause of a particular outcome, is at odds with but-for necessity. Nevertheless, courts often employ it implicitly, even while they claim to operate under but-for necessity. Judges have dismissed motions to exclude an expert testimony on the basis that alternative causes may exist, because the expert is not expected to disprove every alternative theory in order to make an argument that his is plausible.

Another criticism Kaplan raised against Elhauge's model was that the differentiated Bertrand model assumes a one-shot game with no later coordination, whereas in reality Sanofi and Novartis might interact again and coordinate in the future. The question here is whether assuming a one-shot game is likely to give a substantively misleading result. In the language of the weak necessity framework, the model and the model target do not have to be identical but do need to have compatible causal fields, which specify the bounds within which the model's predictions should fall. In this case, Elhauge defends the choice by citing economic literature that finds one-shot models accurate to empirical data when modeling oligopoly situations (*Castro*, 2015, p. 16-17). This suggests that the assumption generally produces results that lie within what would expect from models without the assumption, and there is no evidence that the model ventures outside what is permitted by the causal field.

IV.ii. Revealing causal structure for regression models

Many econometric models represent structural models that contain implicit causal relationships. As we have already seen, some judges have neglected to investigate the causal structure underlying regressions and simply accept them on the merits of regression as a technique. However, a truly useful analysis will expose the implicit causal structure of a regression to determine its relevance and reliability.

Consider the 2002 case, *In re High Fructose Corn Syrup Antitrust Litigation*. Here, a group of direct purchasers of High Fructose Corn Syrup (HFCS) filed suit against a coalition of primary manufacturers of corn syrup. The plaintiffs accused the manufacturers of explicitly colluding to fix prices. The plaintiffs hired an economist as expert witness. The judge for the case, Richard Posner, summarizes the expert's analysis as follows:

> The plaintiffs' economic expert witness conducted a regression analysis that found, after correcting for other factors likely to influence prices of HFCS, that those prices were higher during the period of the alleged conspiracy than they were before or after. (More precisely, the independent variable that the expert labeled CONSPIRE, which took a value of 1 during the period of the alleged conspiracy and a value of 0 before and after that period, was found to have a positive and statistically significant effect on the dependent variable, which was price.) [. . .] The defendants presented a competing regression analysis done by one of their economic experts, who added a couple of variables to the analysis of the plaintiffs' expert and, presto, the CONSPIRE variable ceased to be statistically significant.
>
> High Fructose Corn Syrup, 2002

Regression models are often presented as one or more structural equations of a form resembling $E = ß_0 + ß_1C_1 + ß_2C_2 + ε$, where $ß_i$ for $i = 1, 2$ measure the strength of causal connection between cause C_i and effect E and ε represents an error term capturing variation in E not explained by C_i. It is common to adopt the convention, *effects on the left, causes on the right* (Hoover, 2011, p. 340).

The variables present in the equation each may be considered a part of a sufficient set for the outcome, but not all of them are NESS conditions, and hence not all are causal. This is because any variable, even a completely irrelevant variable, can be added to a regression model, and the regression's coefficient of determination, or R^2, will increase. A high R^2 is sometimes interpreted as a signal that the model fits the data well and is thus a good model for the situation. Of course, this is not always true, which is why it is important to concentrate on the causal structure of the model when evaluating a regression. A judge facing a regression model may treat the model as any other: she should seek out the NESS conditions, and among them, the factors that are implicitly being treated as part of the causal field. In a regression, the error term is a good analogue for part of the causal field. The error term ε typically captures causal determinants of the outcome E that are not worth spelling out explicitly in the equation.

The causal structure, once revealed, can be analyzed in much the same way as a theoretical economic model. If, as in the HFCS case, the opposing side criticizes the regression model on the basis that it omits certain variables, the addition of which undermine the significance of one cause, the judge should be concerned about *which* variables have been added. The added variables may have a genuine causal relationship with the outcome of interest, but it is also possible that the variables are irrelevant. In the HFSC case, the defendant claimed that the plaintiff's regression should be excluded because the significance of collusion

was undermined by adding a few variables, without explaining the relevance of those variables. This is similar to *Castro* in the sense that the defendant presents alternative causal explanations without undermining the relevance of the existing cause or justifying the causal relationship between the alternative cause and the effect. In both cases, the alternative causal explanations should be completed and evaluated independently of other causal accounts. The judge should inspect whether the added variables are meaningful by relating them with the causal story derived from the target situation.

IV.iii. A lingering issue: what happens when exposing causal structure is not enough?

Now, recall the paper presented earlier, in which Miller et al. criticizes the regression of price and the HHI to argue that greater market power causes higher price level. Supposing that a regression like this is presented in court, the judge may deconstruct the regression and discover the implicit argument that the strong correlation between HHI and price is due to a causal relation between the two. It may not be immediately obvious to the judge why the argument is faulty; a judge who lacks knowledge in economics may not understand the significance of both price and HHI being determined by the same determinants of supply and demand.

This reveals a limitation to the system of evaluation I have suggested: not all judges have a robust background in economic theory. The framework helps a judge to expose an implicit causal framework, and often this is sufficient to facilitate a critical review of the testimony. However, less intuitive relationships like the lack of causal relationship between market share and price may not strike a judge as problematic. The framework I propose may assist a non-expert judge in evaluating economic models, but it does not substitute for genuine economic expertise. In cases where nothing meaningful is revealed by a judge's personal inspection, there

may be a place for the court to appoint a neutral economic expert to evaluate the exposed causal arguments, as Richard Posner has many times suggested (Posner, 1999, p. 96).

V. Conclusion

The weak-necessity causal is a practical strategy to supplement existing methods of evaluating economic models in legal settings. Its main contribution is to direct attention toward the causal claims embedded in all counterfactual modeling, and to recognize causal claims as a starting point for evaluating the fit of a model in a target situation. This is an alternative to *Daubert* standards that provide limited guidance in evaluating the scientific validity of counterfactual models. Non-expert trial court judges remain responsible for being the gatekeepers of scientific evidence, but the intuitive appeal of seeking a coherent causal narrative lightens their burden of weeding through unfamiliar scientific jargon, as they might when evaluating the *Daubert* criteria.

References

Abele, H.A., Kodek, E.G., & Schaefer, G.K. (2011). "Proving Causation in Private Antitrust Cases." *Journal of Competition Law & Economics,* 7(4), 847-869.

[Athey] *Athey v. Leonati*, 1996 S.C.R.3 458 (1996).

Becht, A. C., & Miller, F. W. (1961). The test of factual causation in negligence and strict liability cases.

Bronsteen, P., & Varma, A. (2001). "Daubert rules for economists." *Antitrust*, 15(3), 14-16.

[Castro] *Castro v. Sanofi Pasteur Inc.*, 134 F. Supp. 3d 820, 2015 U.S. Dist. LEXIS 132458, 2015-2 Trade Cas. (CCH) P79, 319 (United States District Court for the District of New Jersey September 30, 2015, Filed).[4]

Chetty, R. (2013, October 20). Yes, Economics Is a Science. *The New York Times*.

[Chisholm] *Chisholm v. Liberty Mutual Group*, 60 Or. 3d 776 (2002).

[Daubert] *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579 (1995).

David, H., McCague, W.P., & Yaniszewski, P. F. (2005). "Proving causation where the but for test is unworkable." *Advocates' Quarterly*, 30(2), 216-238.

DeMartino, G.F. (2021). "The specter of irreparable ignorance: counterfactuals and causality in economics." *Review of Evolutionary Political Economy,* 2, 253-276.

Friedland G. (2009). Discovery of the function of the heart and circulation of blood. *Cardiovascular journal of Africa*, *20*(3), 160.

Giocoli, N. (2020). "Rejected! Antitrust Economists as Expert Witnesses in the Post-Daubert World." *Journal of the History of Economic Thought*, 42(2), 203-228.

[4] Unpublished documents from this case were accessed via Nexis Uni (formerly Lexis Nexis Academic), a legal database.

Elzinga, K.G. (2022). “In the Beginning: The Creation of the Economic Expert in Antitrust.” *Journal of Law and Economics*, 65, S519-S542.

Haack, S. (2015). “The Expert Witness: Lessons from the U.S. Experience.” *Humana.Mente Journal of Philosophical Studies,* 28, 39-70.

Haack, S. (2005). “Trial and Error: The Supreme Court’s Philosophy of Science.” Supplement, *American Journal of Public Health*, 1(95), S66-S73.

Halpern, J.Y., & Pearl, J. (2005). “Causes and Explanations: A Structural-Model Approach.” *The British Journal for the Philosophy of Science,* 56(4), 843-887.

Harbecke, J. (2021). “Counterfactual theories of causation and the problem of large causes.” *Philos Stud,* 178, 1647-1668.

Hartnett, A.E. (2017). “Keep Calm and Causation On: Reframing Causation Analysis in Private Section 1 Antitrust Actions at Summary Judgment.” *Iowa Law Review,* 102, 2291-2323.

Haw, R. (2012). “Adversarial economics in antitrust litigation: losing academics consensus in the battle of the experts.” *Northwestern University Law Review*, 106(3), 1261-1306.

Hoover, K.D. (1994). “Econometrics as observation: the Lucas critique and the nature of econometric inference.” *Journal of Economic Methodology.* 1(1), 65-80.

Hoover, K.D. (1990). “The logic of causal inference: Econometrics and the conditional analysis of causation.” *Economics and Philosophy,* 6, 207-234.

Hoover, K.D. (2001a) *Causality in Macroeconomics.* Cambridge University Press.

Hoover, K.D. (2001b). *The Methodology of Empirical Macroeconomics.* Cambridge University Press.

Hoover, K.D. (2005). “The methodology of econometrics,” *Palgrave Handbook of Econometrics,* Palgrave Macmillan, 61-87.

Hoover, K.D. (2011). "Counterfactuals and causal structure." *Causality in the Sciences*. Oxford University Press, 338-360.

[HFCS] *In re High Fructose Corn Syrup Antitrust Litig*., 295 F.3d 651 (2002).

Langenfeld, J., & Alexander, C. (2010). "*Daubert* and Other Gatekeeping Challenges of Antitrust Experts." *Antitrust*, 25(3), 21-28.

Lee, T. C. (1988). "Court-Appointed Experts and Judicial Reluctance: A Proposal to Amend Rule 706 of the Federal Rules of Evidence." *Yale Law and Policy Review*, 6(2), 480-503.

Mackie, J.L. (1965). "Causes and Conditions." *American Philosophical Quarterly,* 2(4), 245-264.

Mackie, J. L. (1974), *The Cement of the Universe: A Study in Causation*, Oxford University Press.

[Ohio] *Ohio ex rel. Montgomery v. Louis Trauth Dairy*, 925 F. Supp. 1247, 1252 (1996).

Pascal, Blaise, 1623-1662. (1958). Pascal's Pensées. New York: E.P. Dutton.

Pearl, J. (2000). Causality: Models, reasoning, and inference. New York: Cambridge University Press.

Peruzzi, E. (2023). "Models on trial: antitrust experts face *Daubert* challenges." *Journal of Economic Methodology,* 30(4), 337-351.

Posner, R. (1999). The Law and Economics of the Economic Expert Witness. *Journal of Economic Perspectives,* 13(2), 91-99.

Shapiro, C. (1989). "Antitrust: What went wrong and how to fix it." *Antitrust*, 35(3), 33-45.

Sidak, J.G. (2013). "Court-Appointed Neutral Economic Experts." *Journal of Competition Law & Economics,* 9(2), 359-394.

Stapleton, J. (2015). “An extended but-for test for the causal relation in the law of obligations.” *Oxford Journal of Legal Studies*, 35(4), 697-726.

United States v. United States Steel Corp., 251 U.S. 417 (1920).

Werden, G. (2008). “The Admissibility of Expert Testimony.” *Issues in Competition Law and Policy,* 1(33), 801-817.

Woodward, J. (2003). *Making Things Happen: A Theory of Casual Explanation.* Oxford University Press.

Wright, R. (1985). “Causation in Tort Law.” *California Law Review,* 73, 1735-1826.

Wright, R. (2011). The NESS Account of Natural Causation: A Response to Criticisms. In R. Goldberg (Ed.), *Perspectives on causation.* Hart Publishing.