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Jurisprudence Meets Physics

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For many system level questions jurisprudential data has grown to a size and scale that no longer lends itself to traditional analytic techniques driven by human examination and direct analysis. While there will always be vast numbers of specific questions well within the capabilities of humans, an understanding of the system as a whole is no longer among them. Over the past several decades jurisprudence has begun to use mathematical and other analytic techniques many of which were developed in the physical sciences. It is now time for jurisprudence to embrace more fully the analytic tools of these other disciplines, specifically those coming out of physics, in order to continue to produce new insights to aid in the structure, function, design of judicial systems and the analysis of judicial dynamics.

Keywords: judicial dynamics, jurisprudence, analysis, physics, nontraditional data, generative methods

INTRODUCTION

Jurisprudential data grows monotonically over time. Every law that is passed, every case that is decided, every brief that is filed increases the size of the jurisprudential dataset. In 1756 Blackstone published a version of his lecture notes on English Common Law that later became the four volume set Commentaries on the Laws of England [1]. He was able to do this based upon his efforts to understand the common law developed over approximately the first 20 years of his legal career and with a relatively small number of other individuals. Today, even if one only examines US Federal judicial opinions, this would be a difficult feat. **Figure 1** shows the monotonic increase in opinions over time. The quantity of opinions just within the United States is now well into the millions. Even with very optimistic assumptions (each being only ten pages in length and being able to read a page in 2 minutes for 12 hours a day), it would take a team of one hundred people years to read them all. And, of course, the number of opinions would continue to grow over that period.

Moreover, federal opinions are not the only part of this jurisprudential dataset. There are executive orders, statues, regulations, state court opinions, treaties, constitutions, court transcripts, etc. The task of understanding a nation's judiciary is now beyond the scope of a human, or even a team of humans, over the course of their career. It is now time for jurisprudence to embrace more fully the analytic tools and techniques from other disciplines that are designed to deal with this scale. For example, CERN is able to process approximately one petabyte of data per day, and the Large Hydron Collider alone produces about twenty-five petabytes of data per year. Given that there are tools and techniques from physics and other fields that can handle the scale of jurisprudential data, will these analytic techniques provide any useful insights for jurisprudential study? In what follows, I will argue that not only have these techniques produced meaningful insights for jurisprudential study, but they can also produce insights that are not able to be created by other means.

Is it valid to approach jurisprudence with such a new set of tools? Simply put, yes, it is consistent with concepts of jurisprudence to use tools and techniques from outside the legal discipline to study the law. [2] commented on the decline of law as an autonomous discipline as the field of economics grew in importance within jurisprudence. This was further stressed a few years later when Posner articulated an approach to jurisprudence that is consistent with the perspective taken here:

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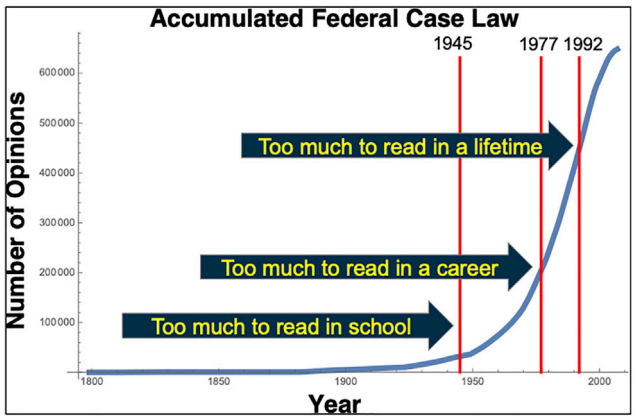

FIGURE 1 | The monotonic accumulation of judial opinions over time.

"By 'jurisprudence' I mean the most fundamental, general, and theoretical plane of analysis of the social phenomenon called law. For the most part it deals with problems, and uses perspectives, remote from the daily concerns of legal practitioners: problems that cannot be solved by reference to or by reasoning from conventional legal materials; perspectives that cannot be reduced to legal doctrines or to legal reasoning" ([3] at xi).

ANALYTIC METHODS

The artifacts generated by a nation's judiciary are becoming more and more accessible. For example, the Free Law Project's CourtListener website provides access to the text of millions of judicial opinions from many Federal and State jurisdictions (www.courtlistener.com). The Harvard Caselaw Access Project has digitized forty million pages of US court opinions spanning 360 years (www.lil.law.harvard.edu). As a final example, transcripts of London's Old Bailey court from 1,674–1913 have been digitized and made available online (www.oldbaileyonline.org). The US Courts even have biographical information available for all justices that have sat and are sitting on a court. And, of course, the code of federal regulations and US code are all available in machine usable formats.

Researchers have made great use of these datasets. Notable early work in this space includes [4] and [5]. These works examined judicial voting behavior through correlation analyses to shed light on the decision making of justices and whether or not a judge's decisions are consistent over time and topic, as well as consistent with institutional traditions such as stare decisis. This line of correlative analysis of judicial dynamics has been significantly extended and broadened over time with works such as [6] that examined the statistical mechanics of the US Supreme Court.

Bias in judicial decision making has also received analytic-based analyses, such as those by [7], and [8]. [9] and [10] both studied law from a geometric perspective created by embedding the text of opinions in a high dimensional space. Finally, researchers are even having success predicting the citations a judicial opinion contains based upon its language [11].

As data about judiciaries and their actions have increased researchers have begun studying different aspects of dynamics of legal systems, from their development to their structure. For example, Barron et al. [12], explored the dynamics of debates from the National Constituent Assembly during the French Revolution during which the new French state was formed. Katz and his many collaborators have studied the dynamics of lawsuits around the US tax code, the movement of clerks from one court to another, the citation structure among the US code and judicial opinions, and created methods of characterizing the temporal dynamics of laws and regulations (e.g. [13,16]).

Many of the aforementioned studies have benefited from tools and techniques developed within Physics, including, inter alia, Ising models, graph analysis, information theory, statistical mechanics, and maximum entropy methods. For example, Barron et al., supra, used a natural language processing technique, topic modeling, to transform the raw text of the speeches into a set of "topics" (here a topic is a collection of co-occurring words) with a numeric value characterizing how likely each topic was contained within the document. Now that concepts of all the texts could be related to each specific text, the authors could use another technique, Kullback-Leibler Divergence, to measure changes in ideas contained within the speeches over time. This is an example of how these new tools can be used by interested researchers to explore collections of documents far too large to read or examine individually. Another example of the utility of these approaches comes from [17]. Here the authors used similar techniques to those of Barron et al., but here the unit of analysis was national constitutions. With these techniques the research team was able to show the flow of concepts from one constitution to another across both time and space and was able to characterize the relative impact of a given constitution based upon its "downstream" influence.

GENERATIVE NUMERIC METHODS

While analytic methods have experienced tremendous growth, so much so that the Santa Fe Institute published a volume on law as data [18], generative methods have experienced much less. For the present discussion I will use generative numeric methods to be representations of judicial processes through time based upon models of their function at the exclusion of numeric approximations used for some analytic methods, e.g., the approximation of stochastic partial differential equations. More specifically, I refer to the use of simulation as a means of testing our understanding of the generative mechanisms at play within a judicial system. The analytic methods discussed supra do an excellent job of producing insights into the current state of a legal system and how that system changed over time, but they do not provide as much insight into why a judicial system produced the observed dynamics or how the system might respond to a perturbation. Here, I argue, progress can be made with the combination of jurisprudential theory and simulation.

Furthermore, as a judiciary is made up of many dynamically interacting heterogeneous components (judges, lawyers, citizens, etc.) who may learn and adapt through time and who are distributed across a meaningful space (jurisdictions), the most efficient way to analyze the system's potential future state is to explicitly represent it and simulate its state changes through time [19]. Typically, this is done via the agent-based model [20,21].

As discussed by [22] the use of agent-based models has dramatically increased over the past 20 years, however they remain largely absent from the jurisprudential literature. As highlighted by the examples discussed by Benthall and Stranburg, when law and agent-based models do collide it is largely in the space of regulation and policy analysis or, more generally, a topic within law and economics. These are truly important uses of agent-based models as they allow for a richer representation of human behavior and decision making than most other methods [23] and have led to many insights, but this is not where the use of agent-based models should end.

In my opinion jurisprudence has before it one of the most fascinating subjects of study available to any discipline. It is studying a complex system that has become self-aware and is now trying to guide itself into specific equilibria, e.g., our society has formalized governing institutions that then created laws and regulations in order to induce its members into particular sets of behavior. The use of agent-based models to examine this aspect of jurisprudence appears to not have been largely embraced . . . , yet.

This is unfortunate as agent-based models provide the jurisprudential scholar with a truly new way to study a society and its judiciary. What if France had a different judicial system? Is a common law judicial tradition a good way to solve hard problems? Ceteris paribus, if the costs associated with courts were to change in manner X what would happen to their utilization? If all judges in a judiciary are slightly biased does that make the system as a whole slightly or greatly biased? If one assumes that a better understanding of a nation's judicial system is critical for the long-term stability and prosperity of a nation, then agent-based modeling provides the jurisprudential scholar with a uniquely powerful way to explore these and many other questions. Unfortunately, I am aware of only three works that specifically use an agent-based model to explore legal or judicial dynamics ([24–26]). These works explored the evolution of stable norms/institutions, the impact of changing information quantities on jurispathic and jurisgenerative judicial decision making, and the evolutionary dynamics of judicial systems respectively. Agent-based models can be particularly useful for abductive exploration, perhaps most famously performed by [27] during his analysis of segregated settlement dynamics in large US cities. In that work Schelling was able to show that even with a society that prefers integrated neighborhoods, if individuals have even a slight bias and do not coordinate their movements, segregated settlement patterns will emerge. And, thus, he was able to create a coherent system from seemingly incoherent signals (individuals prefer integration but create segregated settlement patterns).

BEHAVIORAL AND EXPERIMENTAL JURISPRUDENCE AND AN ANALYTIC COUPLING

Relatively new trends from cognitive psychology and game theory that will aid dramatically the development of our understanding of jurisprudential dynamics are Behavioral Law and Economics [28] and Experimental Jurisprudence [29]. This growing body of literature highlights another example jurisprudence can take from physics: that of the tight coupling of theory and experimentation with perhaps the clearest example those where the existence of a subatomic particle is determined theoretically long before it is discovered experimentally. On the jurisprudential side, one potential example of this coupling could be the Coase Theorem [30]. Coase's theoretical analysis concluded that while the law establishes how negotiations commence it will not impact the conclusion. This analysis was game theory-based and assumed no transaction costs. This conclusion and the relative impact of the rather strong assumption about transaction costs could be experimentally studied within the growing field of experimental jurisprudence.

Another example of the utility of this coupling of techniques relates to the body of jurisprudential literature relating to the notion that common law (judge made law) will evolve to higher levels of efficiency over time largely irrespective of how judges decide the outcome of a case, see generally [31]. Unfortunately, when [32] tested this theory empirically they found no evidence of this increasing efficiency over time. We now have theory and analysis at odds with each other. Here generative techniques may be used to explore how this inconsistency could arise and what it might mean. [26] was able to show through a simulation-based analysis that judicial problem solving may exhibit punctuated dynamics resulting in very short periods of improvement and long periods that resembled random walks. This being the case, a relatively small sample of judicial dynamics would be more likely to show random activity than improvement. In this abductive analysis simulation was used to show that what at first seemed like incoherent results from theory could actually be coherent. Given ongoing advances in cognitive science, experimental jurisprudence, and behavioral law and economics, it is not difficult to imagine using agent-based models to explore the decision-making dynamics of juries, social ideas of justice, or, more tactically, the functioning of a court room or judiciary and how that functioning may be made more efficient.

DISCUSSION

The combination of tools, techniques, and practices of physics and jurisprudence would be a very powerful way to explore judicial dynamics and better understand what drives these dynamics and how we might create more effective judicial systems and reforms to existing systems. Together these fields could observe a particular dynamic, analyze data collected from it, expose statistical regularities in the data, then formulate a closed form expression of the system that is consistent with the regularities found in the data. The abstract representation can be used to understand the basic dynamics of the system and bound

its behavior. As understanding improves, the model system can be moved from a closed form representation to that of a simulation allowing for the relaxation of assumptions often needed to express a complex system in closed form. I believe it is the tight coupling of analysis, theory, human-centric experimentation, and generative analyses that will allow jurisprudence to create ever new and more useful insights into judicial dynamics.

While it is likely naive to envision a time when jurisprudence has explanatory and predictive power on par with physics, one can foresee a time when jurisprudence is a science made up of qualitative and quantitative methods; where theory, quantitative analysis, and simulation come together to provide a more complete picture of justice and judicial dynamics. As societies face questions about judicial reform, the impact of bias in decision making, or the use (and impact of) artificial intelligence-based systems within a judicial system these methods become more important, especially when coupled together. These methods provide us with a way to understand the potential impact of changes to, and reforms of, a judiciary. Additionally, these methods provide a way to experiment with a judiciary en silico before making changes that could potentially have negative social or judicial consequences and may be difficult and time consuming to undo.

Until recently it was difficult to conceptualize how these tools could be leveraged within the field of jurisprudence. However, as data continues to become more available, agent-based modeling tools become easier to use, and computer hardware becomes more powerful hopefully this will begin to change. As can be seen in much of the literature highlighted herein, and more generally within this special issue, the narrative data produced by judicial systems can now be fruitfully analyzed and used to produce many new insights and test our intuitions about judicial dynamics in ways unavailable a few years ago. This, combined with emerging academic programs that combine law and data science, will produce the next generation of researchers forging a new jurisprudential science with a tight coupling among theory, experimentation, and analytics all of which will be well informed by other fields such as physics.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: www.uscourts.gov.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of the work and it has been approved for public release, case numbers 13-4197.

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