An Objectivist's Guide to Objective Chance

Abstract

Several philosophers have developed accounts to dissolve the apparent conflict between deterministic laws of nature and objective chances. These philosophers advocate the compatibility of determinism and chance. I argue that determinism and chance are incompatible and criticize the various notions of "deterministic chance" supplied by the compatibilists. Many of the compatibilists are strongly motivated by scientific theories where objective probabilities are combined with deterministic laws, the most salient of which is classical statistical mechanics. I show that, properly interpreted, statistical mechanics is either an indeterministic theory or else its probabilities are not chances, just as incompatibilism demands.

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1 Introduction

There are no objective chances in a deterministic world. So believes an *incompatibilist* about chance and determinism. According to a "small but vocal contingent" (Eagle, 2011, 269) of philosophers, incompatibilism is the default view among most philosophers, one which members of this contingent believe ought to be overturned in favor of compatibilism, which allows the possibility of chances in a deterministic world. Their intuitions are driven by ordinary language use of the term "chance" or by the use of objective probabilities in science; the "silent majority" rests in idle opposition on the apparently obvious truth of incompatibilism. Indeed, the detractors have pointed to the lack of explicit argument in support of incompatibilism as a sign of its vulnerability (Glynn, 2010; Eagle, 2011; Emery, 2015). While neither Nixon nor his silent majority had a good reason for continuing the war, I claim that incompatibilists certainly do have such for maintaining their metaphysical doctrine. I provide the basic argument and supporting rationale for it in this paper, to make the fundamental incompatibility of chances

and determinism as plain as it may be made.

Much of the discussion concerning chance in recent decades grows out of David Lewis's influential contributions to the topic. Lewis was explicit about his view of the question before us:

> To the question of how chance can be reconciled with determinism, or to the question of how disparate chances can be reconciled with one another, my answer is: *it can't be done*. (Lewis, 1986, 118)

On this point I am in full agreement with Lewis. His approach to chance, however, brings together several considerations—for example, his famous "principal principle", the "best systems" analysis of laws, particular intuitions about the nature of chance, and more—which from my point of view have little to do directly with the irreconcilability of chance and determinism. To a significant extent they even obscure the particular issue. Thus, while many of the compatibilists have, in my view, successfully criticized Lewis's views on chance, I do not think they have thereby brought incompatibilism into any doubt.

For Lewis, the connection between credences and chance, enshrined in the principal principle, is our best (and only) guide to chance—hence the title of his famous paper, "A Subjectivist's Guide to Objective Chance" (Lewis, 1981). As most commentators allow now, a lot more informs an analysis of chance than this important connection, as argued particularly by Arntzenius and Hall (2003) and witnessed by the several principles offered by Schaffer (2007). Surely a complete account of chance should make plain how agents such as ourselves can come to know them and how we should set our beliefs in relation to them. Nevertheless, the fundamental incompatibility of chance and indeterminism is independent of agential considerations. If it is a fact at all, it is an objective, metaphysical fact, so it should be explicable directly in metaphysical terms without the encroachment of pragmatic considerations and the like. Accordingly, I aim herein to offer only an "objectivist's" guide to objective chance.

Already in these few paragraphs I have employed a number of terms which have engendered considerable confusion in the literature: e.g. chance, probability, determinism, objective, subjective, etc. To this list of troublesome terms I should add ontic and epistemic probability as well. My initial task will be to adequately clarify the notions referred to by these terms along with their relations. Not only is this necessary to appreciate my main point, but it is also important for bringing into sharper relief questions about chance and probability that do require further philosophical investigation. When their work is understood as being in pursuit of these further questions rather than as arguments for compatibilism, it is clear that compatibilists have made many insightful contributions, for example by drawing attention to the role of explanation (Emery, 2015), through the rigor of (List and Pivato, 2015)'s formal approach, and by focusing attention on the admissibility of evidence bases (Handfield and Wilson,

2014). My larger aim in arguing for incompatibilism is thus to urge philosophers to recognize that suitably understanding the relations of various kinds of probability to determinism is propaedeutic to understanding the full significance of various kinds of probability in ordinary language and science.

That said, the obviousness of incompatibilism does not belie its argument, so I shall waste no time in providing it. The *basic argument for incompatibilism* runs as follows:

1. Chance entails indeterminism.

2. Indeterminism is the contrary of determinism (so inconsistent).

3. Therefore chance is inconsistent with determinism.

Correctly understood, this argument should be quite compelling (and obvious, so I claim no novelty by stating it). It is, as said, an entirely metaphysical argument: chance here is to be understood in an ontic sense, and determinism is a metaphysical thesis about the world. Since I doubt that compatibilists deny the validity of this argument or the truth of the second premiss, it must be the case that they believe chance does not imply indeterminism. The burden of the remainder of the paper is to show that they are wrong to believe this—without falling into pointless disagreement over the "correct" meaning of chance.

I will proceed by first clarifying the terminology mentioned above, then by engaging with the various counter-arguments of the compatibilists. I will take in turn the three main camps of compatibilists: the reductionists, the contextualists, and the relativists. A major sticking point for compatibilists is the presence of chances in apparently deterministic theories from physics like Bohmian quantum mechanics and classical statistical mechanics. In the second half of the paper I will resolve the scientific threat to incompatibilism by showing that these theories are either indeterministic or else not chancy. As many compatibilists think of the probabilities in these theories as chances, and since this is a guide to objective chance (not objective probability in general), I concentrate on the former case. While characterizing these theories as indeterministic goes against much conventional thinking, conventional thinking has been much too careless in interpreting probability in physics. While some of the laws of these theories are certainly deterministic, not all of them are (that is, if they are theories with chances). Thus worlds with these laws are indeterministic worlds and hence do not impugn incompatibilism.

2 Against Deterministic Chance

I begin with the less controversial notion in this debate: determinism. Determinism, as it appears the basic argument for incompatibilism, concerns the metaphysics of worlds. It is the thesis that the world is deterministic. Accordingly, by the first premiss I mean the claim that a world with chances is an indeterministic world.

It is not any collection of particular occurrent facts about a single world that make it deterministic; it is the laws of the world that do. That is to say, a world is deterministic if and only if the laws at that world are deterministic (Lewis, 1983, 360). The laws are deterministic if and only if any two nomologically possible worlds (with respect to the laws) which agree on the relevant facts at one time agree for all times (Earman, 1986, 13). Although this latter definition is not entirely satisfactory, it is a definition that participants in the present debate have been willing to accept (in some form or another). The laws are indeterministic if and only if there exist nomologically possible worlds (with respect to the laws) which agree on the relevant facts at one time but do not agree for all times. If the laws are indeterministic, then the laws allow what one might call "branching"; for example, different futures may occur given the state of the world at a particular time. Another way to capture the idea is like this: if determinism is true, then each nomologically possible history can be reduced to a state of the world at an individual time; if indeterminism is true, then only (non-singleton) collections of possible histories can be reduced to a state of the world at an individual time.

Compatibilists believe that chance is consistent with determinism, so they believe that a world with deterministic laws can have chances. Chances are usually modeled as probabilities. There are, of course, many things that can be modeled by probability theory, not all of them reasonably considered probabilities. Among the things modeled by probability theory that are reasonably considered probabilities, two distinctions in particular will be important for what follows.

First is the distinction between ontic (or metaphysical) probabilities and non-ontic probabilities. Ontic probabilities are often described as probabilities which are part of the "furniture of reality" and which exist in the world whether anyone is around to know about them or not. These descriptions are not precise enough, since what I will call "objective probabilities" could also be characterized in these terms. If ontic probabilities are truly "in the world", then it is because they derive from some "probabilistic" element in the world, a degree of fundamental randomness in the nature of things, according to which states of affairs come to be. The existence of genuine ontic probabilities indicates, in other words, that there is a law of nature which mandates that possible outcomes are realized only randomly (in proportion with the probabilities assigned to those outcomes). Thus, non-trivial ontic

probabilities entail indeterminism, since only a (non-singleton) collection of possible histories (those to which a non-zero probability is assigned) can be reduced to states of the world at times under the action of this law.

I will use the term "chance" to refer exclusively to ontic probabilities (or at least probabilities that purport to be ontic, such as Humean chances). This is how the term is typically used in metaphysics; it is a (semi-)technical term. Obviously not everyone uses the term in this sense. Indeed, it is usually not used in this sense in everyday contexts, as some compatibilists have been quick to point out. Nevertheless, one is free to adopt common language terms for technical concepts. If you believe this choice trivializes the present debate, then to some extent I agree. The point is, after all, that the basic argument for incompatibilism is close to trivial. Nevertheless, there is much that remains to be said on the topic for the sake of clarification and ramification—not to mention the fact that some compatibilists think that ontic probabilities really can be consistent with determinism.

One reason that they may think this is that they include other kinds of probabilities in the category of chances. For example, the frequentist and "best systems" interpretations of probability are often described as ontic interpretations of probability. Both of these interpretations reduce probabilities to certain facts about the world: to frequencies of outcomes in the case of frequentism and to facts acceptable to Humeans, the best systematization of which produces probabilistic laws, in the best systems case. Frequencies are obviously compatible with both determinism and indeterminism, since they have nothing to do with laws. They merely describe occurrent facts in a particular way. Thus they are ontic only in the (irrelevant) sense that the facts they describe are ontic. Humean chances, however, derive from probabilistic laws (Lewis, 1981; Loewer, 2001, 2004), which are the output of the best systematization of Humean-sanctioned occurrent facts. Humeans deny that laws and chances have an independent existence from the occurrent facts whence they come. Nevertheless, it is reasonable to consider their laws and chances ontic insofar as they do in fact suitably reduce to these facts. Since they are meant to play the same roles as ontic laws and probabilities, it is "as if" Humean laws are ontic laws, and it is "as if" Humean chances are ontic probabilities. In any case, since Humean chances derive from probabilistic laws, Humean chances are clearly incompatible with determinism.[1]

All non-ontic probabilities are rightly considered agential probabilities: probabilities that agents may use to describe and explain facts about the world, but which are not amenable to an ontic interpretation. They are often used to represent justified degrees of belief (of a rational agent), but they can also represent "objective" evidential support for propositions about the world or can be the probabilities obtained from the method of arbitrary functions

[1] Hoefer (2007) proposes an account of chance motivated by Humean considerations, but Hoefer's chances are not Humean chances as just described; instead they fall within the category of probabilities which I will be calling objective epistemic probabilities.

(von Plato, 1983; Strevens, 2006; Myrvold, 2012). In these cases it is appropriate to describe them as epistemic probabilities. Less-than-rational agents may have degrees of belief (credences) as well, but these degrees of belief are not necessarily epistemic probabilities, since sometimes agents believe things (to a certain degree) that they do not know (to that degree). If an agent does know the probabilities representing appropriately objective evidential support for some proposition, then she should set her credences (degrees of belief) in accord with these probabilities (in keeping with some appropriate version of the principal principle). These objective probabilities, however, may or may not derive from ontic probabilities.

A couple of examples should help illustrate this terminology. Consider, first, the probabilities of quantum mechanics as standardly interpreted. These probabilities are usually thought to be ontic probabilities, i.e. thought of as chances. The indeterminism of quantum mechanics is not usually thought to be a matter of, for example, a lack of knowledge on our part of some non-chancy reality. Rather, it seems that our quantum mechanical world is fundamentally chancy in a way that has been importantly revealed by our observations, experiments, and theorizing. In contrast, consider the drawing of an unknown playing card from a full deck of cards. Suppose the drawer elects to take the top card of the deck. Then there is no non-trivial ontic probability involved in the top card being what it is or will be revealed to be. Nevertheless, for all the drawer knows the card has a probability of 1/52 of being a particular card, e.g. the ace of spades. This is an agential probability. If the drawer thinks the probability of drawing the ace of spades is 1, then he has an unreasonable degree of belief, in which case this is an agential probability which is not an epistemic probability.

One also finds reference in the literature to objective probabilities and subjective probabilities. There is probably no pair of terms so over-loaded in meaning as "objective" and "subjective" in philosophy, which makes it fraught to indulge in their use in this debate. To some the distinction is simply interchangeable with the previous one. For example, Popper claims that "objective physical probabilities are incompatible with determinism" (Popper, 1982, 105). Yet if there are objective agential probabilities, i.e. epistemic probabilities, then this claim cannot be maintained (as the card drawing case shows). One could dismiss this possibility and hold that all agential probabilities are in fact subjective, in which case this distinction would collapse into the distinction between ontic and agential probability. Similarly, Schaffer (2007, 117) marks a distinction between objective chance and epistemic chance. But it is clear that he means to contrast ontic and epistemic probabilities and merely uses "objective" to denote ontic and uses "chance" here equivocally.

There is, however, an important distinction relevant to the present debate which is usefully captured using

the objective/subjective distinction and should be marked. That is a distinction in how probability is grounded or justified. We should say that subjective probabilities are probabilities determined (substantively) by an agent's choice and that objective probabilities are determined (substantively) by facts about the world. This distinction is often made in the context of Bayesian probability. It is not a sharp distinction, since probabilities can be more or less objective, more or less subjective. Nevertheless, it should be clear that agential probabilities may be subjective or objective in this sense, whereas ontic probabilities are necessarily objective, as they are grounded in lawlike features of the world.

Let me now revisit the previous examples and employ the new terminology. First, the probabilities derived from quantum mechanics, as standardly interpreted, are objective ontic probabilities (as all ontic probabilities are necessarily objective). If we set our agential probabilities in accord with these probabilities, then it seems right to regard them as objective, epistemic probabilities. Similarly, it might be reasonably said that assigning the ace of spades a probability of being drawn of 1/52 is objective (because of, say, some principle of indifference, if one accepts it) despite there being no genuine chances involved in determining what the drawn card is. To permit room for rational disagreement, however, it is plausible to suppose that there is some freedom in assigning degrees of belief, such that agential probabilities are not always completely determined by the available evidence. In the extreme case, it might be supposed that assigning any probability of drawing the ace of spaces is rationally permissible given the evidence available, in which case the probability would be appropriately described as subjective. This degree of subjectivity would surely undermine its standing as an epistemic probability however.

To illustrate these distinctions further in the context of the literature on "deterministic chance", consider the claim of Lyon (2011, 414) that there are probabilities which are neither chances nor credences. In introducing the "paradox of deterministic probabilities", i.e. the problem of interpreting the probabilities of ostensibly deterministic theories like classical statistical mechanics, he describes chances as objective probabilities and credences as subjective probabilities (which include, he rightly notes, the "objective" degrees of belief of impermissive Bayesians). Since he accepts that chance is incompatible with determinism (understanding chance in what appears to be the ontic sense) but believes that there are objective probabilities that are not chances, he claims that there is a third kind of probability besides chance and credence, which he calls "counterfactual probability". I agree with Lyon that there is a third kind of probability and, although it is not my concern to argue it here, I believe his third kind of probability naturally falls within the category of objective epistemic probabilities (in my terminology). Indeed, this example illustrates the potentially troublesome usage of terminology in the context of

this debate, since Lyon uses objective and subjective in a way that overlaps in an unclear way with the distinction between chance (objective probabilities) and credences (subjective probabilities).

Making these two distinctions in the way that I have should clear much of the ground of the seeds of confusion which have everywhere sprouted in the literature. These are hardly novel distinctions, but they are distinctions which should be made in this context. With these distinctions in mind, I may restate my claim: it is that chances, i.e. objective ontic probabilities, are incompatible with determinism. Objective probabilities can be compatible with determinism, so long as it is possible to justify non-trivial objective degrees of belief, i.e. epistemic probabilities, in a deterministic world.

I can now turn to criticizing the compatibilists that dispute my claim. I have already pointed out that reductionist chances are straightforwardly incompatible with determinism (Humean chances) or not ontic in the relevant sense (frequentist probabilities), so there are two remaining camps of compatibilists to address: the contextualists and the relativists.

The first camp of compatibilists that I will criticize is the contextualists (Eagle, 2011; Handfield and Wilson, 2014). They would (I suspect) object to the basic argument for incompatibilism by alleging that "chance" in this argument is equivocal: some kinds of chance imply indeterminism, but not all meanings of chance do. As Eagle observes, "the possibility of such equivocation is good evidence that an expression is *context sensitive*" (Eagle, 2011, 283). Indeed. So too is the meaning of the word "law" equivocal between "law of nature" and "law of the land". Natural language words tend to have a variety of meanings which vary based on context. I take it that the relevant context of debate here is metaphysics, in which case one should remove irrelevant equivocation from consideration in order to avoid pointless semantic disagreement. Thus, if one means objective ontic probabilities by chance (as I and others like Lewis do), then the basic argument seemingly goes through without possible objection from the contextualists.

Contextualists tend to think that the incompatibilist thesis has a greater burden of proof than what the basic argument for it suggests. For example, Eagle renders the incompatibilist thesis as follows:

> **IC** If a world is deterministic, then no possible outcome in that world has any chance other than 1 or 0. (Eagle, 2011, 286)

He then claims that "compatibilism will be defensible if there exists some context in which the proposition expressed by IC is false." Similarly, Handfield and Wilson offer this one (for any proposition φ):

> If 'the chance of φ is x' is true at [time] t, then 'the chance of φ is y' is true at t, iff $x = y$. (Handfield

and Wilson, 2014, 5)

They take this to be the central commitment of the incompatibilist position and argue against it by allowing "chance" to refer to any kind of objective probability. In both cases these authors introduce an unreasonable standard for incompatibilism, since few incompatibilists would be so bold as to claim that epistemic probabilities are incompatible with determinism. Such a claim would, in any case, reach beyond incompatibilism, since it would require that only ontic probabilities ground or justify epistemic probabilities. This connection is clearly independent of incompatibilism, which is just the metaphysical claim that ontic probabilities are incompatible with determinism.

Perhaps what contextualists have in mind, though, is that the meaning of "chance" is up for grabs and that we should not presuppose or stipulate a particular meaning for it. This is in keeping with the generally functionalist approach adopted by most authors who have written on chance. To decide the matter, they might say, we need to look at all the available evidence, including the use of the word in ordinary and scientific contexts. Handfield and Wilson, for example, find the ontic conception of chance to be a poor fit with its usage in these contexts. They believe by making chance a contextually relative concept they can do justice to the varied meanings of the term, including the semi-technical version I adopt. As a matter of semantics alone, no doubt they can.

Relativizing the meaning of chance to context, however, makes it easy to overlook important distinctions, especially those mentioned above: that between ontic and agential probability and that between objective and subjective probability. Handfield and Wilson choose to run together such distinctions at the outset of their paper, saying that they "will use 'objective probability', 'objective chance' and 'chance' interchangeably" (Handfield and Wilson, 2014, fn. 1). Yet it is surely an important matter for metaphysical investigation whether the ontology of the world includes genuine chances. Handfield and Wilson evidently agree, pointing out that their contextualist framework can easily be made to accommodate these investigations by supplying the relevant contexts. No doubt it can, but then their use of contextualism is ultimately irrelevant to the metaphysical thesis of incompatibilism.

Handfield and Wilson do, however, offer more than contextualism in arguing against incompatibilism. They also fall within the second camp, the chance relativists (Glynn, 2010; Emery, 2015; List and Pivato, 2015), who allege that there exist different "levels of reality" on which one may locate differing chances. The relativists would apparently object to the first premiss of the basic argument for incompatibilism by alleging that chances may exist on some levels despite the world (or at least some more fundamental level) itself being deterministic. Yet, as List and Pivato (2015) recognize, there is a significant danger in relativizing chances to levels, since it may be argued

that higher level probabilities, insofar as they are inconsistent with probabilities on lower levels, are at best merely epistemic probabilities, in which case the incompatibilist thesis would stand.

To the question of whether this danger can be avoided, my answer is: *it can't be done*. List and Pivato not only recognize the danger but supply the best attempt to avoid it. How they fail is instructive. They assume that higher levels are related to lower levels such that there is a surjective projection map $\sigma : L \to H$ between lower level states L and higher level states H (List and Pivato, 2015, 131-2). This map is used to capture the idea that "macroscopic" states of the world at the higher level are multiply realized by "microscopic" states of the world at the lower level.[2] Once they connect higher levels to lower levels via σ the game is already up. They do not realize it, though, and go on to claim that the higher level probabilities are immunized from the aforementioned danger by introducing independent probability spaces on each level, i.e. independent probability spaces built on L and H. Their "key insight" is that "*only higher-level language is available*" (List and Pivato, 2015, 134) when evaluating chance and determinism on a particular higher level. Indeed, they go so far as to say that it is a "conceptual error" and a "category mistake" to employ a lower-level probability function to evaluate probabilities of higher level events (List and Pivato, 2015, 135). What they say is literally true, I suppose; however the conceptual error is entirely on their side and their key insight is a confusion. By assuming that higher levels are related to lower levels in the way they do they have introduced all the relevant language needed to translate facts transparently between levels. Thus their higher level chances are not at all immunized from what the lower level chances are.

Here is how the translation is done. Let us represent a lower level state $s \in L$ subject to deterministic laws as a trivial probability distribution ρ on the probability space representing that lower level L, i.e. $\rho(s) \mapsto 1$ and $\rho(t) \mapsto 0$ for all $t \in L, t \neq s$. Then the projection map σ can be used to translate that lower level probability space to the higher level, where the measure will of course remain trivial. If we call μ the probability distribution on the higher level H, then $\mu : \sigma(s) \mapsto 1$ (where $\sigma(s)$ is the unique higher level state to which σ maps s) and $\mu : u \mapsto 0$ for all $u \in H \neq \sigma(s)$.[3] This is a trivial probability measure on the higher level in the "higher-level language". There can be no objection to pushing probability measures forward in this way, from lower levels to higher levels, as List and Pivato have provided all the tools needed to do it and no unnatural choices have been made in defining μ. It is just the direct translation of σ from L to H.

[2]The inverse image $\sigma^{-1}(h)$ of a higher level state h is the set of lower level states that project to h.

[3]More elegantly, we define $\mu = \rho \circ \sigma^{-1}$, i.e. the higher level probability distribution is the composition of the lower level probability distribution and the inverse of the projection map from lower to higher levels (extended in the obvious way to the sigma algebras of the relevant probability spaces). It is easy to show that the composition exists and is a probability measure associated with H.

It is clear that the trivial probability measure pushed forward to the higher level probability space will be inconsistent with any probability measure that differs from it. If the probabilities of the lower level are ontic, i.e. chances, then we cannot consider the higher level probabilities to be chances too on pain of contradiction. If the lower level is deterministic, then we cannot consider the higher levels probabilities chances either. In short, List and Pivato's "emergent chance" can at best be epistemic and hence not chance. Their framework therefore supports incompatibilism rather than compatibilism. Mutatis mutandis, the same will be true of other chance relativists. The only way to preserve independent chances on different levels is to give up on plausible relations (like σ) between the levels. This metaphysical picture is irrelevant to the thesis of incompatibilism discussed here, however, which assumes that it is meaningful to say that the world is deterministic.

I conclude, therefore, that the general arguments of the contextualists and relativists against incompatibilism miss their mark. The basic argument for incompatibilism can only be overturned by skeptical, anti-metaphysical arguments which deny its presuppositions. Perhaps this is what some compatibilists aim to provide. But if one thinks that it is perfectly meaningful to discuss the thesis of determinism and the reality of chances, then those arguments will not have purchase. I take it that most compatibilists are motivated instead by a wish to understand the nature of objective probabilities, which probabilities often arise in apparently deterministic contexts. For the sake of these compatibilists, more must be said, since the arguments of this section will have done little to assuage compatibilist intuitions regarding such cases.

3 Apparent Conflicts Between Chance and Determinism in Physics

The kinds of cases that are salient to the minds of many compatibilists include ostensible cases of "chance" in what are generally thought to be deterministic theories (like classical statistical mechanics), and apparently chancy events like coin flips which nevertheless can be modeled by a fully deterministic mechanical dynamics. To firmly establish the incompatibilist thesis it is necessary to explain away seeming conflicts of chance and determinism. Given that the probabilities in such cases are properly thought to be objective, there are two main alternatives: either these theories are not really deterministic, or their probabilities are merely epistemic probabilities.

Many (perhaps all) of the cases plausibly fall into the latter category. While the probability of a coin flip landing heads is reasonably thought of as an objective probability, it is not chancy. It is an objective agential probability. Why use probabilities in this context? According to the method of arbitrary functions, for example, the utility of modeling coin flips probabilistically can be accounted for by first coarse-graining of the space of

possible mechanical initial conditions into the coarse-grained outcomes "heads" and "tails" and then noticing that nearly any suitably random distribution of initial conditions will result in half "heads" and half "tails". Therefore, one has good reason to expect that the probability of heads is 1/2 and the probability of tails is 1/2.

To fully understand the nature of these probabilities, one should ask, "from where does this randomness come?" There are two ways to take the question, depending on whether one asks the question in the context of the so-called "chance setup" (which is here understood as having an underlying deterministic dynamics) or about the conditions that instantiate the setup itself.

On the one hand, the randomness imposed in the context of the chance setup to justify the use of probabilities is purely subjective: one picks "random-looking" initial conditions or chooses a "reasonable" probability distribution over these conditions. Since this randomness is not ontic, involving as it does agential choice, the probabilities are obviously agential probabilities. In the method of arbitrary functions one applies various subjective probability measures to the set of initial conditions and observes that the coarse-gained outcomes are robust under almost all of them. Yet the structure of the space of initial conditions and the coarse-grained outcomes (as just described) are fully objective, which is why such probabilities are rightly considered to be (to some extent) objective. Thus they are objective agential probabilities.

On the other hand, there is the further question of why the initial conditions of actual coin flips have the "random-looking" distribution that they evidently do. That question, however, can only be answered in a larger or different theoretical context. Perhaps the answer is to be found in fundamental chances; perhaps it is merely to be found again in initial conditions.

Obviously, there is much more to be said about how to understand cases of epistemic probability, but a more complete account would require a separate treatment. The topic of this paper, in any case, is objective *chance*. Hence the more pressing cases are those that we tend to think of as involving ontic probabilities, especially cases from physical theory like classical statistical mechanics and quantum mechanics.

Compatibilists have often pointed to classical statistical mechanics in particular as a place where ineliminable, objective probabilities must somehow be compatible with deterministic mechanical underpinnings. As standardly understood, statistical mechanics describes and explains macroscopic (thermodynamic) phenomena by way of the microscopic physics of atoms and molecules. This microscopic physics of classical statistical mechanics is described by classical mechanics; hence, it is conventionally understood to be a fundamentally deterministic theory at the microscopic level. Although some interpreters of the theory would be happy to characterize statistical

mechanical probabilities in agential terms, many others feel that there is some awkwardness in describing them as "subjective" or agential, e.g. because they play a crucial role in generating the empirical content of the theory. They conclude that there must be deterministic chances—non-agential probabilities in a deterministic world—in order to explain the success of the theory.

This apparent conflict between statistical mechanics being a deterministic theory yet possessing ostensibly non-agential probabilities has been called the paradox of deterministic probabilities (Loewer, 2001; Lyon, 2011). The most prominent solution, discussed by Loewer (2001), is to push all probabilities back to an initial time in order to avoid conflict with the deterministic dynamics. What is chancy on such a view is the initial microscopic state of the system. This state is (because of the large number of atoms or molecules involved) obviously epistemically inaccessible. Accordingly, the chanciness inherent in the realization of the actual microscopic initial conditions is translated into an agential probability, due epistemic uncertainty over which of the initial conditions was actually realized (in accord with some sort of principal principle). These agential probabilities can then be carried forward through the deterministic evolution of the system after the initial time to the statistical determination of a system's properties (conditionalizing on other admissible evidence along the way) (Albert, 2000). In short, the epistemic uncertainty in our predictions is ultimately a consequence of uncertainty over the outcome of the initial chance event. Loewer claims that this resolves the paradox of deterministic probabilities, and I agree that it does.

Humeans like Albert and Loewer generally take these initial chances to be descriptive of and reducible to the actual matters of occurrent fact. There was, as an ontological matter of fact, no "chance event" associated with the creation of a system or world, just as Humeans take it that there are no laws actually pushing and pulling objects around. Fundamentally speaking there are only the actual matters of occurrent fact, the "Humean mosaic". Nevertheless, Humeans wish to recover the apparent objectivity of laws and chances (to use them in explanations, for example) and usually do so by arguing that they are part of an objective overall best theoretical system (Lewis, 1973, 1994; Loewer, 1996; Cohen and Callender, 2009). The features of the best systematization of some set of occurrent facts should, moreover, be considered to be metaphysically real, for if they were not real in this sense, then it would be difficult to see how they could play their roles of prediction, explanation, etc. (Loewer, 2001).

Since there is some pressure to globalize statistical mechanics (Callender, 2011), it is common for Humeans to conceive of the entire world as a statistical mechanical system with its own chancy initial conditions. The universe began in some particular macro-state corresponding to a hot, dense "big bang" beginning (the so-called "past state"), the probabilities of which pertain to the particular micro-state instantiated in the initial creation event. Just

as one may take the view that there are governing laws, one may also take these initial chances to involve a genuine ontic randomness, i.e. as full-fledged features of reality. In this case one would describe this story in essentially the same way, but one would say that the world began—as an actual matter of fact—with an initial chance event Demarest (2016).

This non-reductive point of view on ontic probability reveals that statistical mechanics is not really a deterministic theory. Statistical mechanics, interpreted this way, has an indeterministic law governing the initial chance event and a deterministic law that governs the evolution of the system at all other times. Since the only thing that differs between the non-Humean and Humean accounts is a difference over whether the chances, laws, etc. are reducible to other parts of the ontology, both accounts should understand statistical mechanics as an indeterministic theory. Indeed, Loewer (2001) argues that the initial probability distribution should be considered a law because of its essential "law-like" role in the theory. I completely agree. This probability distribution pertains to an initial chance event, which should be understood as a dynamical, law-like transition of state. In other words, although the laws of statistical mechanics are almost always deterministic, they are not *always* deterministic: the evolution of the system is indeterministic at the initial time and deterministic (ever) afterwards.

Therefore Loewer solves the paradox of deterministic probabilities not by adopting compatibilism (as many compatibilists seem to interpret him) but by showing how its indeterministic evolution can be compatible with its deterministic evolution. Hence Loewer's approach does not run aground on the basic argument for incompatibilism at all, since at no time do the chances (and their indeterminism) conflict with the deterministic laws. It is true that Loewer himself and others have described this story as an account of deterministic chance. One is welcome to call it as such, yet it is so only in the sense that it neatly separates the chanciness of the theory from its determinism. Recall that a world is only a deterministic world, however, if *all* its laws are deterministic; otherwise it is an indeterministic world. A statistical mechanical world is therefore not deterministic; the initial chances of statistical mechanics (interpreted this way) imply that the world is indeterministic.

As said, this is a point on which Humeans and non-Humeans should agree, despite their differing ontological interpretations of laws and chances. Nevertheless, many Humeans are made uneasy by the idea of initial chances (Hoefer (2007); Frigg and Hoefer (2013) for example), especially the idea of an initial chance for the entire world. Insofar as they wish the chances of statistical mechanics to be ontic, however, they are necessarily committed to this view. Otherwise their probabilities will be purely epistemic, and they will then have to explain why such probabilities can play the roles that they usually play in statistical mechanics. There is no middle road.

Alas, I expect many will remain unconvinced by my characterization of Loewer's account as incompatibilist and my claim that statistical mechanics is indeterministic. Fortunately, the case can be made stronger, since the initial chance interpretation of the theory is not the only way to resolve the paradox of deterministic probabilities while preserving the ontic nature of the probabilities. Looking at these other resolutions makes it plain (as it may be made) that probabilistic physical theories like statistical mechanics are indeterministic (when the probabilities are interpreted ontically) and support incompatibilism.

A particular chance interpretation of statistical mechanics that resolves the paradox of deterministic probabilities depends merely on a choice of how to separate the deterministic and indeterministic parts of the theory. There are, as one might imagine, several possibilities. The initial chance version simply pushes all the indeterminism of the theory to one particular time. This version is perhaps appealing in our world, since the standard model of cosmology suggests that our universe had a beginning. Yet, just as there is no least positive number, there was no time when the universe came into existence, i.e. no earliest time. Supposing that there was only one chance event, the universe evolved deterministically before and after this event. This bi-directional evolution is admittedly somewhat paradoxical. Consider, then, that conceivably our universe could have existed eternally, in which case it would not make sense at all to talk of an initial time. In this case one might conceive that the chance event that selected a particular deterministic history is "outside of time", i.e. in the same way that one might conceive of the "Creator" selecting the possible universe to actualize (in accord with the appropriate probability measure associated with these possibilities, of course). A similar story should perhaps apply to a past finite universe like our own which did not begin at a particular time.

There are other alternative chance interpretations available though. The easiest place to find them is in interpretations of quantum mechanics, the quintessential chancy theory, as it has been the focus of much interpretative work in the last several decades. In quantum mechanics, Schrödinger's equation is deterministic, yet the popular view of quantum mechanics holds that quantum systems undergo "collapses", an indeterministic change in state. It is because of these collapses that the theory is thought to be indeterministic. Although these collapses are understood to happen during measurements (or periodically or even continuously in more sophisticated collapse interpretations)—that is, quite frequently—the basic idea of indeterministic changes of state, as understood in various interpretations of quantum mechanics, can be adapted to the kind of chanciness in statistical mechanics.

Indeed, appreciating these points suggests how alike statistical mechanics and quantum mechanics are with respect to this issue of probabilities and determinism. One might, for example, observe that the collapse interpre-

tations of quantum mechanics have statistical mechanical cousins, collectively known as "stochastic dynamics" interpretations (Maudlin, 2007). The laws on such accounts are partially or even fully indeterministic. Indeed, these stochastic dynamics interpretations are just other partitions of determinism and indeterminism (chance) in an indeterministic, probabilistic theory.

Consider next the Bohmian interpretation of quantum mechanics, according to which the initial state of a collection of quantum particles is probabilistically related to the quantum wave function in much the same way as the initial microscopic state of a statistical mechanical system is probabilistically related to its macrostate. The interpretations of probability are largely identical between the two. There is an initial chance event, after which the system (or world) evolves deterministically. The Bohmian interpretation is therefore closely analogous to Loewer's solution in statistical mechanics, and, hence, Bohmian mechanics is properly characterized as an indeterministic theory—despite popular claims to the contrary. Insofar as one takes quantum mechanics to be fundamental, then on any interpretation of quantum mechanics the theory is indeterministic.

Note that these initial chance interpretations of quantum mechanics and statistical mechanics are just a special case of the general class of chance interpretations: they merely locate all the chanciness of the theory at one time, viz. the initial time. Since it is obvious to all that collapse theories of quantum mechanics are indeterministic, it stands to reason that stochastic dynamics theories of statistical mechanics are indeterministic as well. Therefore, since the initial chance interpretation is a special kind of stochastic dynamics, it is indeterministic too.[4]

Therefore I conclude that the paradox of deterministic probabilities, which has been raised many times in the literature (Loewer, 2001; Winsberg, 2008; Lyon, 2011), is decisively resolved by properly understanding the notion of determinism and chance in physical theory. The probabilities of statistical mechanics, quantum mechanics, and other probabilistic theories can be interpreted as chances, but then the theories are not deterministic. They are indeterministic theories, albeit theories possessing both deterministic and indeterministic laws. To avoid inconsistency one must only cleanly separate the operation of the laws (although there are many possibilities for doing so). It is also possible to consider these theories as fully deterministic, but then their probabilities must be understood as epistemic—so as not to run afoul of the basic argument for incompatibilism.

[4]I imagine one might try to argue that an initial chance is different than chances at other times or recurring chances, but this is implausible. Whether a theory is indeterministic or not should not depend on whether the chance event is at some time or another (at a non-initial time or an initial time, for example).

4 Conclusion

I have argued for the thesis of incompatibilism: chances are incompatible with determinism. The basic argument for this claim is that chance entails indeterminism, and indeterminism is inconsistent with determinism. Chance and determinism are meant in an ontic sense, hence this is an entirely metaphysical thesis. Some compatibilists argue that the notion of chance is contextual in a way that makes it (potentially) compatible with determinism, but I argued that the other contexts they imagine are irrelevant to the thesis of incompatibilism. Some compatibilists argue that chances are relative to levels, but I argued that it is not possible to insulate the levels from the activity of chances on other levels, at least without giving up on a plausible metaphysics of relations between levels. I conclude that such general arguments to not undermine the basic argument for incompatibilism.

In the second part I turned to consider apparent cases of conflict between determinism and chance which have motivated compatibilists. I argued that these are resolved in most cases by understanding the relevant probabilities as objective epistemic probabilities—"counterfeit chances" as Lewis calls them. Physical theories, however, are often naturally understood to involve ontic probabilities, i.e. genuine chances, so the ostensible conflict between determinism and chance becomes more acute. I argued, however, that a proper understanding of the probabilities in these theories makes it clear that their presence makes the theories in question indeterministic, despite them involving some element of deterministic evolution. Only some of the laws of probabilistic physical theories may be deterministic; interpreters have incorrectly inferred that these theories are deterministic on the basis of only the deterministic subsets of their laws.

Appreciating the distinctions used here, i.e. between ontic and epistemic probabilities and between objective and subjective probabilities, suggests interesting directions of further work. Concerning ontic probabilities, the arguments made here suggest that it would be worthwhile to investigate more fully the different solutions of the paradox of deterministic probabilities and evaluate them. However, since so many of our probabilistic theories about the world are not fundamental, it is more pressing to inquire into the nature and justification of objective epistemic probabilities. Particularly crucial here is better understanding the seeming randomness of outcomes (Hoefer, 2007, 563) which leads us to conclude that it is as if they were chancy—I expect that explanatory considerations (not psychological ones) will be central to explicating this notion successfully.

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