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# WHO'S AFRAID OF *CETERIS-PARIBUS* LAWS? OR: HOW I LEARNED TO STOP WORRYING AND LOVE THEM

ABSTRACT. *Ceteris-paribus* clauses are nothing to worry about; a *ceteris-paribus* qualifier is not poisonously indeterminate in meaning. *Ceteris-paribus* laws teach us that a law need not be associated straightforwardly with a regularity in the manner demanded by regularity analyses of law and analyses of laws as relations among universals. This lesson enables us to understand the sense in which the laws of nature would have been no different under various counterfactual suppositions – a feature even of those laws that involve no *ceteris-paribus* qualification and are actually associated with exceptionless regularities. *Ceteris-paribus* generalizations of an 'inexact science' qualify as *laws* of that science in virtue of their distinctive relation to counterfactuals: they form a set that is *stable* for the purposes of that field. (Though an accident may possess tremendous resilience under counterfactual suppositions, the laws are sharply distinguished from the accidents in that the laws are collectively as resilient as they could logically possibly be.) The stability of an inexact science's laws may involve their remaining reliable even under certain counterfactual suppositions *violating* fundamental laws of physics. The *ceteris-paribus* laws of an inexact science may thus possess a kind of necessity *lacking* in the fundamental laws of physics. A nomological explanation supplied by an inexact science would then be irreducible to an explanation of the same phenomenon at the level of fundamental physics. Island biogeography is used to illustrate how a special science could be autonomous in this manner.

## 1.

*CP clauses are meaningful*

First things first. Defer the venerable problem of specifying the difference between claims expressing laws and claims expressing accidents. Consider just the *meaning* of a generalization qualified by "in the absence of disturbing factors", "other things being equal", "unless prevented", or something like that. The qualifier may simply list some factors and demand the absence of anything similar. For example:

> In the eighteenth-century British navy, only aristocrats were commissioned officers – unless the individual was the protégé of an aristocrat, or there was a case of fraud, or he distinguished himself in an especially gallant manner as a tar, or something like that.[1]

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Despite the qualifier's open-endedness, this claim is perfectly meaningful. It's easy to imagine what would constitute a counterexample to it and what would explain away an apparent exception. Let's elaborate this common idea (Scriven (1959), Molnar (1967), Rescher (1970), Hausman (1992)).

If a *ceteris-paribus* clause is meaningful, there is a tacit understanding of what makes a factor qualify as "disturbing" or as "like" the examples listed. Perhaps at the mere mention of any given factor, there would be immediate agreement on whether or not it qualifies as "disturbing". But this kind of unreflective unanimity is neither necessary nor sufficient for the *ceteris-paribus* clause to be meaningful. It's unnecessary because a consensus may develop only after the given factor is carefully compared to canonical examples of disturbing factors. (Or not even then.) There must, at any rate, be sufficient agreement on the relevant respects for comparison that analogies with canonical examples could supply a compelling reason for (or against) characterizing a given factor as "disturbing". Thus, when agents contemplate applying "All $F$'s are $G$, *ceteris paribus*" to a given $F$, they can justify their belief that the *ceteris-paribus* condition holds (or doesn't), and their justification for deeming a given factor "disturbing" doesn't depend on their first ascertaining whether the given $F$ is $G$.

*Unanimity on the violators of CP clauses is not necessary for their being meaningful*

Take the "law of definite proportions":

*The law of definite proportions contains a CP clause*

> Any chemical compound consists of elements in unvarying proportions by mass, *ceteris paribus*.

This qualifier could have been expressed as

> . . . unless the compound is like ruby or like polyoxyethylene or something like that.

To understand this qualifier, one must know at least some of the following (Christie 1994). Ruby is composed of aluminum, oxygen, and chromium, different samples differing by even a factor of 5 in their chromium per unit mass of oxygen. Aluminum atoms are bonded to oxygen atoms, which are bonded to one another, forming a network running through the solid. Randomly, chromium atoms replace aluminum atoms. (They are similar in size and bonding capacities.) Ruby is $(Al, Cr)_2O_3$; its proportions are indefinite. Polyoxyethylene, in contrast, is a long-chain molecule beginning with $CH_3$, ending with $CH_2OH$, and containing many $CH_2$—O—$CH_2$'s between. Because its length is variable, its proportions are indefinite; it is $CH_3(C_2H_4O)_nCH_2OH$.

*The meaning of that clause*

Considering this background, one could offer compelling reasons for characterizing (say) olivine ( $(Mg, Fe)_2SiO_4$) as *like* ruby and nylon as *like* polyoxyethylene. The *ceteris-paribus* clause has a determinate meaning. Likewise, indefinite proportions arising from the fact that different isotopes of the same element have different masses do *not* fall under *this* "*ceteris paribus*".

*"Something like that" is ineliminable in the CP clause*

Seemingly, we could reformulate the *ceteris-paribus* clause as

> unless the compound is a network solid or a polymer,

eliminating anything "vague". But the appearance of greater "explicitness" here is illusory. What is a network solid? It's something *like ruby* in the above respects. Once those respects have been grasped, no greater explicitness is achieved by replacing "like ruby" with "network solid".

*By making the clause more explicit we sacrifice accuracy*

Moreover, our new qualifier does not apply to exactly the same cases as our original one: not every case that is like ruby or like polyoxyethylene *or something like that* is clearly a network solid or a polymer. Take DNA. It fails to exhibit definite proportions since a DNA molecule's proportions depend on its length and its ratio of adenine-guanine to cytosine-thymine base-pairs. It isn't a network solid since it comes in discrete molecules. Yet DNA is like a network solid in one of its reasons for failing to exhibit definite proportions: certain subunits are able to replace others (of similar size and bonding capacities) randomly. (In DNA, however, those subunits are polyatomic.) Likewise, DNA is not a polymer, strictly speaking, since its "repeated" subunits are not all the same; there are two kinds, A-G's and C-T's, and there is no sequence they must follow. But DNA shares with polymers one reason for failing to exhibit definite proportions: a DNA molecule may be any length, and with greater length, a smaller fraction of its mass is contributed by endgroups.

A qualifier applying to exactly the same cases as the original one is

> . . . unless the compound is a network solid or a polymer *or something like that*.

But this doesn't avoid "vagueness".

*The "something like that" is required in the application of terms: their rules cannot be made fully explicit*

This doesn't show that there is no way to replace the original qualifier with something co-extensive yet "fully explicit". But in what sense would such an expression really *be* fully explicit? It would derive its content in just the way that the original qualifier did: by virtue of our implicit background understanding of what would count as compelling reasons for (or against) the correctness of applying it to a given case. There's nothing about how the "fully explicit" term *network solid* derives its meaning to distinguish it from the "vague terms"*ceteris paribus* and *like ruby* in the above examples.[2]

Earman and Roberts (1999) worry that if "in advance of testing" there is no statement of "what the content of a law is, without recourse to vague escape clauses", then there is no way to "guarantee that the tests are honest" because "the scientific community as a whole" could "capriciously and tacitly change what counts as an 'interfering factor' in order to accommodate the new data as they come in" (p. 451). But how does a claim *without* a "vague" *ceteris-paribus* clause supply the "guarantee" that Earman and Roberts crave? Even if the hypothesis is "explicit", there is never a *guarantee* that the scientific community will exercise good faith rather than tacitly re-interpret its hypothesis (and whatever statements of its meaning were issued in advance of testing it).[3] Suppose scientists originally make the definite proportions hypothesis "explicit" with the qualification

*Objection: CP clauses hinder testability*

*Reply: making clauses explicit does not by itself disallow a subsequent reinterpretation of terms (hence no gain in "honesty")*

> . . . unless the compound is a network solid or a polymer.

They then encounter DNA. There is nothing to *guarantee* that they won't unanimously, but incorrectly, say that DNA qualifies as a polymer in precisely the original sense.[4]

However, scientists *could* offer compelling reasons against the correctness of so classifying DNA: all of the canonical "polymers" so qualify because they involve many repeated (i.e., identical) small units, whereas DNA does not. This is *explicit enough* to resolve this case. The same kind of reasoning is available to determine a "vague" *ceteris-paribus* clause's applicability to a novel case. These examples are thereby distinguished from the twaddle that Earman and Roberts fear *ceteris-paribus* laws are in "danger" of becoming. For instance, suppose Jones says, "I can run a four-minute mile, *ceteris paribus*". He tries and fails. Were there no background for understanding the *ceteris-paribus* clause, there would be no basis for Jones to argue that it included "except on a muddy track". Suppose that Jones cashes out the qualifier as

*Nevertheless on a case-by-case basis such reinterpretations can be dismissed*

*And the same restrictions can be used for the CP clauses*

> . . . except on a muddy track, or when I have hurt my leg, or something like that.

Again he tries and fails to run a four-minute mile, and this time, the track is in good condition and he is healthy. Suppose Jones alleges that the race's having been held on the third Sunday in March is relevantly like the listed disturbing factors. Clearly, Jones now ascribes no determinate meaning to the qualifier.

Even when a given interpretation of a *ceteris-paribus* clause – such as "unless it involves many repeated (i.e., identical) small units" – is explicit enough for certain agents to determine the clause's applicability to one case, it may not be explicit enough for them to determine the clause's applicability to some other case. The ideas behind "identical" or "small" may require cashing out. This process will continue indefinitely as necessary, on a case-by-case basis. That should be considered "business as usual" rather than symptomatic of a poisonous vagueness.[5] Only the supposition that a "fully explicit", Platonic version of the definite proportions hypothesis exists would lead one to characterize such a *ceteris-paribus* clause as "lazy" (Earman and Roberts 1999, p. 461).[6]

*Hence the use of CP clauses is a legitimate part of scientific practice*

2.

So *ceteris-paribus* clauses are nothing to worry about. But why should we love them?

*Advantage of CP clauses: laws need only lead to good predictions*

One important lesson they teach us is that a law need not be associated straightforwardly with a regularity. It may be associated only with an inference rule that is 'reliable' – i.e., that leads to conclusions close enough to the truth for the intended purposes. To discover the law that all $F$'s are $G$, *ceteris paribus*, scientists obviously must understand what factors qualify as 'disturbing'. But they needn't identify *all* of the factors that can keep an $F$ from being $G$. They needn't know of factors that, when present, cause only negligible deviations from strict $G$-hood, or factors that, although capable of causing great departures from $G$-hood, arise with negligible frequency in the range of cases with which the scientists are concerned. Scientists need know only the factors that are non-negligible for the law's intended purposes: influences that arise sufficiently often, and can cause sufficiently great deviations from $G$-hood, that a policy of inferring $F$'s to be $G$, regardless of whether they are under those influences, would not be good enough for the relevant purposes. Factors that may cause an $F$ to depart from $G$-hood, but are negligible for the law's intended purposes, need not count as 'disturbing factors'. Hence, though it is a law that all $F$'s are $G$, *ceteris paribus*, it is not true that all $F$'s in the absence of disturbing factors are $G$.

*Scientists need to figure out only some of the disturbing factors*

*Example: Boyle's law*

When Boyle's law was discovered, for example, scientists must have understood its *ceteris-paribus* clause. But they did not know all of the factors that can cause gases to deviate from $PV = k$. They had not yet justified the kinetic-molecular theory of gases. They did not know that the forces exerted by gas molecules upon each other, the molecules' sizes, their adhesion to the container walls, the container's shape, and a host of other petty influences cause departures from $PV = k$. So in discovering that $PV = k$, *ceteris paribus*, scientists couldn't have discovered that $PV = k$ holds when the gas is 'ideal' in the above respects. Rather, the *ceteris-paribus* clause in Boyle's law covers the 'disturbing influences' recognized by scientists when discovering the law. It restricts the law's scope to relatively low pressures, high temperatures, and purposes tolerant of some inaccuracy. So qualified, $PV = k$ is good enough – *reliable*.[7] It "holds true for the 'permanent' gases under the experimental conditions usually employed in the common laboratory courses in physics, within the precision available in such experiments" (Loeb 1934, p. 140).

The *ceteris-paribus* clause has a pragmatic dimension, restricting the law's application to certain purposes. The $F$'s aren't all (*ceteris paribus*) $G$. In both of these respects, *ceteris-paribus* laws aren't associated with regularities in the straightforward manner demanded by regularity analyses of law *and* analyses of laws as relations among universals.

*So CP laws can be analyzed neither as regularities (as empiricists prefer; see Earman's article), nor as relations between universals (as realists prefer)*

This viewpoint is not new. Mill wrote:

> It may happen that the greater causes, those on which the principal part of the phenomena depends, are within the reach of observation and measurement .... But inasmuch as other, perhaps many other causes, separately insignificant in their effects, co-operate or conflict in many or in all cases with those greater causes, the effect, accordingly, presents more or less of aberration from what would be produced by the greater causes alone .... It is thus, for example, with the theory of the tides. No one doubts that Tidology ... is really a science. As much of the phenomena as depends on the attraction of the sun and moon ... may be foretold with certainty; and the far greater part of the phenomena depends on these causes. But circumstances of a local or casual nature, such as the configuration of the bottom of the ocean, the degree of confinement from shores, the direction of the wind, &c., influence in many or in all places the height and time of the tide .... General laws may be laid down respecting the tides; predictions may be founded on those laws, and the result will in the main ... correspond to the predictions. And this is, or ought to be meant by those who speak of sciences which are not *exact* sciences. (1961, 6.3.1, pp. 552–553)

*Mill's example of Tidology (discussed in sect. 4)*

One might cavil at honoring these *ceteris-paribus* generalizations with the exalted title "natural laws". (Mill (1961, 6.3.2, p. 554) said they "amount only to the lowest kind of empirical laws".) I could just shrug: what's in a name? But it would be better to clarify the reasons for regarding these *ceteris-paribus* generalizations as full-fledged laws. We must tackle the venerable question deferred at the outset: How do laws differ from accidents?

*Nothing prevents us from treating CP laws as "natural laws"*

*Transition to the distinction between laws and accidents*

## 3.

Focus not on some dubious metaphysical picture of what laws have got to *be* to deserve the honor, but rather on what laws *do* in science. The received wisdom identifies several functions distinctively performed by laws, including supporting counterfactuals, grounding explanations, and being inductively projected from observed instances. Alas, none of these

*Wrong grounds for the distinction mentioned* well-worn slogans suffices to pick out a role that no accident can play. Nevertheless, there is presumably some kernel of truth in these slogans, and they suggest that some *ceteris-paribus* generalizations can perform the roles characteristic of laws.[8] In a suitable context, Boyle's law supports the counterfactual, "Had the gas's pressure been half, its volume would have been double". The predictive accuracy of Boyle's law was confirmed by instances. We can use Boyle's law to explain why a certain gas's volume halved: we doubled the pressure on it.[9]

*CP generalisations can play the roles usually assigned to laws*

Let's get more specific about one of these roles. Laws supply reliable information on what the world would have been like had $p$ been the case, for any counterfactual supposition $p$ that is 'physically possible', i.e., logically consistent with every logical consequence of the laws.[10] In other words:

*How CP generalisations support counterfactuals*

> *Nomic Preservation (NP)*: The laws would have been no different had $p$ obtained, for any $p$ logically consistent with every physical necessity.

For example, had I missed my bus this morning, the natural laws would have been no different: I would have been unable to get to my destination by making a wish and clicking my heels. Routinely, the laws are used to extrapolate what would have resulted from different initial conditions.

Counterfactual suppositions are often entertained in 'non-backtracking' contexts: in the closest $p$-worlds, the course of events remains just as it actually was until about the moment with which $p$ is concerned, at which point history embarks on a different course (one that includes $p$). However, this change of course is disallowed by the actual laws if they are deterministic. (Let's suppose they are; this should make no difference to the laws' logical relation to counterfactuals.) Accordingly, David Lewis says that a small "miracle" (a violation of the actual laws) occurs in the closest $p$-world to make room for $p$ to hold. But if laws must correspond to exceptionless regularities, then this "miracle" runs counter to *NP*. Lewis therefore rejects *NP*. But I cannot countenance "Had I missed my bus this morning, the laws of nature would have been different"!

*Non-backtracking explained*

*Violations of laws are required to account for backtracking*

Elsewhere (Lange 2000, pp. 73–76), I have examined various options for reconciling *NP* with the demands of non-backtracking, I've argued that the correct option is to reject the assumption that every law of a given possible world corresponds to an exceptionless regularity there. Rather, "All $F$'s are $G$" can have exceptions in the closest $p$-world and still express a law there, so long as these violations fail to undermine the law's *reliability*. In the $p$-worlds that are optimally close in a non-backtracking context (where $p$ is 'physically possible': consistent with the reliability

*Since CP laws permit violations (as long as they remain useful in predictions), NP can be reconciled with backtracking* of the actual laws), any violation of an actual law remains 'offstage': the departure from "All $F$'s are $G$" is *negligible* because it occurs *before* the period of interest in the possible world's history. In a non-backtracking context, we don't care how $p$ managed to come about, only what difference $p$ would have made to subsequent events. For instance, in asking what the Earth would have been like today were there no moon (e.g., how the tides would have been different), we are not to consider how this moon-less state of affairs could have come about (e.g., whether the Earth would have been left with a stifling Venusian atmosphere had its $CO_2$ not been blown away in the cataclysmic impact creating the Moon).

This argument doesn't exploit the alleged peculiarities of *ceteris-paribus* clauses or special sciences. Even if there is a stratum of fundamental laws of physics corresponding to exceptionless regularities in the actual world, there must be an offstage exception to these laws in the closest $p$-world, although the laws are no different there. Such a law $m$ is still *reliable* in the closest $p$-world (since any departure from it is offstage, in a non-backtracking context), and so "had $p$ held, then $m$ would have held" is close enough to the truth for the relevant purposes. This argument should lessen any urge we may feel to dig in our heels and say (in reply to the argument in Section 2) that since certain $F$'s experiencing no 'disturbing factors' are nevertheless not $G$, it cannot be a law that all $F$'s are $G$, *ceteris paribus*. The exceptions, like the offstage miracles, may be negligible for the intended purposes.

Let's turn this point around. In revealing that a law need not be true so long as it is reliable, *ceteris-paribus* laws point us toward the solution to a puzzle about all laws, even those without *ceteris-paribus* qualifiers: How do the actual laws remain laws under counterfactual suppositions considered in non-backtracking contexts? That's one reason I love *ceteris-paribus* laws.

## 4.

The best way to see that certain *ceteris-paribus* generalizations should be considered "laws" is by getting clearer on the laws' distinctive scientific roles and then observing that certain *ceteris-paribus* generalizations play those roles, especially in sciences like Mill's "Tidology". Let's pursue this strategy in connection with laws' capacity to support counterfactuals.

*We will show that CP generalisations can play the role of laws in concrete scientific practices*

Is the range of counterfactual suppositions under which an accident would still have held *narrower* than the range under which a law would still have held? No. Suppose a large number of electrical wires, all made of copper, have been laid out on a table. Had copper been electrically insu-

*An example to show that accidental generalisations can be less fragile than laws (in counterfactual circumstances)* lating, then the wires on the table would have been useless for conducting electricity. Look what just happened: the law that all copper is electrically conductive obviously wouldn't still have held had copper been electrically insulating. But (in the envisioned conversational context) this counterfactual supposition fails to undermine the accident that all of the wires on the table are made of copper. So the range of counterfactual suppositions under which an accident is preserved can in some respects extend beyond the range under which a law is preserved.

Seemingly, then, there is no sharp distinction between laws and accidents in their power to support counterfactuals: some accidents are more fragile, other more resilient under certain sorts of counterfactual suppositions, and while laws are quite resilient, there is no sense in which they are more resilient than accidents. However, I think that adherents to this increasingly popular view are giving up too easily. A sharp distinction *can* be drawn here between physical necessities and accidents.

*But we should still be able to draw the distinction between accidents and laws*

To begin with, many philosophers have endorsed something along the lines of *NP*: that the laws would still have held under any counterfactual supposition logically consistent with the laws. No accident is always preserved under all of these suppositions. But *NP* doesn't justify attributing to the physical necessities especially great counterfactual-supporting powers. That's because the *range* of counterfactual suppositions under consideration in *NP* has been designed expressly to suit the physical necessities. Suppose again that it is an accident that all of the wires on the table are copper. This accident's negation is physically possible, and so the accident is obviously not preserved under all physically possible suppositions. So it is *trivial* that no accident's range of invariance includes every counterfactual supposition logically consistent with the physical necessities.

*This discussion gets a bit too complex...*

What if we allow a set containing accidents to pick out a range of counterfactual suppositions especially convenient to itself: those suppositions logically consistent with every member of that set? Take a logically closed set of truths that includes the accident that all of the wires on the table are copper but omits the accident that all of the pears on my tree are ripe. Here's a counterfactual supposition consistent with every member of this set: had either some wire on the table *not* been made of copper or some pear on the tree *not* been ripe. What would the world then have been like? It is not the case (in many conversational contexts) that the generalization about the wires would still have held. (Indeed, in many contexts, it is the case for neither generalization that it would still have held.)

The same sort of argument could presumably be made regarding any logically closed set of truths that includes *some* accidents but not *all* of them. Given the opportunity to pick out the range of counterfactual suppositions convenient to itself, the set nevertheless isn't resilient under all of those suppositions. Trivially, every member of the set of *all* truths would still have held under any counterfactual supposition logically consistent with all of them, since *no* counterfactual supposition is so consistent.

Here, then, is my preliminary suggestion for the laws' distinctive relation to counterfactuals. Take a logically closed set of truths. (Truths – so as yet, I have left no room for *ceteris-paribus* laws. Stay tuned.) Take the counterfactual suppositions *p* that are logically consistent with every member of the set. Call the set *stable* exactly when for every member *m* of the set, *m* is reliable in the closest *p*-world(s): any departure there from *m* is negligible for the purposes for which this counterfactual world is being discussed (as I explained in connection with non-backtracking contexts, for example). So "had *p* held, then *m* would have held" is correct.

According to *NP*, the set of all physical necessities is stable. As I just argued, no set containing an accident is stable, except for the set of all truths, which is trivially so. What makes the physical necessities special is that *taken as a set*, they are resilient under as broad a range of counterfactual suppositions as they *could* logically possibly be: *all* of the physical necessities would still have held under *every* counterfactual supposition under which they *could all* still have held. No set containing an accidental truth can make that boast non-trivially (Lange 1999, 2000).

The logical necessities and the set of all truths are trivially stable. The set of physical necessities is stable non-trivially. Because it is as resilient as it could be, there is a sense of necessity corresponding to it. No sense of necessity corresponds to an accident, even one that would still have held under many counterfactual suppositions. The notion of 'stability' gives us a way out of the circle that results from specifying the physical necessities as the truths that would still have held under certain counterfactual suppositions: those consistent with the physical necessities.

*The laws of inexact sciences: criterion of stability*

How should this framework be applied to an "inexact science" like Mill's Tidology? What would it take for there to be laws of some such science – *ceteris-paribus* laws reflecting only "the greater causes"? We need to add two ingredients to our framework. First, we must permit a stable set to include not only truths, but also 'reliables' such as Boyle's law (for certain purposes).[11] Second, we must recognize that an inexact science's concerns are limited. A set is stable *for the purposes of a given inexact science* if and only if it is invariant under every counterfactual supposition of interest to the science and consistent with the set.

*The case of island biogeography*

Take island biogeography, for example, which deals with the abundance, distribution, and evolution of species living on separated patches of habitat. It has been suggested that *ceteris paribus*, the equilibrium number

$S$ of species of a given taxonomic group on an 'island' (as far as creatures of that group are concerned) increases exponentially with the island's area $A$: $S = cA^z$. The (positive-valued) constants $c$ and $z$ are specific to the taxonomic group and island group – Indonesian land birds or Antillean beetles. One theory (the "equilibrium theory of island biogeography" developed by Robert MacArthur and E. O. Wilson) purporting to explain this "area law" is roughly that a larger island tends to have larger available habitats for its species, so it can support larger populations of them, making chance extinctions less likely. Larger islands also present larger targets for stray creatures. Therefore, larger islands have larger immigration rates and lower extinction rates, and so tend to equilibrate at higher biodiversity. Nevertheless, a smaller island nearer the 'mainland' may have greater biodiversity than a larger island farther away. This factor is covered by the "*ceteris paribus*" qualifier to the "area law". Likewise, a smaller island with greater habitat heterogeneity may support greater biodiversity than a larger, more homogeneous island. This factor is also covered by "*ceteris paribus*". And there are others. Nevertheless, to discover the "area law", ecologists did not need to identify *every* factor that may cause deviations from $S = cA^z$, only the "greater causes". Like Boyle's law, the area law is intended to yield predictions good enough for certain sorts of applications, theoretical and practical, from planning nature reserves to serving as the first step in constructing divers ecological models.

*The meaning of the equation*

*The CP clauses involved*

Assume (for the sake of argument) that the "area law" is indeed accurate enough for these purposes (Figure 1). What must its range of invariance be for it to count as a law of island biogeography? There are counterfactual suppositions under which the fundamental laws of physics would still have held, but under which the "area law" is not preserved. For example, had Earth lacked a magnetic field, then cosmic rays would have bombarded all latitudes, which might well have prevented life from arising, in which case $S$ would have been zero irrespective of $A$. Here's another counterfactual supposition: Had evolutionary history proceeded differently so that many species developed with the sorts of flight, orientation, and navigation capacities possessed by actual airplanes. (This supposition, albeit rather outlandish, is nevertheless consistent with the fundamental laws of physics since airplanes exist.) Under this supposition, the "area law" might not still have held, since an island's size as a target for stray creatures might then have made little difference to its immigration rate.[12] (Creatures without the elaborate organs could have hitched rides on those so equipped.)

*Stability is preserved, since the range of concerns of a particular inexact science is limited*

Unlike the fundamental laws of physics, generalizations from inexact sciences aren't preserved under every counterfactual supposition consistent with the fundamental laws of physics. Accordingly, it has sometimes

*We cannot reject the laws of inexact science merely because they are not fundamental laws of physics*

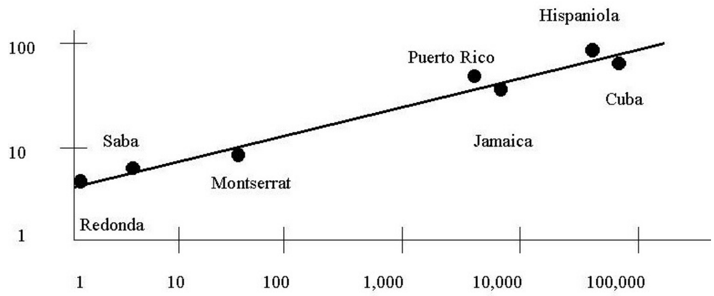


*Figure 1.* The area (in square miles) of various islands in the West Indies is depicted on the $x$-axis. The number of amphibian and reptilian species on each island is depicted on the $y$-axis (MacArthur 1972, p. 104).

been concluded that generalizations from inexact sciences fail to qualify as natural laws. But this argument presupposes that a law *of* (say) *island biogeography* would have to withstand the very same range of counterfactual perturbations as a fundamental law of physics. In an argument against the possibility of laws in sciences other than fundamental physics, this presuppositions amounts to begging the question.

The area law is not prevented from qualifying as an island-biogeographical law – from belonging to a set that is stable for the purposes of island biogeography – by its failure to be preserved under the two counterfactual suppositions I just mentioned, although each is consistent with the fundamental laws of physics. The supposition concerning Earth's magnetic field falls outside of island biogeography's range of interests. It twiddles with a parameter that island biogeography takes no notice of or, at least, does not take as a variable. Of course, biogeographers draw on geology, especially paleoclimatology and plate techtonics. Magnetic reversals are crucial evidence for continental drift. But this does not demand that biogeography be concerned with how species would have been distributed had Earth's basic physical constitution been different. Biogeographers are interested in how species would have been distributed had (say) Gonwanaland not broken up, and in how Montserrat's biodiversity would have been affected had the island been (say) half as large. On the other hand, biogeography is not responsible for determining how species would have been distributed had Earth failed to have had the Moon knocked out of it by a cataclysm early in its history. Biogeographers do not need to be geophysicists.

*Further elaborations of the same claim*

The counterfactual supposition positing many species capable of covering long distances over unfamiliar terrain nearly as safely as short ones over familiar territory is logically inconsistent with other generalizations that would join the "area law" in forming a set stable for the purposes of island biogeography. For example, the "distance law" says that *ceteris paribus*, islands farther from the mainland equilibrate at lower biodiversity levels. Underlying both the area and distance laws are various constraints: that creatures travel along continuous paths, that the difficulty of crossing a gap increases smoothly with its size (*ceteris paribus*), that creatures (apart from human beings) lack the organs, technology, culture, and background knowledge to make orientation and navigation virtually flawless, and so forth. These constraints must join the area and distance laws in the set stable for island-biogeographical purposes.[13]

The area law's *ceteris-paribus* clause does not need to rule out exceptions to these constraints. Although it isn't the case that the area law would still have held, had these constraints been violated, the area law's range of invariance may suffice for it to qualify as a law of island biogeography because *other* island-biogeographical laws, expressing these constraints, make violations of these constraints physically impossible (as far as island biogeography is concerned). Here's an analogy. Take the Lorentz force law: In magnetic field $B$, a point body with electric charge $q$ and velocity $v$ feels a magnetic force $F = (q/c)v \times B$. Presumably, it isn't the case that this law would still have held had bodies been able to be accelerated beyond $c$. But this law requires no proviso limiting its application to cases where bodies fail to be accelerated beyond $c$. That's not because there are actually no superluminal accelerations, since a law must hold not merely of the actual world, but also of certain possible worlds. The proviso is unnecessary because *other* laws of physics deem superluminal acceleration to be physically impossible. Hence, the Lorentz force law can belong to a stable set – can have the range of invariance demanded of a law of physics – without being preserved under counterfactual suppositions positing superluminal accelerations.

There may actually be *no* laws of island biogeography. Perhaps only a case-by-case approach makes approximately accurate predictions regarding island biodiversity. Perhaps there aren't just a few "greater causes", but many significant influences: weather and current patterns, the archipelago's arrangement, the island's shape, differences between island and mainland conditions, the character of mainland species, an island's habitat heterogeneity, different potential source areas and colonization capacities for different species, the presence on the island of competitors with and predators and parasites on potential colonists, and various idiosyncracies (such as the choices made by individual creatures and rare storms promoting immigration of species with low dispersal capacities). It's an open *scientific* question whether there are island-biogeographical laws. I

*The question is not about the actual existence of the laws of a particular science, but about understanding its autonomy (i.e. being governed by its own laws)* want to understand what this issue *is about* – what it would take for such a science to have its own set of (*ceteris-paribus*) laws: to be *autonomous.*

A set stable for island-biogeographical purposes needn't include all of the fundamental laws of physics. The *gross* features of the laws of physics captured by constraints like those I've mentioned, along with the other island-biogeographical laws and the field's interests, may suffice *without the fundamental laws of physics* to limit the relevant range of counterfactual suppositions. For instance, had the geographic ranges of species been originally set and ever since maintained by miraculous Divine intervention, the "area law" might not still have held. But a set doesn't need to include the laws of physics in order to put this counterfactual supposition outside the range over which the set must be invariant in order to qualify as stable for island-biogeographical purposes. This supposition already falls outside that range in virtue of falling outside island-biogeographical concerns, which are limited to the *evolutionary* tendencies of island species. (Likewise for the supposition of deliberate human intervention.)

Similarly, the area law would still have held had there been birds equipped with organs weakening gravity's pull somewhat, assisting in takeoffs. The factors affecting species dispersal would have been unchanged: smaller islands would still have presented smaller targets to off-course birds and so accumulated fewer strays, *ceteris paribus*. The island-biogeographical laws's range of stability may thus in places extend beyond the range of stability of the fundamental laws of physics; the island-biogeographical laws don't reflect every *detail* of the physical laws.

*The stability of CP laws of inexact science (island biogeography) does not coincide with the stability of physical laws; hence its lawhood is understood differently than the lawhood of physics*

The island-biogeographical laws's necessity derives from their range of stability. But that range is not wholly contained within the fundamental physical laws's range of stability (since it includes some suppositions inconsistent with the physical laws). Consequently, the physical laws's stability is not responsible for the island-biogeographical laws's stability. In other words, the island-biogeographical laws do not inherit their *necessity* from the fundamental laws of physics. The island-biogeographical laws's necessity is not borne by the fundamental physical laws; the range of stability of the island-biogeographical laws extends in some respects beyond (though, in other respects, is more limited than) that of the fundamental physical laws. The approximate *truth* of island-biogeographical laws might follow from the laws of physics and certain accidents of physics. But the *lawhood* of island-biogeographical laws – their stability (for the field's purposes) – cannot so follow. For that stability depends on their remaining reliable under certain counterfactual suppositions violating fundamental physical laws.

Hence, if there turned out to be island-biogeographical laws, island biogeography would have an important kind of autonomy. Because the lawhood of island-biogeographical laws would be irreducible to the lawhood of the fundamental laws of physics (and initial conditions), the nomological explanations supplied by island biogeography (of, for instance, Mauritius's biodiversity) would be irreducible to the explanations of the same phenomena at the level of fundamental physics (Lange 2000, Chap. 8).

*The reductive failure is occasioned by CP laws*

That's pretty cool. It's another reason to love *ceteris-paribus* laws.

NOTES

[1] See Rescher (1970, p. 173).

[2] Of course, 'network solid' has a context-independent meaning whereas different tokens of '*ceteris paribus*' (and 'like ruby') may mean different things depending on the generalizations to which they are attached.

[3] Consider the arguments that in December 2000, the Florida Supreme Court changed rather than re-interpreted election laws.

[4] Thus, unreflective unanimity doesn't ensure that '*ceteris paribus*' has determinate meaning, just as Earman and Roberts (1999, p. 451) say.

[5] There may even be disagreement over whether some expression is explicit enough for the relevant agents to be able to give *reasons* for or against its application to various cases. For example, while five U.S. Supreme Court justices held in December 2000 that the 'intent of the voter' standard is not sufficiently explicit for ballot counters, Justice Stevens dissented, contending that it is no less vague than the customary 'beyond a reasonable doubt'.

Wittgenstein's rule-following point, which motivates my argument (Lange 1993, 2000), applies to *any* meaningful remark (descriptive claim, rule, whatever) – contrary to Earman and Roberts (1999, pp. 449–450).

[6] Earman and Roberts distinguish this "lazy" sense from the "improper" sense of the '*ceteris paribus*' allegedly attached to (say) Coulomb's law. They see this law as requiring no qualification because it relates two bodies' charges and separation to the *component* electric forces they exert upon each other (1999, p. 461). Earman and Roberts

> do not understand how anything short of a blanket anti-realism can motivate the notion that [a] component of a total impressed force is unreal. . . . [M]odern physical theory from Newton onward gives two reasons to take certain component forces as having real ontological significance: first, the theory gives an account of how the component force arises from the distribution of sources (masses for the gravitational force, charges for the electrical force, etc.); and it promotes a form of explanation in which the total resultant force is obtained as a vector sum of the component forces that are due to sources. (p. 474)

Apparently, they argue that component forces are real because they are causal actors: the local causes of the net acceleration of the body feeling them, the effects ultimately of distant electric charges etc. Presumably, the picture endorsed by Earman and Roberts says that for each real component electric force acting on a body, there is a distant charge whose electric field causes exactly that component force. But this view leads to a problem. Classically, reality is ascribed to the electric field $E$ (i.e., the net = total = resultant field) in virtue of its possessing energy with a density proportional to $E^2$. (See Lange 2002, Chap. 5.) But the individual electric fields $E_i$ of various bodies cannot themselves each possess energy with a density proportional to $E_i^2$, else there would be the wrong total quantity of field energy. (That's because $[E_1 + E_2 + \cdots]^2$ doesn't generally equal $E_1^2 + E_2^2 + \cdots$.) Thus, the classical argument for the net field's reality doesn't carry over to its components' reality. So there's reason short of blanket anti-realism for interpreting the component forces (associated with these component fields) as unreal. (Also see Lange 2000, pp. 164–165.)

I've *not* followed Cartwright and Giere in characterizing as a ceteris-paribus law a claim (e.g., Coulomb's law) purportedly describing the action of a single influence. I've argued (Lange 2000, pp. 180–183) that a law like Coulomb's requires no provisos ruling out the presence of other forces. I *have* characterized as *ceteris-paribus* laws various claims (such as Boyle's law) that aim to characterize the *net* outcome of *all* the (non-negligible) influences. I had regarded the 'law of thermal expansion' as a law of the latter kind. If it is actually a law of the former kind (as Earman, Roberts, and Smith say), then it is not an example that serves my purposes.

7 Compare Earman and Roberts (1999, p. 463).

8 Compare Rescher (1970, pp. 170–171). See my (2000).

9 A general account of confirmation and explanation would identify what it is about Boyle's law (its relation to counterfactuals? to unification? to causal powers?) that makes it explanatory.

10 I restrict myself throughout to counterfactual suppositions (and logical consequences of the laws) that do not include expressions like 'law' and 'accident'. For details relevant to this section and the next, see my (2000).

11 Accordingly, we must expand the notions of a 'logically closed set' and $p$'s being 'consistent with every member of the set'. For example, $p$'s consistency with $m$ requires only that $p$ be consistent with $m$'s *reliability*: the claims to which we would be entitled, by reasoning from $p$ in accordance with the inference rule associated with $m$, could all be close enough to the truth for the relevant purposes. Also, I'm assuming that each of the set's members is of interest to the field, so that its reliability for the field's purposes is non-trivial. See my (2000, Chap. 8).

12 Suppose the 'target effect' to be so significant that without it, the species-area relation would have violated $S = cA^z$.

13 See MacArthur (1972, pp. 59–60) on 'continuity principles'.

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