

## THE COST OF CLOSURE: LOGICAL REALISM, ANTI-EXCEPTIONALISM, AND THEORETICAL EQUIVALENCE

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**ABSTRACT:** It is commonly assumed by philosophers of science that logically equivalent theories are in fact theoretically equivalent. I argue that two theses, anti-exceptionalism about logic (which says, roughly, that logic is not *a priori*, that it is revisable, and that it is not special or set apart from other human inquiry) and logical realism (which says, roughly, that differences in logic reflect genuine metaphysical differences in the world), make trouble for both this commitment and the closely related commitment to theories being closed under logical consequence. I provide three arguments. The first two show that anti-exceptionalism about logic provides an epistemic challenge to both the closure and the equivalence claims; the third shows that logical realism provides a metaphysical challenge to both the closure and the equivalence claims. Along the way, I show that there are important methodological upshots for metaphysicians and philosophers of logic. In particular, there are lessons to be drawn about certain conceptions of naturalism as constraining the possibilities for metaphysics and the philosophy of logic.

### INTRODUCTION

I am interested in how two theses about logic interact with a question in the philosophy of (and, at least on some understandings, the metaphysics of) science. The first thesis is *anti-exceptionalism* about logic, which (very) roughly says that logic lacks at least some of the following properties: we can know about it *a priori*; its truths are analytic; inquiry into it is “special” in some way, set apart from other human inquiry; and logic is not revisable. The second thesis is *logical realism*, which is (again roughly) the thesis that differences in logic directly reflect genuine metaphysical differences in the world.<sup>1</sup>

I find both theses plausible, and they interact with each other in important ways. Logical realism may be difficult to make sense of on certain exceptionalist pictures of logic (for example, if one thinks that all logical truths are analytic, one may also be committed to a picture of analyticity on which the world cannot, by definition, make a contribution to logical truths). And anti-exceptionalists may need to take logical realism seriously as an epistemic possibility, since their epistemology of logic is both difficult, and must involve an openness to asking and answering wide-ranging questions, including those about the metaphysics of logic.

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<sup>1</sup> Thanks for helpful discussion on a distant ancestor of the ideas in this paper to Hans Halvorson (and many others!) and an audience at the Workshop on the Logic of Totality in Glasgow, 2017, and for helpful discussion of this paper to the Melbourne Logic Seminar, 2021. Thanks also to Katrina Elliott and Jill North for important background discussion, as well as two anonymous referees for this journal for helpful and constructive comments.

My goal here, however, is not to motivate the connections between anti-exceptionalism and logical realism. Instead, I will argue that anti-exceptionalism and logical realism provide important insights into a debate in the philosophy of science over *theoretical equivalence*. What this question of theoretical equivalence amounts to is difficult to spell out. This metaphysician would like to characterize it as the question of when differences in theories reflect genuine differences in actual metaphysical commitments of those theories. (But I suspect that some philosophers of science would disagree that equivalence has much to do with metaphysical commitment at all; more on this in section one.) Many contemporary philosophers of science working on equivalence seem to take logical equivalence to entail theoretical equivalence.<sup>2</sup> And an intimately related commitment can be seen in syntactic conceptions of what scientific theories are; it is part and parcel of the syntactic conception of theories that theories are closed under logical consequence.

For ease of discussion, I'll refer to the claim that theories are closed under logical consequences as CLOSURE; I'll refer to the claim that logical equivalence entails theoretical equivalence as EQUIVALENCE ENTAILMENT.

Anti-exceptionalism and logical realism provide the bases for arguments that CLOSURE is a mistake, and thus, perhaps more relevantly for contemporary philosophy of science, that EQUIVALENCE ENTAILMENT is also a mistake. And while it might already seem that we are deep in the philosophical weeds, these arguments matter for at least two reasons: first, they show that philosophers of science who endorse EQUIVALENCE ENTAILMENT are obscuring important epistemic and metaphysical questions about reality. While those questions arguably belong to the fields of metaphysics and the philosophy of logic, not the philosophy of science, it is crucial that philosophers of science not conceive of equivalence in such a way that precludes metaphysicians and philosophers of logic with naturalistic commitments from asking them. Many contemporary metaphysicians exhibit an attitude of deference to what philosophers of science tell us about the status of science. So while an attitude of *silence* or non-commitment on the metaphysics and epistemology of logic is perhaps justified in the philosophy of science, the idea that philosophers of

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<sup>2</sup> A (quite incomplete) set of examples: Quine (1975), who I will discuss momentarily; Barrett and Halvorson (2016a, 2017); Glymour (1970, 1977); Halvorson (2012, 2019); Teh and Tsementzis (2017); Weatherall (2016, 2017); and for summary and discussion of recent views, Weatherall (2019a, 2019b). Those who might reject this (in almost every case due to objecting to purely formal accounts of equivalence in the first place) include Bradley (2019), Butterfield (forthcoming) (who explicitly argues against EQUIVALENCE ENTAILMENT), North (2009, forthcoming); Ruetsche (2011), Van Fraassen (2014). Metaphysicians like McSweeney (2016, also see her 2019a for related issues), Miller (2005a, 2005b, 2017), and Sider (2011, 2020, ch. 5) also are not committed to it (or rather: their accounts of equivalence do not have EQUIVALENCE ENTAILMENT baked in), though as we will be clear later, metaphysicians and (some) philosophers of science may be talking past each other on this issue.

science could settle questions in the metaphysics and epistemology of logic—and indeed, do so without much in the way of argumentation, or explicit philosophical attention, but rather with a (typically not explicitly justified, and often implicit) commitment of their own accounts of theoretical equivalence, or of what a scientific theory is—seems wrong-headed to me. At least, it seems wrong-headed if anti-exceptionalism is true, or if logical realism is a live possibility.

Second, on some understandings of what anti-exceptionalism is, it seems likely that science, scientific data, and the philosophy of science themselves can and should contribute to the investigation of logic itself. After all, some anti-exceptionalists claim that logic is perfectly general, but also that the methodology of logic must be continuous with general inquiry. Science is an important source of information about the world, and the philosophy of science can give (those of us with realist commitments) key insights into what science does and does not tell us about how the world is. But if philosophers of science simply assume that logical equivalence entails theoretical equivalence, and if theoretical equivalence has something to do with the actual metaphysical commitments of a theory, then they are stripping themselves of this power: they seem to be silencing themselves about insights into logic that might be mined from scientific inquiry and theorizing.<sup>3</sup>

Here is the plan for the paper. In §1, I briefly lay out philosophers of science' commitment to both CLOSURE and EQUIVALENCE ENTAILMENT. In §2, I introduce logical anti-exceptionalism, and then argue that anti-exceptionalists should resist both CLOSURE and EQUIVALENCE ENTAILMENT when it comes to scientific theories. In §3, I introduce logical realism, and then briefly motivate the idea that anti-exceptionalists should be open to it (even if they would hedge their bets against it). In §4, I argue that even the possibility of the truth of logical realism makes trouble for CLOSURE and EQUIVALENCE ENTAILMENT. I conclude by making some brief remarks about where all this leaves us in §5.

## 1. EQUIVALENCE (AND CLOSURE)

Most accounts of theoretical equivalence in science are committed to the idea that scientific theories *are* closed under logical consequence. But most of these accounts come from philosophers who are

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<sup>3</sup> Putnam's (in)famous (1968) case for adopting quantum logic, partly on the basis of considerations from physics, comes to mind here.

at least suspicious of “hardcore” metaphysical realism. But even hardcore metaphysicians like Theodore Sider, seem at least in places to be committed to the idea that whatever theoretical equivalence is, sentences like ‘A’ and ‘A & A’ *must* be equivalent, even if they are meaning-wise inequivalent (Sider 2020, 181-182).<sup>4</sup>

Rarely do we see EQUIVALENCE ENTAILMENT made explicit. However, it is implicit in most of the going accounts of equivalence, because they all have a much more permissive standard of equivalence than mere logical equivalence. Thus logically equivalent theories are treated as simply equivalent by many contemporary philosophers of science. There are two exceptions that are particularly notable for my purposes. First, Jeremy Butterfield (forthcoming) argues for a similar conclusion to the one I argue for here: we should reject EQUIVALENCE ENTAILMENT. His reasons, however, are (quite) distinct from mine: he provides an argument that dual theories can be formalized as logically equivalent, but are clearly not actually equivalent on either an ordinary or standard philosophical understanding of what equivalence is. I am entirely sympathetic to his argument. One way of conceiving of the way in which our arguments are distinct is to note that the considerations I will raise against EQUIVALENCE ENTAILMENT are in a sense *extra-scientific* considerations; they have little to do with actual science itself. In contrast, Butterfield’s argument takes scientific considerations and shows that they might be formalized in a way that seems to provide a counterexample to the entailment claim. So while Butterfield’s argument does involve an appeal to the philosophy of logic, it is quite a different one from mine. (And indeed while I’m sympathetic to Butterfield’s arguments, I’d be (pleasantly) surprised if he were sympathetic to mine.) The second exception is Jill North (forthcoming), whose view I will discuss momentarily.<sup>5</sup>

But Butterfield and North are exceptions, not representatives. Thomas Barrett and Hans Halvorson, for example, say (my emphasis):

Although we have the notion of logical equivalence, one might want other criteria for theoretical equivalence. Logical equivalence is *too strict* to capture the sense in which some theories are equivalent. Indeed, as remarked above, theories can be logically equivalent only if they are formulated in the same signature. And there are

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<sup>4</sup> This is perhaps misleading, though, since Sider is not committed to the idea that logical equivalence entails theoretical equivalence.

<sup>5</sup> John Wigglesworth (2017) and Jack Woods (2018) both directly address a related, but actually distinct, question about the relationship between theoretical equivalence and anti-exceptionalism. Whereas I am concerned with what general stance about theoretical equivalence between *scientific* theories anti-exceptionalists should take, Wigglesworth and Woods are concerned about what anti-exceptionalists should think about the nature of and equivalence of *logical* theories themselves.

many theories in different signatures that are nonetheless equivalent in some sense (2016, p. 468).

That anti-exceptionalism about logic might make trouble for commitments to CLOSURE and EQUIVALENCE ENTAILMENT may be surprising, since Quine (whom many consider the original source of anti-exceptionalism) himself makes both commitments explicitly, and indeed in some ways seems to be one of the sources of contemporary commitments to EQUIVALENCE ENTAILMENT:

Currently the theory itself, then, is often identified with an infinite set of sentences, namely, the logical consequences of the theory formulation. Such has usually been my own usage. A single theory, in this sense, admits of many formulations; all that is required is that they be logically equivalent. (318)... It is usual in the literature to require of a theory that it be deductively closed. In our present terms, what this means is that if you change a formulation of a theory merely by annexing some logical consequences of that formulation, the result will still be a formulation of the same theory. We have insured this by requiring only that the reconstrual of predicates render the formulations logically equivalent, not identical. Thanks to the circumstances that any formulation is equivalent to itself plus any of its consequences, it is easily shown that theories as I have defined them are deductively closed (1975, p. 318 and 321).

Quine goes on, however, to note that there is a broader notion of a ‘theory’ that this commitment to closure cannot capture. And yet, he explicitly sets aside the very concerns of this paper, instead working in a framework that holds the language—and the logic—fixed. (Though I note that the third argument I will make motivates the rejection of CLOSURE *even holding* the language (and logic) fixed—but it is an argument that Quine would have rejected.) Indeed, his rejection of the above characterization of theories is that it provides us with a notion of equivalence that is too *weak*, not too strong. (319).<sup>6</sup> While I take myself to be an anti-exceptionalist, and anti-exceptionalists are perhaps inspired by Quine, I think it’s likely that Quine would have rejected all three of the arguments I will make here (considering, for example, his remarks about deviant logicians changing the *subject* and not the *doctrine* (1970 p. 82-83)).<sup>7</sup>

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<sup>6</sup> Sider (2020, p. 178-80) gives a fuller account of the complexities (and issues with) Quine’s account.

<sup>7</sup> The tension between certain ways of understanding anti-exceptionalism about logic and Quine’s commitments in his 1975 paper and 1970 book may just be an instance of the tension Dummett (1974) notes between, on the one hand, Quine’s rejection of the analytic-synthetic distinction and, on the other, his “center-periphery” model of the web of belief. For discussion and an interesting resolution, see Sher (1999). To be clear, though, Quine interpretation is very far from my goal here, nor am I qualified to engage in it.

Why should we care about theoretical equivalence at all, and by extension closure? One answer comes to us from Halvorson (2020, p. 16 and ch. 8.4): he claims that positions about theoretical equivalence can be used to make sharper distinctions between various forms of scientific realism and anti-realism. Indeed, insofar as we think theoretical equivalence is an important topic worthy of attention from philosophers of science and metaphysicians, I assume that we do so *because* we take it to be equivalence, full stop—the reason that theoretical equivalence is an important topic is that tells us when two theories make the same commitments about the world, and thus, tells us when apparent distinctions between theories are in fact merely notational, or not tracking real worldly differences. Thus questions of equivalence might be taken to be paradigmatically “heavyweight” questions about the commitments of theories.

However, things are not this simple. North (forthcoming, ch. 7) disentangles a notion of structural or formal equivalence (and, later, of ‘informational’ equivalence) from one of *metaphysical* equivalence. In so doing, she makes clear that structural or formal equivalence is not sufficient for metaphysical equivalence. For example: North compares Einstein’s theory of special relativity and Lorentz’ ether theory. We need not go into any details here but the following: “where Einstein’s theory does away with absolute simultaneity, Lorentz’s theory posits an ether, whose absolute state of rest corresponds to an absolute simultaneity structure that picks out a preferred simultaneity frame” (North, forthcoming, p. 199); Clara Bradley (2019) also uses this case to motivate rejecting formal accounts of equivalence). There is an important sense in which Einstein and Lorentz’ theories are *formally* or *structurally* equivalent, but they are (very obviously) not metaphysically equivalent—indeed, they are plausibly not *physically* equivalent: one posits ether, the other does not. There is, as North emphasizes, more to a theory than its formalism. And yet most of the accounts of equivalence in the recent literature are accounts of formal equivalence (or partially formal equivalence, since they often assume empirical equivalence as well).

Perhaps the lesson here is that proponents of those formal accounts don’t have metaphysical, or even physical, equivalence as a pretheoretic target; they are doing something different, not trying to identify when two theories say the same, or different, things about the world. There are two things to note about this: first, Halvorson’s claims about the relevance of equivalence to understanding different positions along the scientific realism-anti-realism spectrum can no longer be made sense of, since, on this proposal, theoretical equivalence has nothing to do with what we are metaphysically (or even physically) committed to. It is easier to make sense of Halvorson’s claim about the connection between the realism-anti-realism spectrum and equivalence if we instead

thought that philosophers of science who prefer formal accounts of equivalence themselves tend to have anti-realist tendencies—that it is not that they are ignoring metaphysics, but rather are assuming there is nothing there to ignore.

Second, and more relevantly for my purposes here: even if formal accounts of equivalence are intended to be silent about metaphysics—or simply just whether two equivalent theories say the same thing about the world, or, as North puts it, whether they have the same “picture of the world”—“naturalistic” metaphysicians take what they say seriously, and naturalistic metaphysicians in turn seem to get taken more seriously than their less naturalistic counterparts do by philosophers of science. Witness philosophers like James Ladyman and Don Ross (e.g. 2007), who seem to be reading *constraints* on what the world could be like (as in: there can’t be any further metaphysical distinctions beyond the ones allowed by the science), metaphysically speaking, off of these formal “theoretical” equivalences to construct their “ontic structural realism” view. Indeed, the view basically says—here I am paraphrasing from North’s (forthcoming, p. 214) discussion—that there can be no “picture” of the world from a theory that reaches beyond its formal structure; the right picture of the world is constrained to whatever can be read off the formal structure. While I happen to think that Ladyman and Ross’s views are mistaken, they are taken seriously (and rightly so). And I don’t think they would be if it were crystal clear to naturalistically inclined philosophers that we ought not read metaphysical (or just even straightforwardly physical) equivalence off of scientific or theoretical equivalence.<sup>8</sup>

Thus my sense is that whatever is intended by “theoretical equivalence”, it is important to demonstrate that accounts of equivalence that assume EQUIVALENCE ENTAILMENT are mistaken if they (either intentionally or accidentally) contribute to shaping what can be said about the metaphysical and physical world. And since even proponents of formal accounts, like Halvorson, think that there is an important connection between commitments to realism and anti-realism and accounts of equivalence, it seems to me worth taking seriously the idea that theoretical equivalence has something to do (though granting that it is a bit messy what this something is, exactly) with equivalence-full-stop, and showing that if this is right, many accounts are problematic from the perspectives of the anti-exceptionalist and the logical realist. Theoretical equivalence is supposed to

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<sup>8</sup> North (forthcoming, p. 214) makes a point similar to this one, and her clarity there has helped me better understand what is at stake here.

at least bear in at least some important way on theories' actual commitments with respect to reality. This, while vague and hand-wavy, should be enough to motivate my arguments.<sup>9</sup>

## 2. TWO ARGUMENTS FROM ANTI-EXCEPTIONALISM

*Anti-exceptionalism* about logic is summed up by Ole Hjortland as follows:

At the heart of the position are three familiar Quinean claims: gradualism, that logical theories are continuous with non-logical scientific theories; revisionism, that logical theories are revisable by pretty much by the same standards as other theories; and nonapriorism, that logical theories ultimately answer to a posteriori evidence. (2019b, 251).

I think this is relatively clear, so I will not elaborate.<sup>10</sup> But I will quickly discuss one choice point. Many anti-exceptionalists endorse what Hjortland calls 'gradualism': the claim that logical inquiry is continuous with scientific inquiry, and more specifically, that the epistemology of logic is no different than the epistemology of science. But notice that we might have a view that counts as anti-exceptionalist without this commitment. Hjortland and Benjamin Martin first define "methodological" anti-exceptionalism as follows: "theory choice within logic is similar in important respects to that of the recognised sciences" (2020, p 2) but then immediately say that "Methodological AEL explicitly rejects that logic is epistemically foundational, and thus that logical

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<sup>9</sup> Butterfield suggests that there is essentially no *question* as to whether theoretical equivalence is supposed to be "about the world"—and that there would not be such a tradition of trying to pin down a formal notion of it if this was not its role: "Theoretical equivalence' is of course a term of art in the post-positivist tradition, that takes 'scientific theory' as a unit of analysis and accepts some sort of theory/observation distinction. In principle, you could define it however you wish. But all hands agree that we need some notion of 'theories making the very same claims about the world, i.e. not only observational claims but also theoretical ones'. For one thing, we need some such strengthening of the idea of observational (also known as: empirical) equivalence, in order to articulate and then assess the under-determination of theory by data, namely as a matter of observationally equivalent, but theoretically inequivalent, theories. Here, the phrase 'claims about the world' obviously invokes interpretation. But interpretation is liable to be vague, and even controversial, not least because of widespread post-Quinean suspicion of meanings. Hence the long tradition of using formal ideas from logic to try and give a precise explication of theoretical equivalence." (forthcoming, p. 6).

<sup>10</sup> Most contemporary anti-exceptionalists trace their lineage back to Quine (1951). Contemporary anti-exceptionalists (casting a broad net here—some anti-exceptionalists would reject some of the Quinean claims!) include (among others): Bueno and Colyvan (2004); Hjortland (2017, 2019a); Maddy (2002, 2012, 2014); Martin and Hjortland (2020); Priest (2006a, 2014, forthcoming); Russell (2014, 2015); Sher (2011, 2013, 2016); Williamson (2013, 2016); Wyatt and Payette (2018). See also the articles in Hjortland (ed.) (2019b), especially Read (2019) for valuable clarity about choice points for both exceptionalists and anti-exceptionalists.

propositions are known immediately through non-inferential means.” (2020, p. 2). One could hold the latter claim without holding the former; to do so is to grant that inquiry into logic is continuous with the rest of *human* inquiry, but not to insist that it must be science-like, or a science, or use the same principles of theory choice as science.

Why does this matter? I am an anti-exceptionalist who is also (in some sense) a non-naturalist (methodologically: in the sense that I think that human inquiry does and should work in all sorts of very un-science-like ways; thus I reject the closely associated ‘abductivism’ about logic that most anti-exceptionalists endorse), and I do not endorse this standard conflation. Anti-exceptionalism needn’t be packaged with this sort of methodological naturalism; the third argument I will make, from the possibility of logical realism, will be rejected by many on naturalistic grounds.<sup>11</sup>

We should be careful about distinguishing the claim about methodology being similar to science from a nearby claim that anti-exceptionalists need not accept, namely that anti-exceptionalism requires that philosophers of logic take (non-logic-oriented) science to *constrain* our inquiry into logic. Anti-exceptionalists can be committed to the epistemic claim in the first sense (the methodology of logical inquiry should be (or is?) just like the methodology of science), but not in the second sense. They might think this, for example, because sources of evidence for logical theory choice are found outside of the bounds of the natural sciences, or because what logic is trying to *explain*, if anything, is not a target of the natural sciences.<sup>12</sup>

I won’t argue for anti-exceptionalism here. Instead, I will assume it is true, and simply show that it challenges both closure and the (related) idea that logical equivalence is sufficient for theoretical equivalence. Before I do so, though, I need to say something further about the epistemology of logic. In order for my two arguments in this section to work, the epistemology of logic cannot be incredibly *easy*. And simply denying that logic is a priori, or claiming that it is revisable, is not enough to show that the epistemology of logic is not easy.

There is plenty of evidence that the epistemology of logic is hard, and that anti-exceptionalists in particular should not be supremely confident of any particular view about logic. Examining what actual anti-exceptionalists believe, and on what basis, can give us a kind of meta-argument that the epistemology of logic is indeed difficult. Hjortland (2017) does just this, though he concludes something distinct from what I want to. He notes that two prominent anti-

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<sup>11</sup> Those anti-exceptionalists who wish to exclude methodological stances like my own can feel free to substitute ‘anti-shmexceptionalism’ in sections 3 and 4 (where these issues begin to matter).

<sup>12</sup> See Hjortland (2017 and 2019b, footnote 1) for discussion of this point.

exceptionalists, Graham Priest and Timothy Williamson, come to radically different conclusions about logic—Priest is a dialetheist, Williamson endorses classical logic—based on similar methodological commitments, including a commitment to abduction as the central method of theory choice in logic. Hjortland himself rejects some of Williamson’s commitments, and in the end endorses a specific form of pluralism, but his conclusions are not as relevant to us as what he demonstrates about disagreement amongst abductive anti-exceptionalists is: there is significant peer disagreement among anti-exceptionalist *experts*, and, while I won’t here wade into the debate about what those experts should do in the face of such disagreement, I do think that it makes obvious that the epistemology of logic is difficult. (And anyway, despite being quite convinced of their own views, neither Priest nor Williamson seems to think it is easy to begin with.)

The first argument is simple. If anti-exceptionalism is true, then the notion of logical consequence that we use to close the theory is, itself, open to revision. Anti-exceptionalists must be open to the idea that sometimes either the evidence or theory choice considerations should lead us to a change in logic rather than a change in some other part of our scientific theory. We will have much less to revise, if such revision proves necessary, if we don’t initially treat our theories as closed under logical consequence. We should develop theories that are less likely to need major revisions and more likely to only need minor ones. Therefore, we should not accept CLOSURE.

To elaborate, I will discuss a few complications. First, I am not suggesting that we can somehow avoid selecting a logic to regiment our theories. Scientific theories involve all sorts of necessary presuppositions, assumptions, etc., and must be regimented. Still, no matter what we need to assume logically in order to state a theory and any of its consequences that we might need in order to apply that theory, we can’t possibly need all of the logical consequences of the claims in that theory. (For example, suppose for the sake of simplicity that we have a theory that is a single sentence which itself is a long conjunction of all of the substantive claims of the theory. I can’t see why we would ever need to conjoin that sentence and itself. This is just an instance of Sider’s ‘A’ and ‘A&A’.)

Second, in order for this argument to make sense, it must be clarified that philosophers of science seem to mean something different from, for example, epistemologists when they talk about closure. Epistemologists typically note that closure principles are obviously false if they take us from knowing that *p* to knowing that *q*, where *q* is any logical consequence of *p*. This is because, on at least many versions of these principles, we must *know* or *recognize* that *p* entails *q* in order to know *q*

if we know  $p$ .<sup>13</sup> So closure principles in epistemology typically invoke an epistemic condition on entailment itself. (Thus perhaps proponents of epistemic closure can maintain it in the face of anti-exceptionalism, provided some of our beliefs about logical entailment can still amount to knowledge.) Not so, as far as I can tell, for scientific theories: here we are supposed to have in mind a purely formal notion of closure, one that has nothing to do with our epistemic situation with respect to any particular logical consequence of a theory. Every logical consequence of a theory is included, not just the ones we know to be, or can recognize as, consequences.

That the closure of scientific theories has nothing to do with which of a theory's consequences we have epistemic access to suggests that there might be a problem with my first argument. If what is included in the closure of a theory is just what its logical consequences in fact are—that is, whatever it is that settles the actual facts about logical entailment, that same thing settles the facts about closure, independent of our epistemic situation—then there is no epistemic worry from anti-exceptionalism. For logic is revisable precisely because it is an epistemically dynamic discipline. If instead we treat it as akin to, e.g., an ideal but unreachable final theory of physics—stripping away all of its epistemic baggage—or a true theory of things-in-themselves—stripping away our lack of access to those things—it is not (or at least might not be) revisable.<sup>14</sup> In other words: if CLOSURE is about metaphysical closure, then how could my first argument, which is epistemic, apply to it?

The answer is that CLOSURE is also not about this sort of “pure” metaphysical closure. Take the debate over equivalence. There, philosophers are not invoking any kind of mysterious or unknown concept of entailment—as they would have to be if they were both good anti-exceptionalists and were attempting to invoke purely metaphysical facts about logic. Instead, I take it, some mix of the following is occurring: they are basically conventionalists about logic, and so they don't think there are any deep metaphysical facts about logic that undergird the epistemology or use of logic; or they are in fact good anti-exceptionalists and they are invoking a concept of entailment that has a similar epistemic status to that of “our best” theories of (e.g.) physics; that is, they are

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<sup>13</sup> I'm glossing over important and complex details here since only the general idea is important here.

<sup>14</sup> Here again there are thorny issues. For example, a plausible view holds that while logic is not merely conventional, it does depend in important ways on facts about mental states and/or human activities, including human inquiry itself. If so, then it is not as if the metaphysical facts are settled wholly independently from us, and thus, even if closure were a purely metaphysical matter, our inquiry would affect it. I set these very important issues aside here and ask my reader to envision a picture on which logic—the “one true” (or many true, if pluralism is the case) logic—is settled wholly independently of us. Sher (2016), for example, has a view which grounds logic in both mind and world (though in a different way than I just suggested).

assuming that our theories are closed under whatever logic they are regimented in, but granting that this logic is just whatever we happen to have the strongest, most robust epistemic support for at any given time. In either case it seems to me that my arguments in this section threaten CLOSURE (and similarly, EQUIVALENCE ENTAILMENT).<sup>15</sup>

Third, I appealed to a likely false claim in giving the first argument: that we should develop theories that are less likely to need major revisions and more likely to only need minor ones. It is plausible that there are cases—indeed, many cases—in science in which progress was made by having a theory, T, that was radically wrong, be replaced by a theory, T', which had little in common with T. However, such cases involved a shift in (e.g.) what was doing the explanatory or predictive work in T and T'. The logic of a scientific theory is not what does that kind of work. So we should refine the principle to say something like “we should develop theories that are less likely to need major revisions *of parts of the theories that don't bear on the explanatory or predictive power of those theories* and more likely to need minor revisions with respect to those parts of the theories”. That is a mouthful. The best way to see what it means is to move on to a first pass at the second argument.

Second argument: if anti-exceptionalism is true, then (at least in many cases) we don't know about logic a priori and logical truths are not analytic (at least in many cases). Also, logic is rationally revisable. Specifically, we don't know what the contours of the consequence relation are a priori, and the consequence relation is rationally revisable. From these three claims it follows that we should not be certain that we are correct about the consequence relation. Our scientific theories aim at truth. It is better for us to minimize the number of false claims they contain.<sup>16</sup>

If we might be wrong about the consequence relation, then commitment to CLOSURE (and by extension EQUIVALENCE ENTAILMENT) increases the chance that they will contain false claims, as well as increasing the chance that they will contain more false claims than they otherwise would (even if they would contain false claims were they not closed). Let the ‘core’ claims of our theory be those that are required to do the jobs we want our theory to do (e.g. predict and explain phenomena). Suppose that the core claims of our theory are all true, but that we have the wrong

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<sup>15</sup> Sider's (2020, p. 186) remarks about equivalence being “nontransparent” suggest that some accounts of equivalence (at least, Sider's himself) really are intended to be purely metaphysical: “Theories can therefore be epistemically or conceptually inequivalent in some perfectly good sense but nevertheless, given how the metaphysical chips have fallen, not correspond to any distinction in fundamental reality. For an account of equivalence in the philosophy of science, these features seem acceptable.” (186). I am skeptical that his claims map onto how less metaphysics-inclined philosophers of science are thinking about this issue, though.

<sup>16</sup> I set aside issues of idealization here, though there are some important things to say about those issues and anti-exceptionalism.

consequence relation (one which allows for more logical consequences rather than fewer). It will follow that many of the claims in our theory are false. But none of the false claims in our theory will be core claims; they are all dispensable with respect to what we need our theories to do, namely predict and explain phenomena. We don't need them. The kind of Occamist principle that says 'don't posit claims you don't need to do the work your theory is intended to do' is a plausible principle of theory choice.

There are reasons not to go in for such an Occamist principle. But a much weaker version (which seems plausible) can do the work here: we shouldn't include claims in our theories that (a) we don't need to do any of the work we need our theories to do (e.g. predict, explain, etc.) and (b) might be false/increase the chance of making our theories false. So, if anti-exceptionalism is true, then we shouldn't accept CLOSURE (and it is a short step from there to showing that we should not accept EQUIVALENCE ENTAILMENT). The idea that doing so is harmless comes, I suspect, from some combination of two things: first, the hangover of exceptionalism: if logic is a priori and analytic, then treating theories as closed under logical consequence doesn't carry the threat of either falsifying or increasing the number of falsehoods in our theories; and second, the idea that we are "holding fixed" the language and logic of theories when engaging in scientific theorizing (as Quine suggests). But anti-exceptionalists should reject both of these claims, at least insofar as they think equivalence matters philosophically.

I re-emphasize: I am making an epistemic argument: we might be wrong about our consequence relation; if so, we might be including huge amounts in our scientific theories that (a) add nothing whatsoever to those theories, and do none of the work we need our theories to do, and (b) might be false.

This argument should be enough to convince the anti-exceptionalist that she should not accept CLOSURE (and similarly for EQUIVALENCE ENTAILMENT); or rather, it should be enough to convince the anti-exceptionalist that there are important considerations against doing so. Perhaps there are overriding reasons to accept CLOSURE or EQUIVALENCE ENTAILMENT. However, I very much doubt it. It seems to me that instead, what has happened is that philosophers have assumed EQUIVALENCE ENTAILMENT, and rather than defend it have instead focused their attention on what else needs to be said. Again, I'm not suggesting that we don't need quite a bit of logical machinery in our scientific theories. I'm suggesting that we can't possibly need *all* of the logical machinery—and all of the logical consequences—that we get from CLOSURE.

To sum up: claims in our theories should earn their keep—they should only be there if we need them. Genuinely harmless and trivial consequences of those claims can be let in too. But the anti-exceptionalist about logic should worry about whether the logic we have regimented our theories in is correct. If it is not correct, then the logical consequences of our “core” theoretical claims will *not* be harmless. We do not need every logical consequence of our core theoretical claims, even if we do need lots of them. So we should not accept CLOSURE. By extension, we should not accept EQUIVALENCE ENTAILMENT, since, if we have the wrong logic, it is quite likely that purportedly logically equivalent claims will make distinct commitments about the world (since logical equivalence in the wrong logic is clearly not guaranteed to be genuine equivalence).

It is important to flag that we might have strong pragmatic reasons to hold our logic fixed in order to be able to give an account of equivalence at all. This is because we must hold *something* fixed in order to be able to compare theories to begin with. If such an account is to be formal, then we need some sort of shared ground (either in the theory or the metatheory) from which to construct it. I don’t deny this. The point is that anti-exceptionalists should think that while there might be contexts in which we might want to adopt accounts of equivalence that make logical equivalence sufficient for equivalence, in order to learn things about the relationships between theories, we must recognize that there is nothing particularly special about those contexts that ensure that EQUIVALENCE ENTAILMENT tracks the truth about equivalence, as opposed to simply being a feature of a shared choice we have made about what to hold fixed. We might instead choose to fix some other shared (formal or non-formal) feature of theories fixed to evaluate how they relate to each other and the world. While there are more general concerns along these lines for the anti-exceptionalism, in this case the anti-exceptionalist should simply deny that there is any truth-tracking formal account of all-things-considered theoretical equivalence to be given, while recognizing that in some (non-epistemically-special) contexts we will want to treat logical equivalence as sufficient for theoretical equivalence.<sup>17</sup>

In this section, I’ve given two closely connected epistemic arguments against CLOSURE and EQUIVALENCE ENTAILMENT, and I’ve implicitly assumed in it that if we did get the consequence

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<sup>17</sup> Thanks to an anonymous referee for pushing me to address this. Since some philosophers of science don’t seem to think we need a formal account of all-things-considered theoretical equivalence, the anti-exceptionalist can just join them in denying its necessity. But there are both deeper and broader issues here; one thing we might wonder about, for example, is whether a coherentist epistemology is consistent with the kind of anti-exceptionalism under discussion here (in which logic *truly* isn’t special); we need something to hold fixed to be able to state what it is for our beliefs to cohere in the first place. (Jack Woods (2019, §0.5.1) makes this point.)

relation right, there would be no issue. In sections three and four, I question that implicit commitment by turning to a metaphysical argument against both CLOSURE and EQUIVALENCE ENTAILMENT. I argue that CLOSURE (and, by extension, EQUIVALENCE ENTAILMENT) has served to obscure the possibility of *logical realism*, by effectively presupposing that it is false; so it has obscured an important metaphysical possibility. If theoretical equivalence really is a heavyweight question—a guide to when two theories make distinct commitments about the world—then EQUIVALENCE ENTAILMENT stacks the deck against logical realism.

### 3. LOGICAL REALISM

Let *logical realism* be the thesis that there are some cases in which there are some metaphysical difference between the commitments of an atomic sentence and the commitments of a logically complex sentence that is logically equivalent to that atomic sentence. The logical realist thinks that there are at least some cases in which the logical components of, or structure of, something logically complex reflects more than just the status of its non-logical components. So, to return to Sider's example, the logical realist who believes that there is *conjunctive structure* in our world thinks that there is a worldly distinction between the metaphysical commitments of 'A' and those of 'A & A' true.<sup>18</sup>

I will not give a full argument for logical realism here, but I will quickly motivate the idea that the view should be treated as an epistemic possibility—which is all I need for my third argument.

First, I note that McSweeney (2019b) explicitly argues that metaphysical realists are already implicitly committed to logical realism. (Sider (2011) suggests something similar.) If they are right about this, metaphysical realists already have a reason to care deeply about logical realism.

Second, there is a parallel (indeed, perhaps more than a parallel—perhaps the two theses are intimately entwined) between logical realism and what I will call 'mathematical realism' (where that is

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<sup>18</sup> Recent discussions of (but not necessarily endorsements of) realism include Almog (1989), Berto (2015), LaPointe (2014), Maddy (2014), McSweeney (2019a, 2019b, 2020b), Tahko (2009, 2019), Rush (2014), Raven (2020), Sher (2011, 2016), Sider (2011). The status of a definition of logical realism in the literature is messy, and the boundaries are unclear. (For example: does Williamson (e.g. 2015) count as a realist? One understanding of his view is that logic describes the most general features of reality, in which case he does, on my view. Does Sher (e.g. 2016)? Sher wants to ground logic in both the mind and the world.) McSweeney (2019b) and Tahko (2019) describe some of the issues at stake in trying to get clear on what realism *is*, but much more work needs to be done here. Also see Priest (2006b, p. 302) on the relationship between semantic and metaphysical dialetheism.

understood as the disjunction of standard object-based mathematical Platonism, realist versions of mathematical structuralism, views on which numbers are properties rather than objects, immanent realist views on which mathematical objects or properties are located, in some sense or another, where their instances are (e.g. Maddy (1990)) and so on—essentially, any view of mathematics on which mind-and-language-independent reality directly grounds or makes true mathematical truths). And mathematical realism is often taken to be motivated by scientific practice, via indispensability arguments. It is also often taken to be motivated by *mathematical* practice; the idea being that mathematicians take themselves to be doing something real; and we should treat mathematics with the same respect we do other sciences. (I take it this sort of argument is often connected to indispensability arguments in the following sort of way: mathematics is wildly successful as applied to the empirical realm; this gives us a reason to think that mathematicians are doing something truth-tracking; so we should let them go all out.)

There is, however, an obvious objection to assuming that there is an analogous indispensability argument for logic. No one thinks that our scientific theories quantify over logical entities (like connectives, or quantifiers themselves) or entailment itself; mathematical practice does not suggest this, nor does scientific practice, and in some cases at least, it leads to contradiction. This would be a fair objection if logical realism were confined to object-type Platonism about logical constants; but it isn't. Logical realism merely says (in the case where we are realists about conjunction, and there is conjunctive structure in our world) that there is some worldly difference between whatever it is that makes 'A' true and whatever it is that makes 'A & A' true. Perhaps we should treat these things similarly to properties and relations; or perhaps they are "joint-carving" without corresponding to entities at all.<sup>19</sup>

There are many other ways to motivate logical realism. For example, one might think that just as we need to posit laws of physics, we need to posit laws of logic (e.g. the law of non-contradiction); and that these laws don't come from *us*; they come from the world. This gives us a more indirect—but potentially more plausible—motivation for logical realism.<sup>20</sup> Or, and perhaps relatedly, if we think logic is normative, and we might buy into logical realism for analogous reasons to those that motivate the moral realist, if we find such reasons compelling in the metaethical case.

I don't take myself to have zeroed in on any kind of narrow—or even perfectly clear—conception of what logical realism is. And again, I don't think that these sketches of potential

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<sup>19</sup> For discussion of the various views available here, see McSweeney (2019b) and Tahko (2019).

<sup>20</sup> See McSweeney (2020a) for discussion of this issue in slightly different terms ("grounding" logical laws).

motivations for logical realism should convince anyone of the view. My only claim is that we might want to take logical realism seriously enough to not rule it out by fiat when we define scientific theories. If one is wholly convinced of a certain tenets of exceptionalism about logic, one might think that logical realism is nonsense on methodological grounds.

But the anti-exceptionalist ought to think it is a live option, even if one that she doubts. (Perhaps she can even have a very low credence in it; more on this in the conclusion.) For the anti-exceptionalist, the epistemology of logic is hard. This is not just because deciding how to weigh or reason about the evidence is hard, nor even just because it is hard to determine what should count as the evidence, but because it is hard—or should be hard—to determine what questions philosophers of logic should even be asking, and, in a broader sense, what logic even is. One question that I think is worth asking (and which many have asked, in various different ways) is this: is there anything about reality, independent of us, that settles the question of what the correct logic is? And I take realism, in very broad brushstrokes, to be the view that answers this question in the affirmative.<sup>21</sup>

#### 4. LOGICAL REALISM AND CLOSURE

I'll use the subscript “narrow” to refer to a collection of sentences that is not closed under logical consequence, but which, according to the logical anti-realist, says everything worldly that its closure does, and I'll use the subscript “wide” to pick out its closure. If we insist on defining scientific theories such that they are closed under logical consequence, and if logical realism is true, then there is no way to state a theory that only says what the narrow version of a theory says.

For any arbitrary theory (here I use “theory” in a broad, neutral sense)  $T$ , according to the logical realist,  $T_{\text{narrow}}$  and  $T_{\text{wide}}$  may well make two very different sets of metaphysical commitments.  $T_{\text{wide}}$  (likely) tells us much more about the world and how it is structured than  $T_{\text{narrow}}$  does; for it tells us everything about the way the world is *logically* structured in addition to telling us whatever  $T_{\text{narrow}}$  tells us. So  $T_{\text{narrow}}$  and  $T_{\text{wide}}$  express distinct metaphysical commitments.

It's worth pausing to discuss my qualifications above, in order to help clarify the kind of realist position I have in mind. First: Let  $T'_{\text{narrow}}$  be the simple theory that only contains the following

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<sup>21</sup> Note that even the pluralist about logic should be interested in this question—not just someone who thinks there is “one true” logic. The pluralist can, for example, entertain a view somewhat akin to ‘plenitudinous’ or “full blooded” realism in the philosophy of mathematics, which is a realist view that also, I take it, motivates pluralism about mathematics. I have in mind views like Balaguer (1998), Linsky and Zalta (1995). See also Hjortland (2017) and Da Costa and Arenhart (2018) on the relationship between anti-exceptionalism and pluralism.

two claims: (i) *Donkey is grey* (ii) *Leroy is black*.  $T'_{\text{wide}}$  will contain such items as (iii) *Donkey is grey and Leroy is black* (iv) *it's not the case that it's not the case that Leroy is black*.  $T'_{\text{wide}}$  will thus invoke logical notions (conjunction, negation, etc.) that appear nowhere in  $T'_{\text{narrow}}$ . Correspondingly, it will invoke a notion of logical consequence that cannot be read directly off of the content of  $T'_{\text{narrow}}$ , for  $T'_{\text{narrow}}$  contains nothing but atomic sentences. We must make a boatload of assumptions (indeed, we must select a “one true” consequence relation to close  $T'_{\text{narrow}}$  under) in order to move from  $T'_{\text{narrow}}$  to  $T'_{\text{wide}}$ . In such a case, I take it that it is obvious that the logical realist should think that  $T'_{\text{wide}}$  makes many more worldly commitments than  $T'_{\text{narrow}}$  does, and so they are distinct.

In section two, I raised some epistemic concerns with making those assumptions (if logic is not a priori, and is revisable, why would we tack on logical consequences to  $T'_{\text{narrow}}$  if  $T'_{\text{narrow}}$  says what we need it to say, and nothing more, about the world?). Here, though, I raise the analogue metaphysical concerns: if logical realism is true, there is a literal difference in metaphysically relevant content between  $T'_{\text{narrow}}$  and  $T'_{\text{wide}}$ , *even if* we get the consequence relation right when we move to  $T'_{\text{wide}}$ .

To spell this out a bit more: there are (at least) two different “levels” of logical realism that might be at stake in moving from narrow to wide theories. First, there is “constant realism”: hold fixed that we have the right consequence relation; still (depending on what one thinks about the dependence relations that hold between entailment and the individual constants), we have the possibility of there being some sort of (not-purely-conventional) fact of the matter about which collection of constants is most joint-carving.<sup>22</sup> For the constant realist, logical equivalence can't possibly entail theoretical equivalence, since we can have logically equivalent theories in which distinct constants appear.

Second, there is “consequence realism”: as in the toy case of  $T'_{\text{narrow}}$  and  $T'_{\text{wide}}$ , our initial theory might not lend itself to any particular regimentation.  $T'_{\text{narrow}}$  contains only two atomic sentences. For the consequence realist, how we choose to close  $T'_{\text{narrow}}$  will make a worldly difference; for there is a fact of the matter about which entailment relation(s) correspond to genuine worldly structure. (Depending on one's other views about logic, one might be both a constant and a consequence realist, or hold that one is more fundamental than the other/there are dependence relations here, etc.) This issue is distinct from the epistemic challenge; here, it is not that we might make an epistemic mistake in regimenting our theories. Instead, the challenge is metaphysical: when

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<sup>22</sup> For discussion see McSweeney 2019a, 2019b and Sider 2011 (ch. 10). The issues here are much more complex than I am making them out to be; I have, for example, not discussed the relationship between quantification and predicate functors (see e.g. Dasgupta 2009, Donaldson 2015).

regimenting our narrow theories involves narrowing in on a consequence relation that can't be immediately read off of our core (narrow) theories, then our wide theories will commit us to more, metaphysically, than their narrower cores do.

Thus, to endorse CLOSURE is to rule out the possibility of expressing only the content of narrow theories, which, at least in some cases, will make distinct metaphysical commitments (if logical realism is true). Why might we care about this, though? First of all, we might point out that there are no theories like our toy cases; there is always enough logical regimentation that goes into stating any scientifically plausible  $T_{\text{narrow}}$  that, my opponent might say, we won't be adding anything harmful for the realist when we move to  $T_{\text{wide}}$ . This isn't right, though, if logic is in the world. First, suppose we are consequence realists. If we had a kind of 'immanent realist' view of consequence somewhat akin to Maddy's (1990) earlier views about sets (see her 2014 for discussion about logic), then even if we didn't make any new logical assumptions when closing our theory, we would be saying distinct things about the world by closing the theory. That's because we would be saying something about in what parts of the world consequence relations are to be found.<sup>23</sup> Second, suppose we are constant realists. Then we holding our consequence relation fixed when we move from  $T_{\text{narrow}}$  to  $T_{\text{wide}}$  is not sufficient to ensure we say nothing new about the world—we might end up committed to claims involving less fundamental constants that are not in  $T_{\text{narrow}}$ .

One might worry that whether we treat  $T_{\text{narrow}}$  or  $T_{\text{wide}}$  as the 'true' scientific theory might be a merely verbal matter, and so long as we can express  $T_{\text{narrow}}$  at all, we need not worry about the distinction in metaphysical commitments. This is a mistake. Even if the question of which of  $T_{\text{narrow}}$  or  $T_{\text{wide}}$  count as a scientific theory turns out to be merely verbal, there are two serious concerns.

First: logical realism is a thesis that pairs best with some version of anti-exceptionalism.<sup>24</sup> So our anti-exceptionalist arguments from section two are particularly salient if logical realism is true. No logical realist should believe that her favored logic is the One True logic with certainty. If logical realism is true, then logic must be something we can be wrong about—there are some external facts about the world, not located within us, our minds, or our language, that settle what the One True Logic is. (Logical realism commits us to the idea that, for example, that we could universally agree

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<sup>23</sup> I realize this may sound bizarre.

<sup>24</sup> Logical realism is in fact consistent with the claim that we *can* know which logic is correct a priori, e.g. by examining our intuitions. But I am suspicious of this, just as I am suspicious of wholly depending on intuitions in deciding metaphysical questions (if we want to be genuine realists about metaphysics). I part with other anti-exceptionalists, perhaps, in maintaining that neither logic *nor* metaphysics (nor science!) is exclusively (or almost exclusively) an empirical endeavor; all that matters here is that we can be *wrong* about the One True Logic, and that it is hard, if logical realism is true, to know that we've gotten it right.

upon a consequence relation, and yet turn out to be wrong about it.) If there is worldly logical structure, we arguably have less evidence (at least empirical evidence!) about it than we do about all sorts of things. So, if our credence in logical realism is above zero, and logical realism entails that we can't be certain of the One True Logic, then for any  $T$ , we should be less certain of  $T_{\text{wide}}$  than we are of  $T_{\text{narrow}}$ .

In particular cases, there are possible facts about  $T_{\text{wide}}$  that might compensate for the claim that we should be less sure of  $T_{\text{wide}}$  than  $T_{\text{narrow}}$ . If  $T_{\text{wide}}$  somehow better captured the physical facts than  $T_{\text{narrow}}$  did, or if it did better with respect to some theoretical virtue (say, parsimony, or explanatory power) than  $T_{\text{narrow}}$  did, then we might be willing to make a tradeoff here. We often make such tradeoffs in theory building. But it is hard to see how either of these could be the case even in the case of any particular theory. If there is a difference in parsimony or simplicity between any  $T_{\text{wide}}$  and  $T_{\text{narrow}}$ , surely  $T_{\text{narrow}}$  wins. (Recall that we can stuff lots of logical stuff into  $T_{\text{narrow}}$ —just not *all* of the logical consequences of everything we consider to be core). And it is hard to see what physical facts would be better captured by  $T_{\text{wide}}$  than  $T_{\text{narrow}}$ , since  $T_{\text{wide}}$  is just the logical closure of  $T_{\text{narrow}}$ , and physicists don't seem to take logic itself to be part of the subject matter of physics. So it is hard to see what, even in any particular case of theory choice, would justify the move to  $T_{\text{wide}}$  for the logical realist.

But even if there are particular cases where we want  $T_{\text{wide}}$ , this doesn't much matter to my point here, which is that we ought not *define* theories in a way that obscures possible distinctions between narrow and wide theories. Doing so, I claim, obscures the possibility of logical realism—for even assuming that we have the epistemology of logic right, which enables us to avoid my arguments in section two, if logical realism is true, then there are genuine metaphysical differences between  $T_{\text{narrow}}$  and  $T_{\text{wide}}$ .

Now, scientists (and many philosophers of science) don't care about all the possible metaphysical distinctions we could make. But to not care about those distinctions, or not think that they belong in (say) a physical theory, should involve being silent about them in a theory, rather than making them impossible (by definition) to represent in the theory. To take a salient similar example, we don't pack all of pure mathematics into every scientific theory, and we don't (or at least, shouldn't) think that the complete mathematical extension of a theory (where the complete mathematical extension of a theory is just that theory + all the claims of pure mathematics) is no different than that theory.

If we did do these things, they could only be made sense of by taking an anti-realist stance about mathematics—it wouldn't make sense to interpret them as neutral with respect to the metaphysics of mathematics. That's because if realism about mathematics is true, it doesn't make any sense to claim that the complete mathematical extension of a theory is equivalent to that theory: the complete mathematical extension commits to much more, metaphysically speaking, than the theory itself does. My claim is that we do something similar by claiming that logically equivalent theories are theoretically equivalent.

And just as physical theories should be neutral with respect to the question of whether realism about chairs is true, they should be neutral with respect to whether realism about mathematics and logic are true (unless indispensability arguments about mathematics commit science to the existence of mathematical objects; but that's a violation of neutrality in the opposite direction than is under discussion). Mathematics and logic are more difficult cases than chairs; we need to make a large number of assumptions about mathematics and logic in order to meaningfully state scientific theories, and we need make none about chairs. But the point here—in both the epistemic and the metaphysical arguments—is that we ought not make more assumptions than we need, and that assuming either logical or mathematical closure at best obscures the possibility of logical or mathematical realism, and at worst hands over the power to determine whether realism is true to scientific theorizing and practice.

It might be difficult to entertain the toy example of tacking on extra mathematical claims to a scientific theory, and then asking whether it is equivalent to the original theory, because it is such a toy case: presumably we would never end up in a situation where we were (knowingly) doing this, because we would consider the “tacked on” theory to be epistemically and theoretically inferior to the original theory. But if this is right, it helps prove my point here in a way that I hope will be intelligible to philosophers of science (and not just sympathetic metaphysicians). The idea—in both this argument and the previous one—is that if we were really good anti-exceptionalists, CLOSURE would similarly result in theories being epistemically and theoretically inferior to their narrow cores. There are important differences; additional mathematical structure is at least superficially metaphysically committing in certain ways that logical structure is not. And in many cases CLOSURE doesn't involve tacking new logical systems and structures onto a theory, exactly, but instead just fully extending the ones that are there. (Though see my comments in §2 about why this isn't always the case.) But there are enough similarities that the mathematical case helps illustrate the point.

In some ways a closer analogue is mereology: while composition/existence of mid-sized artifacts is often used as an example of a metaphysical issue that science is silent about, it may well be that we want some facts about what composite entities there are built into our theories; but if so, it doesn't follow that we should claim that a narrow theory that includes some facts about what composite entities there are is equivalent to that theory plus all of its "compositional consequences". Imagine we did do such a thing; it looks like metaphysicians who took "our best science" to constrain metaphysical theorizing would then be forced to infer that either anti-realism, or, at best, some sort of easy ontology view were true of ordinary material objects. For in this case science would tell us that there is no real distinction, after all, between a theory that doesn't posit the existence of tables and one that does. And such an extension of a theory needn't involve adding any "new" mereological structure: we can imagine that the mereological commitments of the theory that doesn't posit tables just happen to be consistent with the standard principles of the mereological universalist. Thus this case is akin to the logic case: we might think of ourselves, if we rejected the possibility of realism when it came to mereology, as harmlessly extending the commitments of our theory using structure that accurately captures the mereology of the objects we are in fact committed to, physically. Closing a theory under certain mereological principles, when it is utterly unnecessary to do so (but when those principles are consistent with the mereological structure already found in that theory) would be absurd. The question is why it is any less absurd to do so under a particular notion of logical consequence, when it is unnecessary to do so (but when that notion of logical consequence is consistent with the logical structure already found in the theory).

In summary: taking CLOSURE (and by extension, EQUIVALENCE ENTAILMENT) to be true obscures the possibility of logical realism. Or, put differently, treating scientific theories as closed under logical consequence rules out by fiat the possibility of logical realism. Defining scientific theories so that there is no way to state  $T_{\text{narrow}}$  as a theory presupposes that logical anti-realism is true. It presupposes that the transition from  $T_{\text{narrow}}$  to  $T_{\text{wide}}$  is metaphysically harmless, in the sense that it does not change the metaphysical commitments of  $T_{\text{narrow}}$ , and this is precisely what the logical realist denies. So defining theories as closed under logical consequence is deeply problematic given the possibility of logical realism; but it also serves to obscure the viability of logical realism, by excluding it almost by definition.

One might insist that the question of logical realism is a purely metaphysical question, one that shouldn't be addressed in science anyway. Metaphysicians tend to make much more fine-grained distinctions between theories than scientists do, and there is nothing wrong with that. It is also

plausible that metaphysicians have to respect the constraints of our best scientific theories. However, if we treat science as ruling out logical realism by fiat, something has gone wrong; science has stepped into the business of determining the answers to metaphysical questions that are not within its purview. (Compare the questions I raised above, of whether we should allow science to settle the question of whether mathematical realism is true, or whether mereological universalism is true.)

I conclude that an important metaphysical position, logical realism, is obscured by both EQUIVALENCE ENTAILMENT and CLOSURE, and that thus neither principle should be endorsed by anyone who wants to even leave open the epistemic possibility of logical realism. I believe that anti-exceptionalists should be open to the epistemic possibility of logical realism, and thus should reject our two principles.

## 5. CONCLUSION

If anti-exceptionalism about logic is true, we should not accept either CLOSURE or EQUIVALENCE ENTAILMENT. If anti-exceptionalism is true, then doing so forces us to include a great many possibly false claims that have no bearing on the truth of our core theories into our theories themselves. And if logical realism (which should be treated as an open epistemic possibility by anti-exceptionalists) is true, then treating scientific theories as closed under logical consequence bakes a host of metaphysical commitments into the very definition of a scientific theory.

If our credence in logical realism is quite small, we might not think that much is at stake in ruling out logical realism in the way we talk about and define theories. I don't think this is right, for two related reasons. First, on the metaphysics of science side: the risk is in making realism inarticulable. Anti-exceptionalism is often motivated by or packaged with empiricist or naturalist methodology more generally. And if it turns out that this same methodology recommends not making metaphysical distinctions between equivalent theories, then using a notion of equivalence that excludes the possibility of logical realism will result in it looking like the methodology is inconsistent with logical realism; but it isn't. Second, on the scientific practice side: ruling out logical realism might stifle imaginative moves in science that the anti-exceptionalist should support; if our choice of logic directly reflects the metaphysics of a theory, then there are simply more options for what count as genuine moving parts in our theorizing. Even if there is only a small chance of logical

realism being true, we should allow for theorizing that exploits this possibility, since scientific progress sometimes happens by exploring something highly unlikely, such as the rejection of a foundational principle.

While I doubt the metaphysical argument I gave in section four will convince many philosophers of science to revisit their views to allow for the possibility of logical realism, what I can hope for is that my argument raises complications for the kinds of naturalistic commitments in metaphysics that might lead us to conclude, on the basis of EQUIVALENCE ENTAILMENT, that logical realism is not a live option. Perhaps the proponent of EQUIVALENCE ENTAILMENT can respond to my argument by claiming that their notion of theoretical equivalence is domain-specific: it is only supposed to involve equivalence *by the lights of science*, or something like that, and so these considerations about logic, which might be seen as extra-scientific, are irrelevant. I think that is too quick given pressures on metaphysics (and indeed all of philosophy) to be naturalistic in a way that involves taking our best scientific theories to constrain what we can say about the world. Suppose we took the following extreme stance: EQUIVALENCE ENTAILMENT is intended as a merely descriptive claim about what scientists are up to and what theories they treat as equivalent (and an attempt to get clear on what they mean by that equivalence). Since science doesn't care about extra-scientific considerations like the existence of ordinary objects, or the metaphysics of logic, there is no reason to expect theoretical equivalence to account for their possibility. There are many things wrong with this picture—some of which I outlined earlier in the paper. And yet there is nothing to stop philosophers of science from insisting that 'theoretical equivalence' is a technical term of art that we ought not read anything about *real* equivalence off of. If so, perhaps the lesson here is for naturalistic metaphysicians: if scientists—and philosophers of science—intend to leave open the possibility of more fine-grained distinctions than their notion of equivalence allows for, then it is a mistake even on naturalistic grounds to take science to constrain metaphysics in all of the ways in which naturalistic metaphysicians tend to believe it does. (And, perhaps, metaphysical views like Ladyman and Ross's ontic structural realism rest on this sort of mistake.)

Further, naturalistic metaphysicians often attempt to perspicuously describe fundamental reality. But, if it is correct (as McSweeney 2019b argues explicitly, and Sider 2011 less explicitly) that the project of doing so is one that presupposes a commitment to logical realism (because the logical structure of a language is a central part of what makes a language more or less perspicuous for describing fundamental reality), then the metaphysical argument ought to be particularly compelling to them. If scientists and philosophers of science are bracketing the possibility of logical realism, and

metaphysicians of fundamentality are *committed* to logical realism, then metaphysicians of fundamentality must not assume that we can read the metaphysical facts off the relevant science or philosophy of science. So, there is at least a lesson for naturalistic metaphysicians here.

Yet, I am also simply not convinced that philosophers of science want ‘theoretical equivalence’ to be a purely technical term that has nothing to do with *real* equivalence. (See Butterfield (forthcoming) and North (forthcoming, ch. 7) for support for this claim.) And I do not think that ontic structural realism rests on the kind of mistake outlined above; I think it instead rests (partly) on the idea that ‘theoretical equivalence’ (and associated claims about physical theories) is intended to be at least intimately tied up with real, worldly equivalence. Nor will most proponents of formal accounts of equivalence who are committed to CLOSURE and/or EQUIVALENCE ENTAILMENT find logical realism particularly compelling, nor be moved by it to adjust their own views. That is because many of them have metaphysical anti-realist leanings, which in turn supports the idea that they think that all there *is*, in the manner of worldly distinctions, is what can be read off the science.

However, the epistemic arguments I gave earlier in the paper should be compelling to philosophers of science even if the metaphysical argument is not. For there, the epistemic challenge has nothing to do with “making space for” metaphysical distinctions that scientists—and some philosophers of science—might not care about. Instead, the worry is that the difficulty of the epistemology of logic is not being taken seriously enough in thinking about the epistemology of science. If anti-exceptionalism is true, then we are unjustified in treating the epistemology of logic as prior to that of science; as a priori; as ‘conventional’ or a matter of fiat or definition; and as easy. And to be wrong about logic is to be wrong, full stop: something we should very much be worried about in science.

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