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A Truthmaker Indispensability Argument

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Abstract Recently, nominalists have made a case against the Quine–Putnam indispensability argument for mathematical Platonism by taking issue with Quine's criterion of ontological commitment. In this paper I propose and defend an indispensability argument founded on an alternative criterion of ontological commitment: that advocated by David Armstrong. By defending such an argument I place the burden back onto the nominalist to defend her favourite criterion of ontological commitment and, furthermore, show that criterion cannot be used to formulate a plausible form of the indispensability argument.

Keywords Indispensability · Ontological commitment · Platonism · Nominalism · Truthmakers

1 Introduction

Mathematical Platonism is the view according to which there are mathematical entities such as numbers, functions and sets. Nominalism, by contrast, is the view according to which there are no mathematical entities. The central argument in favour of mathematical Platonism is the Quine–Putnam indispensability argument (Quine 1948, 1951, 1960; Putnam 1979a,b). Recently, nominalists have made a case against the Quine–Putnam indispensability argument by taking issue with Quine's criterion of ontological commitment, often seen to be a crucial component of that argument. This strategy for resisting Platonism is extremely important. If successful, the nominalist can dispose of Platonism with relative ease. Thus, we would have before us an easy road to

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nominalism. Contrast this with hard road nominalism.[1] According to hard road nominalism, one must show that our best scientific theories can be reformulated without mathematics. The road is hard because it is extraordinarily difficult to 'nominalise' science in this manner.

In this paper I argue against the above easy-road strategy for resisting the indispensability argument. I do this by, first, defending an indispensability argument founded on an alternative criterion of ontological commitment to Quine's. This leads me to formulate the following weak inductive argument: if there is one plausible form of the indispensability argument that makes no use of Quine's criterion of ontological commitment, then there are others. I strengthen this inductive step by noting two other criteria that may lead to viable forms of the indispensability argument. In doing so, I shift the burden that has been placed on the Platonist to defend the Quinean ontic thesis back onto the nominalist to, first, argue in favour of some particular criterion of ontological commitment and, second, show that such a criterion cannot be used to forge a route to Platonism. Thus, I show that the easy road nominalist has work to do.

2 Indispensability

Let me begin by considering the Quine–Putnam indispensability argument in more detail. The Quine–Putnam indispensability argument for mathematical Platonism can be set out as follows:

(P1) We ought to have ontological commitment to all and only the entities that are quantified over in our best scientific theories.
(P2) Quantification over mathematical entities is indispensable to our best scientific theories.

(C) Therefore, we ought to have ontological commitment to mathematical entities.

Let us focus on P1 for a moment. There are three assumptions crucial to the truth of this premise. First, one must assume naturalism: it is in virtue of one's commitment to naturalism that one looks to science to determine what exists. Second, one must assume that the ontological commitments of scientific discourse are determined by the quantifier commitments of our scientific theories (this is Quine's so-called criterion of ontological commitment). This is because it is in virtue of the fact that scientific theories quantify over mathematical entities that one takes scientific discourse to be committed to the existence of such entities. Third, one must commit to confirmational holism, for it is only if scientific theories are confirmed as wholes that one is ontologically committed to everything that is quantified over in those theories (if only parts of the theory are taken to be confirmed by the evidence, then one might have a principled reason to restrict ontological commitment to the non-mathematical parts of science).

This reveals four strategies for resisting the indispensability argument. First, one might reject naturalism, arguing that we should look somewhere other than science for what exists. Second, one might reject the Quinean criterion of ontological commitment, arguing that the mere fact that scientific discourse quantifies over mathematical

[1] See Colyvan (2010) for further discussion of the easy road to nominalism.

entities gives us no reason to think that science is committed to the existence of such things. Third, one might reject confirmational holism, arguing that only the non-mathematical parts of science are ontologically committing. Fourth, one might argue that two or more of the three assumptions outlined above are at odds (for example, Maddy 1992 argues that the assumption of naturalism in the context of the indispensability argument cannot be squared with the assumption of confirmational holism).

Each of these four strategies has a significant pay-off: if successful, one can defend nominalism without being forced to reject P2. This is important because in order to reject P2 one must carry out a Hartry Field style 'nominalisation' of science, whereby one shows that mathematics is dispensable to our best scientific theories. Given how hard the Field approach is, the success or failure of any strategy whereby one rejects P1 is of the utmost importance for nominalists.

Although the first, third and fourth options for disposing of P1 are important, it is the second strategy that I am primarily interested in here. According to this strategy, one rejects the indispensability argument by finding the Quinean criterion of ontological commitment wanting. One thereby places the burden back onto the Platonist to defend the Quinean criterion at issue, a burden that no Platonist has successfully discharged. A strategy along these lines has been proposed in some form by Azzouni (2004, 1997), Melia (2002, 2000), Leng (2010) (following the lead of Yablo 1998, 2002, 2009), Dyke (2008) and, perhaps, Maddy (1996).[2]

Nominalists who pursue this strategy for resisting the indispensability argument seem to assume that it adjudicates the debate between Platonists and nominalists in favour of nominalism. Now, this is fine if the only criterion of ontological commitment that can be used to run the indispensability argument is the Quinean one. But why think that is the case? On the face of it, one might substitute in any number of criteria for the Quinean one and run the argument. Which is to say, the indispensability argument appears modular: where before we might have thought that there is just one indispensability argument there is, in fact, a whole class of such arguments, each of which employs a slightly different account of the ontological commitments of scientific discourse.

Of course, this does not yet show that one who rejects Quine's ontic thesis is mistaken to conclude against Platonism. After all, it may well be that the only plausible form of the indispensability argument is the Quinean one. If that were so, then rejecting Quine's ontic thesis would be sufficient to put Platonism to rest. But, by the same token, if a plausible form of the indispensability argument that makes no use of Quine's criterion of ontological commitment could be developed, then the truth or otherwise of Platonism would remain decidedly open.

As already noted, in this paper I make a case for an indispensability argument that uses a different criterion of ontological commitment to the Quinean one. The criterion I employ is an Armstrongian criterion of commitment, according to which scientific

[2] Note that the proposals put forward by each of these philosophers are all importantly different. Nevertheless, they each share in common the idea that rejecting Quine's ontic thesis provides a way out of the indispensability argument. For a good overview of the difference between the proposals of Melia, Azzouni and Yablo, see Colyvan (2010).

discourse is ontologically committed to all and only the truthmakers required to make our best scientific theories true (Cameron 2008a, p. 4).

3 The truthmaker indispensability argument

Consider the following variation on the standard Quinean indispensability argument:

(P1*) We ought to have ontological commitment to all and only the truthmakers required by our best scientific theories.
(P2*) The truth of mathematics is indispensable to our best scientific theories.
(P3*) The truthmakers for mathematical statements are mathematical entities

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(C1*) Therefore, we ought to have ontological commitment to mathematical entities.

Call this argument the truthmaker indispensability argument. The first premise of the argument makes similar assumptions to P1 in the standard, Quinean form of the argument. First, P1 assumes naturalism: once again, we are looking to science to tell us what exists. Second, P1 assumes confirmational holism: if only certain parts of science are confirmed and not others, one might reasonably restrict the demand for truthmakers to the non-mathematical parts of science only.

P1 and P1* differ, however, over the criterion used to determine the ontological commitments of scientific discourse. In particular, whereas P1 assumes a Quinean criterion of ontological commitment, P1* of the truthmaker indispensability argument assumes an Armstrongian criterion of ontological commitment.[3] The general plausibility of the Armstrongian criterion is an interesting issue. However, this is not an issue that I will consider here. Rather, it will be sufficient for the purposes of this paper if the Armstrong criterion is generally taken to be a serious alternative to the Quinean criterion. This is, in fact, the case: the Armstrongian criterion has a number of prominent advocates, including Armstrong (2004), Heil (2003), Cameron (2008a) and Dyke (2008).[4]

Consider now the second premise of the truthmaker indispensability argument. The central difference between P2* and P2 is that, according to P2*, the truth of mathematics is indispensable to our best science; P2, by contrast, does not clearly require the truth of mathematics in this manner. Rather, it might be argued, P2 requires only that we have justified belief in mathematics. The question then is whether this 'added strength' of P2* renders the truthmaker indispensability argument less plausible overall. This depends, I think, on whether we have reason to think that science does not require the truth of mathematics.

In *Science Without Numbers* (1980) Hartry Field argues that the truth of mathematics is dispensable to our best science. Field argues for this claim by showing, first, that a Newtonian theory of gravitation can be nominalised (formulated without appealing

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[3] Although this indispensability argument employs Armstrong's criterion of ontological commitment, it is not clear that Armstrong himself would endorse any such argument for Platonism.

[4] Proponents of the Armstrong criterion offer various reasons for preferring it to Quine's (see Schaffer 2008, pp. 8–9 for discussion).

to mathematics) and, second, that mathematics is conservative, where, roughly, some body of mathematics M is conservative over some nominalistic body of assertions T only if for some further assertion S, S is a consequence of the combined theory T + M only if it is a consequence of T alone.[5] If mathematics is conservative over a nominalised science (and such a nominalisation is possible), then (very roughly) the mathematics does not 'add' anything to the science: science can, in principle, be done without mathematics. The upshot is that science does not require the truth of mathematics, since it does not really require mathematics at all, other than, perhaps, to make science easier to do.

The conservativeness result counts against P2*. Note, however, that the conservativeness result is not beyond reproach: both Melia (2006) and Shapiro (1983) have argued against the conservativeness of mathematics, on different grounds (see 1985 for a reply to Shapiro). Note also that Michael Resnik in his (1995) paper offers a powerful pragmatic argument for the view that even if mathematics is not required to formulate our scientific theories, the truth of mathematics is a necessary supposition for scientific practice. More specifically, according to Resnik (1995, p. 171) we can be justified in drawing conclusions from and within science only if the mathematics used in science is true. So even if we could get by without the truth of mathematics as per the conservativeness result, we would never be justified in drawing conclusions from a science in which false mathematics plays a role. Since one of the central goals of scientific practice is to draw such conclusions, then it would seem that the truth of mathematics is required by our best science in some sense. This suggests the following reformulation of P2*:

(P2′) The truth of mathematics is indispensable to scientific practice

If one employs P2′ in the truthmaker indispensability argument, one sidesteps the problem posed by the conservativeness result. In the end, however, there is no real need to do so. This is because, for the purposes of the current project, it does not really matter that the conservativeness result counts against P2*. This is because it also counts against P2: if mathematics is conservative over an appropriately nominalised science, then it is dispensable from science and so the Quinean form of the argument fails to be convincing. In such a situation, the nominalist would have no need for the strategy that is the focus of this paper. That is, there would be no need to resist the indispensability argument by contesting the Quinean criterion of ontological commitment, since one would be able to show that the indispensability argument fails on independent grounds. Thus, since the target of the current project is the class of nominalists who already find Field's project wanting (and are thereby inclined to give up the Quinean criterion of ontological commitment), we can safely set aside the threat posed by the conservativeness result.

But even if we set aside the conservativeness result, P2* remains stronger (and so more controversial) than P2. However, this added controversy need not pose a problem. This is because the strength of P2* trades off against the fact that P2* provides the truthmaker indispensability argument with a distinct advantage over the Quinean form of that argument. One of the criticisms of Quine's indispensability argument is

[5] See Field (1980, pp. 11–12) for further refinement of the definition of conservativeness.

that it seems to require some strange ontological commitments. For example, Maddy (1992, pp. 281–282) argues that the Quinean form of the argument requires commitment to the existence of mathematical idealisations such as infinitely deep oceans and frictionless planes, since such things play an indispensable role in our best science.

The truthmaker indispensability argument, however, does not require commitment to things such as infinitely deep oceans. This is because P2* demands only that the truth of mathematics be indispensable to our best science. Thus, the focus is entirely on the true parts of mathematics, rather than on those parts of mathematics that are heuristically useful but not literally true, such as idealisations involving infinitely deep oceans. Indeed, that the truthmaker indispensability argument can avoid ontological commitment to idealisations such as infinitely deep oceans is not all that surprising. This is because the most that the argument can establish is that we are ontologically committed to the truthmakers required by our best science. Thus, since things like infinitely deep oceans are not required to make any part of science true but, rather, are merely useful in carrying out an analysis of water waves, the truthmaker indispensability argument does not require commitment to such things. Hence, although P2* might be more controversial than P2, it also galvanises the indispensability argument against a Maddy-style objection. So there is balance.

This brings us to the third premise of the truthmaker indispensability argument. The third premise is, I think, where the action is: in order to make a case for the truthmaker indispensability argument one must defend the claim that mathematical entities are the truthmakers for mathematical statements. There are three objections to this premise. First, one might argue that mathematical statements are made true by anything whatsoever, rather than by mathematical entities. Second, one might argue that even if mathematical statements are not made true by anything whatsoever, there are nevertheless alternative truthmakers on offer that can do the necessary truthmaking work. And, third, one might argue that mathematical statements qua necessary truths lack truthmakers entirely. In what follows I defend the third premise of the truthmaker indispensability argument from each of these three objections, thereby making a case for an argument of this kind.

4 Truthmakers and necessary truths

Let us begin with the first objection, namely the idea that mathematical statements might be made true by anything whatsoever. In order to get a sense of the worry here we must consider truthmaker theory in a bit more detail. According to truthmaker theory, the relationship between the truthbearer of a sentence, a proposition, and its truthmaker is one of entailment. Thus, truthmaker theories are often characterised by their commitment to the truthmaker principle (Beebee and Dodd 2005, p. 2):

> (TM) Necessarily, if ⟨p⟩ is true, then there exists at least one entity α such that ⟨α exists⟩ entails ⟨⟨P⟩ is true⟩.

According to Greg Restall, however, the truthmaker principle runs into difficulties when it comes to necessary truths, like mathematical truths (Restall 1996, p. 333). This is because for any necessary truth N, N is trivially entailed by any contingent truth. Thus, given (TM), N will be entailed by a proposition concerning the existence of anything whatsoever; which is to say, anything counts as a truthmaker for N. This is an outcome that Restall finds counterintuitive. Restall (1996, p. 334) complains that his refrigerator should not count as a truthmaker for Goldbach's conjecture and yet, given truthmaker theory, it does.

That necessary truths are made true by anything whatsoever poses a problem for the truthmaker indispensability argument. This is because mathematical truths are necessary truths. Thus, contra the truthmaker indispensability argument, mathematical entities are not required to make mathematical statements true. Rather, all we need is the existence of Restall's refrigerator, say.

One response to the worry might be to adopt Restall's own solution (Restall 1996, pp. 338–339). According to Restall, one can restrict the truthmaker principle by endorsing relevance logic. If one endorses a relevance account of the material conditional then it is not the case that anything whatsoever will count as the truthmaker for a necessary truth. Rather, only those truthmakers that are 'relevant' to any given necessary statement will be acceptable. The trouble with this option, however, is that one must be prepared to endorse relevance logic, which many of us are not prepared to do.

Fortunately, there is an alternative solution available. Following McFetridge (1990), Liggins contends that truthmaking should be thought of as explanation (2005, pp. 111–115). One can think of this as a restriction on the sort of allowable ontology one might propose as the truthmaker for a given proposition. The thought is that, when it comes to truthmakers, not just any slice of the ontology will do: rather, the correct truthmakers are those that seem to explain why a proposition is true. Arithmetic truths become a case in point: even if '$2+2=4$' is entailed by the existence of anything whatsoever, it is not obvious that the existence of anything whatsoever explains why that arithmetical proposition is true. Rather, according to Liggins, it is the existence of the natural numbers that provides an explanation of that proposition's truth (Liggins 2005, pp. 114–115).

Following Liggins, then, we might reformulate the truthmaker principle by treating truthmaking as explanation:

(TM*) Necessarily, if $\langle$p$\rangle$ is true, then there exists at least one entity α such that $\langle\alpha$ exists$\rangle$ entails $\langle\langle$P$\rangle$ is true$\rangle$ and α's existence explains why $\langle$p$\rangle$ is true

Call a truthmaker that explains why a proposition is true an explanatory truthmaker, henceforth an E-truthmaker. By appealing to E-truthmakers, we can reformulate the truthmaker indispensability argument to avoid the Restall problem entirely:

(P1#) We ought to have ontological commitment to all and only the truthmakers required by our best scientific theories
(P2#) The truth of mathematics is indispensable to our best scientific theories.
(P3#) The truthmakers required by science are E-truthmakers
(P4#) The E-truthmakers for mathematical statements are mathematical entities

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(C1#) Therefore, we ought to have ontological commitment to mathematical entities.

Call this argument the E-truthmaker indispensability argument. Note that this version of the argument still employs a form of the Armstrongian criterion of ontological commitment: the ontological commitments of scientific discourse are determined by the truthmakers required for science. It is just that we require an added premise to reflect the fact that the truthmakers required by science are E-truthmakers. Why think that is true? Well, if we are interested in providing a fully explanatory account of what makes science, and by extension, mathematics true then we are going to need the E-truthmakers. This is because, if we treat truthmaking as explanation, it is the E-truthmakers that are required to give a fully explanatory account of this kind.

Of course, the addition of P3# makes the argument more controversial overall. This is because one must now assume a particular account of truthmaking in order for the argument to proceed, and this view of truthmaking may simply be false. Although this added controversy is a cost of resolving the problem in this manner, I see no particular reason why truthmaking should not be thought of as explanation. Moreover, I see no reason why nominalists should find this view of truthmaking objectionable. Thus, I do not think that being forced to treat truthmaking as explanation constitutes a significant strike against the truthmaker indispensability argument.[6]

5 Alternative truthmakers

So much then for the first objection to the truthmaker indispensability argument. The second objection proceeds as follows: According to the third premise of the truthmaker indispensability argument, the truthmakers for mathematical statements are mathematical entities. However, one might contend that this is incorrect, mathematical statements are not made true by mathematical entities. Rather, mathematical statements are made true by some further feature of the ontology, the Fs, such that the Fs are perfectly compatible with nominalism. For example, one might argue that mathematical statements are made true by the existence of proofs, say, or by the existence of certain physical systems in the world.

One response to this objection might be to survey each variety of truthmaker to which the nominalist might appeal and show that it cannot do the relevant truthmaking work (perhaps because the feature of the ontology being appealed to does not sufficiently explain why mathematical statements are true, in the truthmaking sense of explanation). However, such a response would be, at best, piecemeal. In what follows I sketch a more general reply.

Consider the following sentence:

(1) Sydney is the largest Australian city

[6] As an anonymous referee of this journal has pointed out to me, the idea that truthmaking is a kind of explanation may be more controversial than I have suggested. Rather than attempt a defence of E-truthmaking here, however, I will instead note that the view is relatively common amongst truthmaker theorists. In particular, as well as Liggins and McFetridge, Merricks (2007, pp. 29–30), Bigelow (1988, p. 121) and Molnar (2000, p. 82) all assume some form of this view.

Clearly, (1) involves reference to a city called ‘Sydney’. But reference, it seems plausible to suppose, guides the selection of truthmakers for a given sentence. For example, if a sentence refers to Sydney then the truthmaker for that sentence will involve Sydney. We might call this relationship between reference and truthmakers ‘guidance’. With this in mind, consider the following sentence:

(2) 2 is the smallest prime number

Intuitively, this sentence involves reference to the number ‘2’. As such, given guidance, the truthmaker for (2) should involve the number 2 in some way.

Now, consider again the above objection to the truthmaker indispensability argument. According to this objection one denies that (2) is to be treated in the same manner as (1): although the truthmaker for (1) involves the city of Sydney, the truthmaker for (2) does not involve the number ‘2’.

In putting forward this suggestion, however, one must either claim that guidance is false of all sentences in natural language, which seems implausible or one must endorse a non-uniform theory of semantics: a theory of the relationship between reference and truth that holds good for some proper names in the language (i.e. ‘Sydney’) but not for others (i.e. ‘2’). The trouble with this is that, according to Paul Benacerraf, it is a desideratum of a semantic theory that it apply uniformly to all sentences in a given natural language (Benacerraf 1973, p. 666). For Benacerraf this desideratum has its roots in our concept of truth: in order for a semantic theory to be a theory of truth, the semantics at issue must apply uniformly to all names, predicates and quantifiers in use (Benacerraf 1973, p. 666). If Benacerraf is correct, however, then one who pursues the objection under consideration faces a significant challenge: one must provide some independent argument in favour of a non-uniform semantics; a semantics according to which guidance holds of ordinary sentences but does not hold for mathematical sentences.

Now, the Benacerraf challenge may well be a challenge that a determined nominalist can meet. It is not my intention to suggest otherwise. However, the challenge of defending a non-uniform semantics in this context is a difficult one and one that, to my knowledge, no nominalist has successfully answered. Moreover, the difficulty of the challenge is compounded by the existence of ‘mixed’ sentences, sentences that involve reference to both mathematical entities and to entities of the ordinary kind. For example, consider the following ‘mixed’ sentence taken from Colyvan (2005, p. 216): ‘there exists a planet with mass m and location (x, y, z) and a function G that describes the gravitational potential of the planet at time t’. This sentence involves reference to a particular planet and a particular mathematical function. Sentences of this sort are troubling because it is not possible to ‘bracket off’ reference to mathematical entities from reference to ordinary entities in such a manner that the two kinds of reference can be justifiably treated using different semantic theories. Both instances of reference are, in some sense, said ‘in the same breath’. So we have good reason to be pessimistic about the possibility of a solution to the Benacerraf challenge.

6 No truthmakers required

This brings us to the third objection to the truthmaker indispensability argument. One basic assumption of the truthmaker indispensability argument is that mathematical statements have truthmakers. However, one might simply maintain that this is incorrect: mathematical statements are not like other statements in that they lack truthmakers altogether. One might justify this view by arguing that mathematical truths are necessary truths and it is a commonplace to restrict the truthmaker principle to contingent truths only.

The central difficulty with this line of thought is that a view according to which necessary truths lack truthmakers is a substantial thesis, and one that is not universally accepted by truthmaker theorists. For example, Armstrong (2004), Restall (1996), Liggins (2005), Smith (2002) and Gregory (2001) all seem to agree that both necessary and contingent truths have truthmakers. Hence, in the current context, some argument is required for the view that necessary truths lack truthmakers.

One such argument is to be found in Ross Cameron's (2010) paper. According to Cameron, necessary truths do not make any demands upon the world for their truth. That is, there is no way that the world needs to be to 'make' those statements true. Cameron calls this view of necessary truths: trivialism. Cameron (2010, pp. 411–413) defends trivialism in the following manner. Suppose that trivialism is true. If trivialism holds then we have a good explanation of the necessity of necessary truths. For if a necessary truth makes no demand on how the world is for its truth then there is a sense in which that statement is true 'come what may'. Or, to put the point another way, for any necessary truth T no matter how we might 'adjust' the actual world to 'generate' some other possible world, if T is true actually then it will remain true under every permutation; there is simply nothing we can do to the world to make that statement false and this is why it is a necessary truth.

Cameron goes on to argue that if we reject trivialism, however, then we are left without an explanation of the necessity of necessary truths. This is because if a necessary truth is not trivially true, then that sentence must make some demand on how the world is; which is to say, for any necessary truth T, there must be some feature of the ontology (a truthmaker) the absence of which would render T false. If that is correct, however, then the explanation for T's necessity must simply be that the demands it makes on the world are necessarily met. But the claim that T's demands are necessarily met is itself either a trivial necessary truth or a non-trivial necessary truth. If the claim is trivial, then it makes no demand on how the world is for its truth and so it is hard to see how T could be making any such demands either. If, however, the claim is non-trivial then some explanation must be provided for the necessity of this further substantial necessary truth. However, if it is the case that this further substantial necessary truth is necessary because its demands are necessarily met, then we are faced with yet another necessary truth that is either trivial, in which case T looks once again to be trivial, or non-trivial, in which case its necessity must be explained, and so on ad infinitum. Thus if necessary truths are non-trivial then either we are faced with an explanatory regress or the regress bottoms out in brute necessary truths: necessary truths the necessity of which admits of no explanation.

Now, since Cameron takes it to be the case that, when providing an account of the truth of necessary truths, one's account should explain the necessity of those truths, he does not think that appealing to brute necessities is an attractive option. Might one then simply bite the bullet on the regress? Elsewhere, Cameron (2008b, p. 2) provides good reason for thinking that is not a viable option. Roughly, the worry is that the regress at issue is an explanatory regress: the explanation at each level depends on some explanation at the level below. The trouble with a regress of this kind, Cameron explains, is that it is hard to see how any explanation could ever get off the ground in the first place. Thus, according to Cameron, if one wants a substantive explanation for the necessity of necessary truths then in order to avoid an explanatory regress of this kind, one should accept trivialism, thereby accepting a view according to which necessary truths lack truthmakers.

Cameron's argument is interesting. However, the argument rests on the claim that necessities cannot be brute, that the necessity of all necessary truths must be explained. Unfortunately, Cameron does not say a great deal in defence of this claim and the little that he does say seems to apply only to a Lewis-style account of necessary truths, in terms of possible worlds (Cameron 2010, pp. 401–403). Now, for Cameron's broader project, this does not pose a serious problem. This is because Cameron is concerned with providing a new account of how it is that the truth of a necessary truth explains its necessity. Hence, his argument is pitched to those who are already willing to buy into the view that there cannot be brute necessities. In the current context, however, a great deal hangs on the claim that there cannot be unexplained necessities. Hence, something more by way of defence is needed for this claim if one is to turn Cameron's argument into a substantial objection to the truthmaker indispensability argument.

For my part, however, I do not know of any straightforward justification for the view that there cannot be brute necessities. Thus, the success of a Cameron-style argument in the current context is not obvious. Of course, this does not mean that there is not some further argument available for the view that mathematical statements qua necessary truths lack truthmakers: there may well be such an argument. However, I think that we should be pessimistic about the success of any such argument (Cameron's included). This is so for two reasons.

First, if one thinks that mathematical truths qua necessary truths lack truthmakers whilst contingent truths do not, then, once again, one must accept a non-uniform semantics. In particular, one must accept that although what I have called 'guidance' (the idea that reference places constraints on the potential truthmakers for a given statement) holds for contingent truths, it does not hold for necessary truths. Thus, any nominalist who attempts to develop an argument for the view that mathematical statements lack truthmakers must also negotiate the Benacerraf desideratum outlined above: namely, that the semantics for a language ought to be uniform.

Second, any argument for the view that mathematical statements qua necessary truths lack truthmakers must presuppose that mathematical truths are, in fact, necessary. However, not all parties to the Platonist/nominalist debate will agree that mathematical statements are necessarily true. For example, Colyvan (1998, 2000) defends a view that he calls contingent Platonism: the view according to which there are mathematical entities, but only contingently so. Colyvan's case for this view is interesting because it can be adapted for use in the current context.

According to Colyvan, when considering the Quine–Putnam indispensability argument (such as that outlined in Sect. 1), there is good reason to think that if mathematical entities exist, they do so contingently. This is because the fact (if it is one) that quantification over mathematical entities is indispensable to our best scientific theories places mathematical entities on a par with other theoretical entities (Colyvan 1998, p. 118). Thus, since we usually treat the theoretical entities quantified over within science as, at best, contingent entities, then we should do the same with regard to mathematical entities. Indeed, Colyvan even goes so far as to say that this is (or should be) the orthodox view amongst Platonists who are moved by the indispensability argument.[7]

Similar considerations hold with regard to the truthmaker indispensability argument. This is because, like the Quinean indispensability argument, indispensability is playing a key role: it is because the truth of mathematics is taken to be indispensable to our best scientific theories that we are committed to the truthmakers for mathematical statements. Thus, one might argue that the indispensability of the relevant mathematics puts mathematical statements on a par with statements concerning other theoretical entities in science, such as statements involving electrons: in both cases, the relevant statements are contingent truths. If this is correct, however, then even if an argument could be developed for the view that necessary truths lack truthmakers, this would not undermine the case made for mathematical Platonism by the truthmaker indispensability argument. Rather, some independent argument against contingent Platonism would be required, and I know of no such argument.

7 Conclusion

So, the third premise in the truthmaker indispensability argument survives the three objections considered above: the charge that mathematical statements are made true by anything whatsoever; the charge that mathematical statements are made true by things other than mathematical entities, and, finally, the charge that mathematical statements lack truthmakers. Since I have run out of ideas as to how else one might challenge the truthmaker indispensability argument, this concludes my case for an argument of this kind.

By showing that the truthmaker indispensability argument is a plausible argument, I have shown that even if Quine's criterion of ontological commitment is to be rejected, the question of Platonism's truth remains open. Still, perhaps this is not all that worrying for the average nominalist: one can always decide in favour of nominalism by arguing against the Armstrongian criterion of ontological commitment. However, things are not quite so straightforward. Given that the truthmaker indispensability argument is viable, we have a prima facie reason to think that there are other viable

[7] Field (1993) also seems to take the view that if mathematical entities exist, they do so contingently. More specifically, although Field does not think that there are any mathematical entities, he thinks that this is a contingent fact about our world. For further discussion of contingentism in the debate between mathematical Platonism and nominalism see Miller (2010) and Hale and Wright (1992, 1994).

forms of the argument. If we have reason to think that other forms of the argument are viable, however, then it will not do to simply reject the Armstrongian criterion.

In fact, there are at least two further criteria of the ontological commitments of scientific discourse that may lead to viable forms of the indispensability argument. The two criteria I have in mind are as follows:

Criterion (1): We are ontologically committed to whatever it is in our best science that does *significant explanatory work*
Criterion (2): We are ontologically committed to whatever our best science takes to be fundamental

Consider first criterion (1). An indispensability argument employing criterion (1) will be plausible if (i) mathematical entities can be shown to do significant explanatory work in science and (ii) the relevant explanatory work is indispensable to the scientific theories in question. Recently, Baker (2005) and Colyvan (2001, p. 49) have each made a preliminary case for (i): both philosophers argue that mathematical entities do significant explanatory work in explaining physical phenomena. These philosophers also make a preliminary case for (ii): the explanatory work being done appears to be of such a kind that were we to dispense with such entities, our scientific theories would have less explanatory power overall.

Consider now criterion (2). An indispensability argument employing this criterion will be plausible if (i) mathematical entities are fundamental and (ii) the fundamental posits of science are indispensable. On at least one understanding of what it is to be fundamental, (i) seems plausible. Specifically, if it is the case that for some x, x is fundamental just in case x does not supervene on anything for its existence, then mathematical entities would qualify. This is because, intuitively, mathematical entities are not supervenient in this way. There is also a case to be made for (ii): if anything is indispensable to a scientific theory, it is the fundamental posits. This is because the fundamental posits are often doing the most explanatory work. Thus, losing the fundamental posits would seem to undermine the explanatory power of our scientific theories.

That criterion (1) and criterion (2) may feature in viable forms of the indispensability argument is, in one sense, unsurprising. This is because criterion (1) and criterion (2) are each quite similar to the Armstrongian criterion in one important respect: explanation is playing a key role in each case.[8] Thus, if an indispensability argument employing the Armstrongian criterion is viable, then we should expect these other criteria to feature in viable forms of the indispensability argument also.

Perhaps then there is a more general moral to be drawn from the foregoing discussion: viable forms of the indispensability argument may be produced by appealing to a criterion of ontological commitment that allows the Platonist to make use of the explanatory power of mathematical entities. The E-truthmaker indispensability argument is one such argument, but as we have just seen there are likely to be others. If that

[8] With regard to the Armstrongian criterion this might not be immediately obvious. However, as we saw above, truthmakers are thought to *explain* why it is that statements are true. Moreover, this was seen to be crucial in formulating a plausible form of the truthmaker indispensability argument: what I called the E-truthmaker indispensability argument.

is correct, however, then the nominalist cannot hope to undermine the case for Platonism by taking aim at any particular criteria of ontological commitment. Rather, the nominalist must identify and defend a criterion of ontological commitment that does *not* allow the Platonist to make use of the explanatory power of mathematical entities, since only then will she have a plausible strategy for resisting the indispensability argument.[9]

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[9] Indeed, there might be an even stronger conclusion to be had. One might argue that there is no way for the nominalist to discharge this burden, because there is no way to choose between relevantly different criteria of ontological commitment. For an argument to the effect that we lack the resources to choose between criteria of ontological commitment see Melia (1998).

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