On scientific and ontic structural realism

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Structural realism adopts the advantage of naive scientific realism to confirm the intuition of scientists, that their most successful theories are approximately true, while overcoming its disadvantage of being too optimistic about the history of science. In this essay, I will motivate structural realism based on the missing link between truth and predictive success in naive scientific realism. I will argue that structural realism is not successful in closing this gap itself, but it opens up a metaphysical discussion within scientific realism which is fruitful to becoming a scientific realist after all.

Putnam (1965, p. 257) motivated scientific realism as an attempt to legitimate his observation that most scientists talk about theoretical, and thus, unobservable terms of their most successful theories as if they were true. Naive scientific realism (NSR) arises from this intuition as the proposition that one aim of science is to give an approximately true description of reality, including those aspects of reality that are unobservable, and predictive successful theories reach this aim (Godfrey-Smith 2003, p. 176). Here, truth is understood metaphysically as having a special connection to reality[1], and not epistemically like being of high warrant (Psillos 2018, pp. 24-5). This avoids pragmatic anti-realism which counters that the world does not impose reality on us, but we choose how the world is to be described in terms of basic categories[2]. The validity of NSR depends on arguing for the link between the predictive success of theories and their metaphysical truth. I take the No Miracles Argument (NMA) as the best attempt to establish this link using a posteriori reasoning and induction to the best explanation as a reliable method in science: the approximate truth of accepted scientific theories is the best explanation for the cumulative success of science over time (Dicken 2016, p. 69).

For the sake of my argument, I will set aside the discussion of whether this induction

[1] I avoid the phrase "correspondence" because it suggests a picturing or mirroring of the world (Godfrey-Smith 2003, p. 188).

[2] Kant takes these categories as a priori truths whereas Carnap thinks that our language forms them (Creath 2007, p. 316). Modern pragmatism holds against it that categories rather reflect our history and our situatedness in a community acting on the world (Massimi 2018, p. 165).

is properly applied and generally reliable (see AllzÃ©n (2022, p. 2)). NMA itself cannot settle this debate but only show that once the induction is accepted, the argument is consistent (Dicken 2016, pp. 70-1). Another objection points out that NMA is a bad scientific explanation because it fails to provide any novel predictions typical for successful scientific theories (Wray 2018, p. 38). However, I would counter that if NMA explains the link between success and truth, it presents novel knowledge after all. Musgrave (1988, p. 230) claims that this capability is denied by many philosophers because empirical success can at most be evidence but never a reliable indicator of truth. In particular, the base-rate fallacy threatens this very possibility: if the rate of true theories in the overall population of considered alternative theories is low, the prior probability that a successful theory is approximately true is also low. Thus, even the most successful theories will more likely be false due to a low success rate of false theories in general (Vickers 2018, p. 49). Dicken (2016) considers this to be the determining argument against NSR but I agree with Henderson (2015, pp. 1299-1301) that the base-rate fallacy can be defeated: the involved prior probability equals the base rate of true theories only if a random sampling rate is assumed. However, the overall success of science indicates that the scientific sampling procedure is not random but biased in favour of approximately true theories according to NMA. In hindsight, we can therefore assume that the prior probability for the idea that "a successful theory is approximately true" is not very low which defeats the fallacy charge. Of course, this defence relies on NMA and can, therefore, not support its validity either.

Laudan (1981, p. 33) makes a more compelling argument against the link between success and truth from the history of science: many historical theories made correct predictions but involved theoretical terms which are not connected to reality after all. This shows that truth does not necessarily survive "scientific revolutions" while success accumulates over time. Thus, the optimistic induction from past theories in NMA cannot track the truth, and NSR is defeated (Godfrey-Smith 2003, p. 178).

As a consequence of Laudan's objection, a major movement in scientific realism tried to secure at least some form of realism by reducing the predictive success of a theory to some substantial part of it which generally persists through theory change and thereby, allows for truth-continuity again (Psillos 1999, p. 109)[3].

[3]Others tried to defend NSR through limiting their discussion to mature sciences or the most successful theories only. I reject these ideas because they cannot explain the general success of science and how to distinguish the most successful from less successful theories without demarcating them in an ad hoc manner (Psillos 1999, p. 108). Irrespective of the success of these strategies, they do not qualify as

One promising attempt is epistemological structural realism (ESR) of Worrall (1989) who claims that science reveals the structure of unobservable reality, but one should remain sceptical about the postulated theoretical entities (Psillos 1995, p. 20). He observed that the equations of Fresnel's theory of light, derived from ether, are still a limited case of Maxwell's mature theory of electromagnetism, and similar examples are available from the theory of heat but also economics and biology (see Votsis (2018, p. 113)). Therefore, it seems that ESR explains away discontinuities in at least some theory changes while keeping the advantage of NSR to confirm the intuition that science goes beyond knowledge of empirical regularities.

The original version of ESR is restricted to theories that consist of mathematical equations like those in natural sciences. In an attempt to make ESR more generally applicable, Worrall proposes to take Ramsey sentences as the structure of any theory (Votsis 2018, p. 110). Here, ramsification is the process of replacing unobservable terms through existential quantifiers which eliminates the ontological commitment to these terms without losing the postulated relations between them. If the ramsified theory is true, as assumed in ESR, it can be proven that the resulting structure is in a true relation to the part of the world described by at least one part of the theory called model (Frigg and Votsis 2011, pp. 30-1). Unfortunately, the same line of reasoning includes that the Ramsey sentence of a theory is true as long as the theory fits the observational data and has a model of right cardinality but irrespectively of its claims about unobservable entities. Thus, it can be objected that any structure is definable on the Ramsey sentence of a model as long as its cardinality is sufficiently large, such that ESR provides only trivial knowledge beyond the observational predictions (Votsis 2018, pp. 115-6)[4]. The successful defence of ESR requires a more sophisticated way of identifying the unobservable structure of theories in contrast to the non-structural parts. But so far, this seems impossible to me in general terms if one does not simply take it as what survives scientific revolutions. Following this path would deprive ESR of all its advantage and present it as unnecessarily restrictive compared to NSR.

The difficulties of separating the structure of a theory can be avoided by adopting ontic structural realism (OSR): structures replace objects as fundamental entities of reality, and successful theories reveal them (Frigg and Votsis 2011, p. 48). One motivation for

scientific realism as I defined it in this essay.

[4]Ainsworth (2008, pp. 138-40) shows that a ramsified model of a theory becomes true even if it represents the right cardinality for the entities responsible for unobservable relations. This implies that even in this improved case, we lack knowledge about the unobservable structure.

OSR is quantum mechanics where it is an open debate whether quantum particles can be interpreted as individual entities or not (French and Ladyman 2011, p. 29). In its moderate version, OSR accepts such individual objects in its ontology but structures are autonomous. Thus, objects lack intrinsic properties, so properties which can be held by the object independent of other entities[5]. It might be objected that this seems counter-intuitive because most scientists assume that structures supervene on theoretical objects and not vice versa. Also, it seems inconsistent to hold on to the category of objects even though they lack any intrinsic properties which are typically used to define them (Dicken 2016, p. 159). How can OSR know that these are still objects then?

I think that if OSR wants to be convincing, it needs to adopt a more radical or at least eliminativist version. Here, only structures are real and objects are at most place-holders that ultimately reduce to structures. Ecology is one example where this idea fits well because ecosystems as macro-structures are fundamentally relational. Frigg and Votsis (2011, p. 52) object, however, that radical OSR leads to an infinite regress of reality: if in every relation, the relata are relations themselves, a fundamental level of existence is never reached. Interestingly, this "groundlessness" is a well-accepted point in Buddhist philosophy, and Varela et al. (2016, p. 227) argue that the world we experience can be lawful even in such a world without grounding. For example, our experience of colour has no absolute ground either in the physical world or the observer, but still, the colour phenomenon is perfectly commensurable and scientifically meaningful. Further issues arise from explaining causation without assuming individual objects Though, Psillos (2013, p. 30) argues that causality, like intrinsic properties, is part of a metaphysics based on Aristotle, which could be rejected in favour of a Neo-Humeanian stand whose commitment to regularities is without the necessity of a distinct layer of entities supposedly enforcing them.

Is OSR then better off than NSR? I do not necessarily think so. To secure scientific realism, OSR makes the ambitious move to a radically different ontology without fully engaging with the metaphysical positions it leads to. Thus, OSR seems like an ad hoc reaction to save structural realism from the critiques of its epistemological version, rather than scientifically informed. In particular, even though quantum mechanics opens up the possibility that OSR presents the correct ontology, it is far from proven. Therefore, a realist should rather be open to all options in the light of the current knowledge. What is, however, important for my overall argument is the strategic shift of OSR towards

[5]For example, inertial mass could be interpreted through its relation to acceleration which itself is a relational property (Votsis 2018, p. 112).

metaphysics: the ontological clarification of what exists as well as what is "truth" is part of the task to link epistemic success to truth, in particular, the world cannot be equations or models only but needs to be interpreted which is the task of metaphysics (French 2018, p. 395).

Therefore, the sought explanation for the link is required to work from both ends, the epistemological as well as metaphysical. Both NMA and ESR avoid metaphysical discussions by attempting to let epistemic-informed science overtake all the work, very much in the tradition of logical empiricists who denied metaphysics. However, as Putnam (1987, p. 8) points out, "science is wonderful at destroying metaphysical answers, but [is] incapable of providing substitute ones. It takes away foundations without providing a replacement". To make progress, I would therefore suggest that science, as the accepted epistemic endeavour in the West, leads the way with regard to new predictions about the unobservable, but it needs to be balanced by explicating the notion of "approximate truth" required to fulfil the intuition of scientific realists that predictive successful theories are connected to reality. Here, metaphysics needs to play a central role in identifying the notion and its plausibility regarding the latest scientific progress. Metaphysics itself becomes a kind of research program influencing as well as influenced by epistemic progress.

According to this procedure, it becomes obvious why NSR and ESR failed to defend scientific realism: both are based on the naive idea that science is an objective, value-free endeavour able to find absolute truths irrespective of metaphysics. I think a better starting point is the Kantian view that scientific knowledge is always situated in a human perspective, though not a priori (Massimi 2018, p. 166). Thus, scientific knowledge becomes an expression of the relation between our biologically informed cognition and the world it purports to know (Varela et al. 2016, p. XXVII), and it is further contextualised in a cultural-historic manner: scientists have at any given time only access to a finite number of models, which necessarily constrains the available data and possible interpretations of these data. This is not to say that pragmatism or contextualism needs to be endorsed due to underdetermination between rival theories. Instead, realism can be maintained by postulating a mind-independent world with truths independent of individual points of view, while acknowledging that our conditions to know parts of reality depend on our scientific perspective (Massimi 2018, p. 174). Different models provide no incompatible representation of the world but partial and perspective images of an ultimately coherent representation of reality (Massimi 2018, pp. 167-8)[6]. At the same time, scientists should

[6]Miyake (2018, p. 342) provides an example for this co-evolution of models from earth science: The best evidence for the existence of a property beneath the earth surface is reached if measurements report

become humble about the reliability of their models and attune their expectations to the field of science and the kinds of theories involved (Godfrey-Smith 2003, p. 179).

According to this perspective realism, theories are approximately true if accepted and predictive successful, like in NSR, but only if the theory meets relevant perspective standards of performance-adequacy in its context of use[7]. Thus, current scientific truths are the best ones we are entitled to as of today's reached perspectives, and we can utilise them as standpoints for retaining or withdrawing other perspectives dependent on their performance-adequacy. Scientific progress becomes progress of perspectives, and I would argue it is continuous over time including during theory change: the perspectives today are contextualised by the experimental and theoretical insights from the past, and our current variety of perspectives will eventually inform succeeding ones (Massimi 2018, p. 172).

In conclusion, the advantage of naive scientific realism over structural realism is the straightforward confirmation of the intuition of scientists through the No Miracles Argument. But in this most simple and elegant form, it cannot account for the existence of scientific revolutions that lead to at least partial discontinuities in theory change. Epistemological structural realism convinces me in as much as it is not required to retain everything a scientific theory claims to remain a realist. However, this form of structural realism has the disadvantage of requiring a clear distinction between observable and unobservable entities without any other knowledge about them in advance. Its failure led to the development of ontic structural realism which avoids the difficulty of dividing theories by replacing the predominant ontology of individual objects with one containing structures as the basis of reality. I argued that this step is metaphysically overhasty and instead, we should accept a line between the known and unknown somewhere in the unobservable world even though it might not be categorical. What the discussion however shows is that linking epistemic success to a metaphysical understanding of truth requires two arguments, one about the continuity of certain parts of the theoretical entities of a theory and one about how this accumulation of success can inform an acceptable notion of truth. Solving both problems through either epistemology or metaphysics only fails. Instead, both are required and need to inform each other to secure progress. I

diverging results about the supposedly same entity but these then, lead to new aspects about the entity which can be verified independently by rival models.

[7]For example, the exact reference of the term "viscosity" is differently understood in hydrodynamics and statistical mechanics. This does not mean that the term is indetermined, open for a pragmatic solution or never to be determined. Instead, it is only undetermined until the contextual truth conditions are put in place (Massimi 2018, p. 171).

presented perspective realism as a convincing starting point for this endeavour because it allows scientists to accumulate context-informed perspective knowledge about reality while accounting for theory changes. In this regard then, I am a scientific realist.

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