The No-Miracles Argument without Scientific Realism

Richard Dawid[1]

According to the no miracles argument, scientific realism provides the only satisfactory explanation of the predictive success of science. It is argued in the present article that a different explanatory strategy, based on the posit of strong limitations to the underdetermination of scientific theory building by the available empirical data, offers a more convincing understanding of scientific success.

1. Introduction. Having been long overshadowed by other notions of underdetermination, the question of the underdetermination of scientific theory building by the available empirical data has lately attracted increasing attention. [Stanford 2001, 2006] makes the point that it is this form of underdetermination, referred to under the name 'transient underdetermination', that offers the strongest argument against scientific realism. In a more specific scientific context, [Dawid 2006, 2013] argues that indications for strong limitations to the same kind of underdetermination – called scientific underdetermination in that context – are responsible for the trust physicists can develop in their theory despite a lack of empirical confirmation.

The present paper will emphasise the importance of scientific underdetermination for a debate that has mostly been framed in quite different terms so far. Limitations to scientific underdetermination can provide a viable explanation of the predictive success of science and may be abductively inferred on that ground. The resulting argument resembles the classical no miracles argument (NMA) [Putnam 1975], which abductively infers scientific realism from the predictive success of science and is often considered the best available argument in favour of scientific realism. It shall be demonstrated in this paper that the posit of limitations to scientific underdetermination provides a substantially more satisfactory framework for explaining the predictive success of science than full fledged scientific realism.

After a short analysis of some reasons for the failure of classical NMA in Section 2, Sections 3 and 4 discuss the significance of the question of scientific underdetermination in the given context. Section 5 presents the general layout of an argument that works analogously to NMA but is based on underdetermination.

2. Why classical NMA is bound to fail. NMA is a three step argument. First it is asserted that the frequent predictive success of science looks like a miracle as long as one does not assume scientific realism. Then it is argued that scientific realism, i.e. the position that the statements of well-established scientific theories are largely approximately true in a literal sense, can in fact provide a satisfactory explanation of the predictive success of science. Finally, inference to the best explanation leads to the conclusion that scientific realism is probably true. Some philosophers (see e.g. [Musgrave 1985]) have specified step one by emphasising that only successful predictions of genuinely novel phenomena require a realist explanation, while the frequent occurrence of correct scientific predictions which constitute mere extrapolations of a pattern of observations are explicable based on the validity of the

[1] Stockholm University, email: Richard.dawid@philosophy.su.se

principle of induction without any further assumptions. This more specific understanding of NMA shall be adopted in the following.

While the viability of NMA has been questioned in a number of ways, I want to focus on one fundamental problem that may be phrased in terms of a dilemma with respect to the specific interpretation of the notion of "predictive success of science". The latter notion can be understood in two distinct ways. One interpretation takes predictive success of science as referring to the success of individual scientific theories: the philosopher asks why specific scientific theories make successful predictions. In line with [Dawid and Hartmann 2017] I will call this understanding the individual theory based notion of predictive success. The version of NMA based on it shall be called individual theory based NMA. The alternative is to understand the predictive success of science as referring to the scientific process. In this understanding, the phenomenon to be explained by NMA is not the predictive success of individual theories but rather the fact that the scientific process frequently leads to the emergence of theories which make successful predictions. The core of the question is thus shifted to an epistemic level: why are scientists capable of finding predictively successful theories so often? This second notion of predictive success shall be called the frequency based notion. The version of NMA based on it shall be called frequency based NMA. Both the individual theory based and the frequency based understanding of NMA can be found in the literature[2] and quite frequently the distinction is not clearly spelled out. Once the distinction between the two understandings of scientific success has been acknowledged, however, it is quite straightforward to show that neither can fully support NMA: while the individual theory-based notion fails to establish step one of the argument laid out in the first paragraph of this section, the epistemic notion does not support step two.

Looking at the **individual theory based notion of scientific success**, one first notes that it is focused on the theory itself rather than on the historical contingencies of the research process, which makes it insensitive to the distinction between *accommodation* and *novel confirmation. Accommodation* denotes the theory's consistency with empirical data that has influenced its creation, while *novel confirmation* denotes the successful prediction of data that has not influenced the theory's creation. If one focusses on the individual theory and its characteristics rather than on the scientific process, a theory's scientific success is reduced to the fact that the theory saves the phenomena. Novel confirmation on that reading of scientific success does not seem to have higher confirmation value than accommodation. As pointed out in [van Fraassen 1980], however, the explanation of predictive success turns into a fairly unspectacular enterprise on that basis. A theory's success can be understood to be the immediate consequence of two primitive facts: the theory's mathematical structure (plus its physical interpretation) on the one hand and the empirical data on the other. A theory's predictive success then is sufficiently explained by pointing out that, qua its mathematical structure and the way it is fit to the data already available, the theory is empirically adequate with respect to some data set collected after its creation. The scientific realist seems to be at loss to offer a plausible reason why any other explanation of scientific success should be required.

The realist might try to counter this line of reasoning by insisting that a purely analytical argument cannot explain two contingent elements in the observation of a specific theory's predictive success: (i) the observation that this specific theory rather than any other has been successful; and (ii) the observation that we have a predictively highly successful theory on the given subject at all.

The first point has been successfully defeated by Bas van Fraassen's Darwinian argument. The fact that we end up with a successful theory rather than one of the not so successful ones is simply a matter of theory selection based on success. The second point,

[2] An example for an epistemic understanding of NMA is [Musgrave 1985], a recent example for an analytic understanding is [Lyons 2003].

referring to the observation that a predictively successful theory has been found at all, fails because the observation just cannot be shown to be in need of an explanation within the framework of individual theory based NMA. Though it is correct that an individual theory that is randomly chosen from a set of theories that have not been selected according to predictive success is unlikely to be predictively highly successful, this statement on its own does not determine the probability that a theory that is predictively successful has been developed. The additional pieces of information required for stating that probability would be the number of possible scientific theories and the number of theories scientists have developed. The situation may be compared to a lottery where, despite the fact that winning is extremely improbable for each individual player, it may still be likely that someone will do so for the simple reason that many people participate. Analogously, a sufficiently large number of theories that have been developed could make it likely that at least one of those is predictively highly successful on purely numerical grounds. In this light, since individual theory based NMA addresses neither the number of possible scientific theories nor the number of theories that have been developed, it fails to specify a scenario within which the existence of a predictively successful theory can be in need of explanation.

This problem is directly related to the charge, first put forward in [Howson 2000], that NMA commits the base rate fallacy. According to Howson, the supporter of individual theory based NMA fallaciously believes that if a false theory is unlikely and an approximately true theory is likely to be predictively successful, this implies that a predictively successful theory under scrutiny is probably approximately true. As Howson points out, hat inference is not justified as long as the *base rate,* that is the prior probability that the theory is approximately true, has not been taken into account. As argued in [Menke 2014, Henderson 2017 and Dawid and Hartmann 2017], Howson's reasoning applies specifically to individual theory based NMA, which provides no basis for extracting the base rate. In line with the previous analysis, one could characterize the situation the following way: as long as the base rate has not been specified, it has not been demonstrated that a theory's predictive success poses a problem that requires an explanation at all.

So far, we have not even succeeded in establishing the first of the three steps required for a successful abductive inference from scientific success to scientific realism: we have not even found a problem scientific realism could try to solve. The **frequency-based notion of predictive scientific success** does master this first step. The presented arguments that worked against individual theory-based NMA fail against frequency based NMA. The phenomenon of the frequent occurrence of successful predictions of new phenomena in science is a contingent observation about the research process that cannot be explained analytically by comparing data with the theory's predictions. Nor does the setup of the problem suffer from the base-rate fallacy. As demonstrated in [Dawid and Hartmann 2017] extracting a frequency of predictive success amounts to specifying the base-rate in the context of Howson's analysis and therefore does specify what is in need of explanation. While I have no basis for being surprised about the existence of an individual successful theory as long as I know nothing about number of theories that were developed but failed, a significant success frequency among scientific theories may well be surprising and may require an explanation. Darwinian reasoning fails in the frequency-based case as well. Since we now look at the historical record rather than just at an individual theory and its characteristics, the problem of scientific success now can be phrased in terms of novel confirmation: why do scientists so often choose the 'right' theories with respect to empirical data that has not influenced the process of theory selection? A Darwinian answer that consists in pointing to the process of theory selection in this case just begs the question.

The antirealist can still deny the need for explanation by denying any significant tendency towards successful predictions of novel phenomena in natural science (see e.g. [Fine 1986]). This claim looks fairly unconvincing, however. Even though it seems difficult to come up with any kind of theory counting algorithm that would allow for a quantitative assessment of the ratio of scientific theories in a field that give successful predictions, it is obvious that the exact sciences have a dramatically higher rate of novel predictive success than other kinds of scientific analysis (like humanities) or other kinds of intellectual activity (like science fiction). This difference does seem to deserve some kind of explanation.

Epistemic NMA therefore is far more successful than its analytic cousin in establishing that it addresses a serious problem that afflicts the understanding of science. It achieves this success by increasing the explanatory task for scientific realism from explaining an individual theory's predictive success to explaining a tendency of novel predictive success within a research field.

Unfortunately, it thereby raises the bar to a height scientific realism is incapable of jumping. As [Laudan 1981] and [Fine 1986] were among the first to point out, even if the realist were right in asserting that a theory's approximate truth can be inferred from its past predictive success, the available empirical evidence would offer no reason for assuming that the theory's approximate truth extends to those theoretical aspects that are responsible for the prediction of so far untested phenomena. The problem is based on the fact that even the staunchest scientific realist cannot claim that successful scientific theories are absolutely true. In light of the history of science, even very successful theories are expected to fail empirically someday. That failure will then lead to the development of new theories that, in the realist's understanding, will be even closer to absolute truth. In order to account for this view, scientific realists claim merely the approximate truth rather than the absolute truth of successful theories. The concept of approximate truth is deployed specifically in order to allow for the *failure* of an approximately true theory's future predictions. It seems very difficult to defend the idea that the deployment of the very same concept can also explain the theory's predictive success. The scientific realist thus seems in no better position than the antirealist to explain the scientist's capability of generating successful scientific predictions of novel phenomena.

3. The Case for Scientific Underdetermination. The analysis up to this point suggests that NMA fails because it cannot escape a lethal dilemma: if it merely addresses the predictive success of individual scientific theories, there is nothing "miraculous" to be explained; if it addresses a tendency of predictive success in a research field, an interesting problem does arise, but scientific realism is incapable of offering a solution. The present paper aims at providing an alternative to scientific realism that is capable of addressing the second, frequency-based problem in a satisfactory way.

We have already encountered the question that shall be crucial for achieving the envisioned goal. The reason why individual theory based NMA does not get off the ground lies in its silence regarding the question of how many possible scientific theories could fit the available empirical data. It shall be argued in the following that the implicit assumption that the number of possible alternative theories is limited (henceforth to be called the assumption of limitations to scientific underdetermination) is crucial for the intuitive appeal of NMA as well as for advanced attempts to rescue NMA from the arguments presented in the previous section. Eventually it will turn out that the posit of limitations to scientific underdetermination can provide an explanation of the predictive success of the scientific process independently from the posit of scientific realism.

4. Intuition-Based Scientific Realism and its Successors. We start the analysis by raising a question that seems to have no immediate connection to scientific underdetermination. Given the fairly straightforward character of the argument presented at the end of Section 2, why does NMA nevertheless look intuitively very plausible?

In order to get closer to an answer to this question, let us imagine, for the moment, a simpler world than the one we live in. In that world, all physical phenomena can be described by applying to unobservable objects the classical physical laws which guide observable processes. A scientific realist in this 'classical-world' may endorse the rigid 'classicality'-condition that all real objects behave exactly like observable objects. The theorist who wants to avoid false theories in this world can only posit objects of smaller size and must try to reproduce any new microphysical data on that basis. Scientific realism based on the rigid classicality-condition thus implies very severe limitations to scientific theory building by excluding all theoretical schemes that fit the available empirical data but do not have a rigidly classical interpretation. A rigid classicality realist can explain predictive success by pointing to the very limited options of theory building under rigid classicality realism. It may still happen that new phenomenology opens up due to unconceived smaller objects (the present theory thus may not be absolutely true), but no new theoretical principles will be added and the claim of approximate truth can be upheld. An additional assumption on the scarcity of new particles then can provide a basis for explaining predictive success in the given scenario. NMA works in this scenario because rigid classicality realism enforces strong limitations to the underdetermination of theory building by the available data.

For a long time, scientific theory building aimed at defending a watered down version of classical-world, retaining characteristics of observable objects in the conceptions of unobservable objects whenever possible.[3] Successes which were achieved along these lines[4] could then be realistically explained – more or less convincingly - by following the strategy laid out in the classical-world example. Twentieth century physics, however, made life considerably more difficult for the scientific realist. Modern physical theories like special and general relativity, quantum mechanics or gauge field theory jettison so many elements of the intuitive human notions of physical objects, space and time that those elements which have survived so far may be expected to be sacrificed to some future theoretical change. Classical intuitions about the behaviour of physical objects thus don't play a significant role for the construction and interpretation of today's fundamental physical theories. As a consequence, scientific realism has left behind its intuitive roots. Modern NMA is formulated without any direct reference to intuitive notions of physical objects[5] and focuses on the abstract concept of the relation between a statement's empirical success and its truth. The negative implications of this step, however, have already been pointed out: if fully retreating to the described core definition, scientific realism forsakes its normative authority in scientific theory building and thus loses its ability to enforce restrictions to the underdetermination of scientific theory building. Lacking this instrument for providing an epistemological explanation of successful theory choice, it finds itself in the unfortunate situation sketched in section 2.

In order to save NMA, the realist therefore must look for concepts other than ontological naivety which can work as guidelines towards true theories by enforcing limitations to scientific underdetermination. The most popular candidates for this role (see e.g. [Boyd 1984]) are criteria like simplicity, lack of *ad-hoc*-ness, universality or predictive power[6], which seem to play a significant role in the construction and selection of scientific theories. They may be deployed by the realist in the following way. One finds (i) that

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[3] Early claims of a univocal relation between the visible phenomena and the theory compatible with them like Newton's 'deduction from the phenomena' arguably may be understood to a considerable extent as being based on this approach.

[4] Prominent examples are the kinetic gas theory or early atomic models.

[5] Realism at the beginning of the 20th century, to the contrary, was still based on a largely intuitive notion of physical objects. Duhem's arguments against a realist interpretation of scientific theories [Duhem 1906] were mainly attacking the deployment of classical ideas about physical objects in the microworld.

[6] Predictive power denotes the extent to which a theory predicts specific future empirical data. This has to be clearly distinguished from predictive success, which denotes the extent to which a theory's predictions are being empirically confirmed.

successful scientific theories tend to fulfil the abovementioned criteria and (ii) that theories built in accordance with these criteria tend to be successful. Both observations can best be explained by assuming that the true description of reality fulfils the stated criteria or criteria closely related to them. Searching for theories which fulfil the stated criteria then enhances the chances of finding theories which are close to truth.

A careful look at the structure of the above argument reveals, however, that its success does not depend on the core posit of scientific realism. Scientific predictiveness is explained by introducing general scientific criteria like universality which guide the scientific process. and thereby enforce limitations to the underdetermination of theory building. The argument relies solely on the assumption that our present theories in some way reflect the universality or similar properties of the true theory. It remains valid whether or not the substantial claims of current scientific theories are approximately true.

In addition, the assumption that the application of criteria like universality suffices for guiding the scientist towards predictively successful theories is by no means self-evident. Universality would not be a good indicator of a theory's predictive success if the limitations to the underdetermination of theory building which applied with regard to scientific theories that are consistent with the data and at least as universal as the one under scrutiny were not sufficiently strong. Assumptions of strong limitations to scientific underdetermination thus constitute the actual core posits of any attempt to explain scientific success based on the scientists' adoption of some set of preconceptions which guide theory selection. The scientific realist's reference to additional criteria for theory selection thus is based on a misjudgement with respect to the focus of the applied argument. The explanatory power provided by those criteria does not depend on the approximate truth of the scientific theories actually selected. Rather, it is based entirely on the posit of significant limitations to the underdetermination of theory building that is carried out in accordance with the given criteria of theory selection.

5. A Different Way of Explaining Scientific Success. A picture emerges that suggests an altered perspective on the question of predictive success in science. While the explanatory power of scientific realism dwindles in more abstract, unintuitive scientific contexts, the question of scientific underdetermination retains its crucial position for an understanding of scientific success. The search for an explanation of scientific success therefore might better focus on an analysis of the limitations to scientific underdetermination without insisting on the posit of full-fledged scientific realism. The classic form of NMA then could be replaced accordingly by an abductive argument that involves scientific underdetermination rather than scientific realism.

I suggest the following approach. The naturalness of scientific success shall be taken to be expressible in terms of the scientist's options for developing scientific theories based on (i) the available empirical data and (ii) some reasonable general preconceptions about the characteristics of scientific theories. In cases where scientific theory building is vastly underdetermined on that basis, an endorsed scientific theory's chances of predicting novel phenomena successfully are minimal. The more limited the scientist's options are, i.e. the stronger limitations to scientific underdetermination arise, the better are the endorsed theory's chances of novel predictive success.

Scientific success in this picture is explained based on the two crucial assumptions of the validity of some general scientific preconceptions and the occurrence of limitations to scientific underdetermination on the basis of these preconceptions. Let us develop these assumptions a little more carefully. The posit of limitations to scientific underdetermination puts restrictions on the set of all scientific theories which are compatible with the available data. This posit can only be meaningful if it is based on some specific framework that defines which set of theories we are talking about. Such a framework may naturally be provided by scientific preconceptions which guide scientific theory construction. Since the posit of limitations to underdetermination is supposed to explain scientific success, it must rest on solid objective grounds. The scientific preconceptions that provide its framework therefore cannot be understood merely in terms of a working prescription chosen by scientists for pragmatic reasons. Rather, they must be related to the world in a way that allows us to trace the fact of predictive success back to some characteristics of the world itself. It shall thus be assumed that there exists a true theory, or, to be more careful, an empirically adequate theory, that satisfies conditions which represent a stable core of the scientific preconceptions endorsed today. In this sense, today's scientific preconceptions are taken to be partly empirically adequate, which represents a last vestige of the scientific realist claim that our present theories tell us something true about the world. The message we receive is rather weak, however: it amounts to the modest claim that the world can be fully described by a theory that fulfils a stable core of those scientific preconceptions which are adopted by scientists today.

Now the claim of limitations to scientific underdetermination can be formulated. It is asserted that, within the framework defined by the posited set of empirically adequate scientific preconceptions, the underdetermination of theory building tends to be significantly limited in exact natural sciences. This assertion shifts the discussion to an entirely different level and constitutes the crucial conceptual novelty of the suggested approach: the reasons for scientific success are not searched for in the real world and its similarity to our present theories but rather in the wider realm of potentiality. Information is sought about the totality of all scientific schemes compatible with the presently available empirical data rather than just about the one true theory.

The above analysis faces the obvious problem that we do not know the realm of possible theories. Any knowledge about that realm must be rooted in the claim that limitations to the realm of possible theories are necessary for explaining novel predictive success in science. An argument along these lines constitutes abductive inference of the very same kind the scientific realist resorts to in classical NMA: given that the assumption of limitations to scientific underdetermination offers the most straightforward explanation of the predictive success of science and given that no other approach seems to work in a satisfactory way, it is abductively inferred that the claim that there exist very strong limitations to scientific underdetermination in advanced science is indeed true.

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