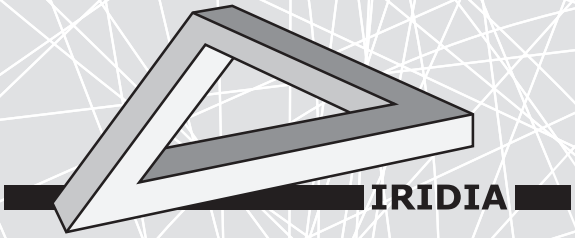

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The Explanation of the Success of Science

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Abstract

The increasing success of science has been traditionally interpreted as a result of the accumulation of truths about reality. This explanation and the cumulative view on which it relies have been challenged on the basis of several criticisms. The more cogent of these criticisms is the pessimistic meta-induction.

In this paper, we propose a novel explanation of the success of science: Through what we call the *negatively cumulative argument*, we advance the idea that science is successful because it accumulates knowledge about negative results. The main original element of the *negatively cumulative argument* is the disengagement of the concept of cumulativity from the one of truth. This disengagement allows the argument to resists the pessimistic meta-induction.

1 Introduction

The explanation of the success of science has been a central issue in the philosophy of science of the last fifty years. In particular, the convergentist explanation (Smart, 1963; Boyd, 1973; Newton-Smith, 1978; Putnam, 1978) has received a special attention in the literature. According to this explanation, science succeeds because it converges toward truth: new theories are supposed to incorporate truths and referents of previous ones and to refine them up to a final picture that truthfully represents reality. The cumulative perspective on which the convergentist explanation stands has been challenged on the basis of several arguments. The more cogent one is the *pessimistic meta-induction* (Laudan, 1981).

In this paper, we propose a novel argument for explaining the success of science. We name it the *negatively cumulative argument*. The core idea of this argument is that the success of science is to be ascribed to the fact that science accumulates knowledge about negative results. Theories are discarded, but something remains in the passage from a theory to its successor: the knowledge about what went wrong. This knowledge and understanding is what allows the scientific community to propose new theories that provide more and more precise predictions.

As we detail in the body of the paper, the original contribution of the negatively cumulative argument is disengaging the concept of cumulativity from that of truth. We describe science as a cumulative process and we ascribe

success to accumulation. Indeed, the undeniable progress that science has displayed through the centuries appears difficult to explain if we do not assume that some knowledge is accumulated even when specific theories are abandoned and replaced by others. Nonetheless, we argue that accumulation should be intended in a negative sense. This allows one to preserve cumulativity while avoiding the challenge of the pessimistic meta-induction. By disengaging the notion of cumulativity from that of truth, the element where the pessimistic meta-induction bites is removed. Failures that science experiences become an essential ingredient of the attainment of success rather than an obstacle to it.

The paper is organized as follows. In Section 2, we briefly survey the main assumptions underlying the convergentist explanation and the criticisms that challenged it. In Section 3, we present the negatively cumulative argument and we discuss the implications and the advantages of a negative view of cumulativity with respect to the views previously proposed in the literature. In Section 4, we conclude the paper with some final remarks.

2 Ontological cumulativity and its problems

A distinctive mark of science is its increasing success. Along the centuries, science has undeniably made great advancements in the control and understanding of Nature. These advancements have been traditionally ascribed to the accumulation of true knowledge about Nature itself. Within the convergentist perspective, in particular, the increasing success of science has been seen in terms of increasing verisimilitude. More precisely, the convergentist perspective stands on the presumption that science advances by continuously refining the correspondence between theories and reality.

The convergentist explanation has a marked teleological and retentionist character that lies on the firm bond between cumulativity and correspondence. Indeed, the basic convergentist presumption is that science does not simply accumulate knowledge about the empirical appearances but rather about the true structure of reality to which science itself is supposed to eventually converge. Accumulation is of an *ontological* nature. This cumulative view of scientific knowledge stands upon what Larry Laudan names the "Russian-doll model of cognitive progress" (1976). According to this view, each theory is like a piece of a more general ontological image of reality that science eventually succeeds to delineate.

The teleological and retentionist explanation of the success of science has been exposed to serious challenges. Laudan's critique (1977; 1981), widely known as the *pessimistic meta-induction*, is one of the strongest ones. On the basis of the observation that a large number of past theories have been proved false and non-referential, though they were predictively successful, Laudan threatens the assumption that the success of a theory indicates that it really catches onto the ontological structure of the world and breaks the basic convergentist link between truth and success.

The counter-arguments that have been formulated in order to answer to the pessimistic meta-induction consist mainly in saving the assumption of on-

tological cumulativity by limiting the impact that failure has on science. Putnam (1978) and Boyd (1984), for instance, try to recover a substantially cumulative image of science by relegating to an immature phase of science those theories that have been proved false and non-referring. In a similar spirit, Kitcher (1993) and Psillos (1999) exclude as not essential to the success of scientific theories the components that have been replaced. Others, like Hacking (1982) and Cartwright (1980), assume that, though theories are replaced, theoretical entities remains invariant. On the contrary, authors like Worrall (1989) and Zahar (2001), remain agnostic with respect to theoretical entities and assume that, notwithstanding the ontologies of theories change, the structural relations of phenomena captured by scientific theories persist.

As it appears from the wide range of strategies adopted in the literature to rescue cumulativity, understanding how knowledge is carried on from old theories to new ones is a central challenge. The issue currently under debate is that, though cumulativity is threatened by the continuous overthrow of scientific theories, it appears difficult to account for the increasing success of science without supposing that something is accumulated in time.[1] Non-cumulative accounts are criticised precisely on the basis of the claimed inability to provide a convincing explanation of the systematic progression of science notwithstanding theory change.

A recent thread in the literature has suggested that to single out a cumulative trend in science notwithstanding failure, the assumption of ontological cumulativity should be dismissed. Interestingly, this thread cuts across antagonistic epistemological positions. For instance, though belonging to two opposing epistemological camps, Bas Van Fraassen (2006) and Alexander Bird (2007) both outline a cumulative account of success that does not stand on ontological cumulativity.

In Section 3, we delineate a cumulative explanation of the success of science that positions itself within the thread opened by Van Fraassen and Bird. Yet, our account of cumulativity differs from theirs in the stress laid on failure as the rationale for success.

3 Cumulativity without truth

In this section we present what we call the *negatively cumulative argument*. This argument is intended to answer to the central issue of providing a cumulative explanation of the increasing success of science that is compatible with theory change. The motivation for defending the assumption of cumulativity is to provide a suitable account of the rational progression of science. As we will show, the notion of cumulativity we outline is immune to the pessimistic meta-induction.

[1] For example, Psillos, among others, has indicated as a priority objective to define a "theory of substantive continuity in theory change" (2000, p. 724).

3.1 Negative cumulativity

The idea that science advances by accumulating truths is a characterizing feature of the modern thought. At least since Kuhn's analysis of scientific progress, the very idea has been taken for granted that the knowledge accumulated by science, if any, is about truth. The advocates of cumulativity have employed this idea to develop a convergentist explanation of the success of science. The opponents have questioned it on the basis of historical counter-arguments and have denied that cumulativity plays a central role in the achievement of success.

In the construction of our argumentation, we assume that the success of science is a product of cumulativity. Following Van Fraassen's (2006) and Bird's (2007) seminal idea, we question the assumption that cumulativity has to be intended ontologically as an accumulation of truths. Yet, we push their reasoning further by arguing in favor of a negative account of cumulativity. While they provide a *positive* account by suggesting that it is the accumulation of what succeeds that explains the success of science, we put forward the idea that it is the accumulation of knowledge about what failed that is responsible for the success. In other words, we fully disjoin the notion of cumulativity from the customarily related notion of truth.

This disjunction is far from being straightforwardly accepted since it entails a fundamental shift in the traditional interpretation of cumulativity. This shift is nowadays compelling because, as sharply pointed out by Van Fraassen and Bird, it is difficult to account for the increasing success of science without supposing that some knowledge is accumulated in time. Yet, it appears arduous to explain why science progresses notwithstanding theory change if both the advocates and the opponents of cumulativity interpret this concept in ontological terms. So far, this interpretation constrained the debate between two extremes: either to reject cumulativity *tout court* or to save cumulativity by putting the issue of scientific revolutions into perspective. In the following, we argue that if cumulativity is intended in negative terms, it can be acknowledged in theory change.

We must admit that a main objection could be raised against what we shall call the *negatively cumulative argument*. Indeed, it seems counter-intuitive to argue that science, which is supposed to convey positive knowledge about reality, advances on the basis of negative knowledge. In Section 3.2, we will show that, notwithstanding the negatively cumulative argument appears counter-intuitive, it remains quite appealing since it avoids major difficulties that challenge the so far proposed views on cumulativity. Here, we introduce the characterizing element of the argument.

The *negatively cumulative argument* stands upon the idea that science is pushed forward by failure. Failure drives science in the sense that the increasing predictive accuracy of scientific theories is the result of a continuously refined ability to catch onto the reasons of wrong judgements and to recover from them. When specific theories fail to pass empirical tests, scientists engage in a sort of reverse engineering procedure aimed at understanding the reason of the failure. This understanding plays a crucial role in the conception and in the design of a new theory that is able to withstand the empirical tests that the predecessor

failed and, as such, to determine a scientific advancement with respect to the past. This advancement can be revolutionary, since the new theory can produce a significant alteration in the ontological account of Nature with respect to the predecessor and can lead to predictions that within the predecessor could not be even conceived. However, in this passage there is something that remains unaltered and that allows to identify a cumulative evolution. This is precisely the knowledge and understanding accumulated about the reason why previous theories have failed. In other terms, successor theories are not progressive with respect to predecessors in the sense that they reproduce the successes that supported the former plus some additional ones. Rather, they are progressive in the sense that they avoid the errors made by their predecessors, from which they inherited precisely the knowledge about what failed.

The negative account of success sketched above differs from both the non-cumulative and the cumulative accounts in one fundamental respect: the relation it establishes between cumulativity and failure.

The negative account is admittedly dysteleological. Coherently with the dysteleological accounts *à la Kuhn*, it characterizes the advancements of science in terms of the increasing predictive ability rather than in terms of the increasing verisimilitude. Nonetheless, unlike the dysteleological accounts proposed so far in the literature, it contains an element of novelty: it is cumulative. By removing from science the goal of converging to truth and by stressing the role played by failures, we do not deny that science accumulates at all. We simply questions the idea that this accumulation must be of a positive character. As far as our negative perspective is concerned, we identify a cumulative progression precisely in the improved ability to rectify hypotheses that clash against reality. Coherently, unlike the traditional cumulative accounts of success, we do not interpret the increasing success of science as an advancement *notwithstanding errors* but rather as an advancement *thanks to errors*. Errors acquire a major epistemic function in that they allow scientists to put forward theories that are able to pass those tests that predecessors failed and possibly new tests that further developments of the scientific practice could determine.[2] This explains why, within this negative perspective, the impact that failure has on science is not mitigated but rather stressed. The ability to extract knowledge from failures becomes the key element to explain the reason of the increasing success of science and of its systematic progression.

It has been claimed in the literature by authors such as Philip Kitcher (1993) and Jarrett Leplin (1997), that a satisfying explanation of the success of science should not simply explain in general how the scientific method succeeds in identifying theories that provide more and more precise predictions, but why specific theories succeed and in virtue of what features. Their argument stands upon the idea that if we do not assume that theories are a better approximation to truth with respect to their predecessors, their success turns out to be miraculous. Coherently with our negative argumentation, we trace back the

[2]It is not the aim of the present paper to investigate in detail the issue of epistemic role of error in science. For an extensive account, we refer the reader to Schickore (2005), which is entirely devoted to this subject. The same subject is treated also in Mayo (1996), which can be seen as an improvement of Popper's falsificationism.

reason why a theory is more successful than its predecessors to a rather different property: the increased *robustness to empirical tests*. The success of a specific theory is not a miracle if we accept that this success is the result of severe testing and, most importantly, of an evaluation of the outcomes of that testing. This evaluation, which is performed at the more general level of the validation procedure, determines the increased robustness of specific theories to potential falsifications and explains why the empirical validation procedure produces such stable results.

In this sense, we can regard the relationship between a theory and its predecessor in terms of being *farther from false* rather than in terms of being *closer to truth*. A theory is *farther from false* if it is capable to withstand empirical tests that the latter failed to withstand, that is, if the error relative to the matching between the expectations drawn from this theory and the actual observations remain under a given threshold that the predecessor failed to attain. A scientific advancement will be then determined by any theory that proves to be *farther from false* than its predecessor. It will be an advancement even if the new theory provides an account of reality that is logically inconsistent with the one provided by the predecessor. This is the case, for instance, of the passage from Newton's to Einstein's mechanics. Though incompatible, these two physical systems constitute a cumulative progression that is not positive but rather negative. Strictly speaking, Einstein's mechanics is not a truth-preserving extension of its predecessor.[3] Rather it is a false-removal progression that results in the extension of the number of cases in which the predictions lie within given margin of errors that the precursor failed to provide.

If we wish to trace a fully cumulative trend within revolutionary transitions in science, we should recognize that there is an asymmetry between the two above mentioned notions of being *farther from false* and of being *closer to truth*. This asymmetry derives from the asymmetry between falsification and verification. While being *farther from false* for a theory can be appraised on the basis of its robustness to empirical tests, it is difficult to determine what does it means for a theory to be *closer to truth*. Defending this mutual entailment would amount to weaken the idea that science advances cumulatively at all since the latter kind of progression cannot be empirically acknowledged. A viable move to preserve the presumption of cumulativity is to argue uniquely in favor of the negative progression and to put aside the ontological one that seems to lack that additional explanatory power that the traditional approaches to cumulativity ascribe to it.

3.2 The appeal of negative cumulativity

It appears from the literature that an account of cumulativity that is robust to challenges is appealing not only for those that traditionally argued in favor of it, but also for those that challenged it. For instance, a convinced oppo-

[3]On the idea that Einstein's mechanics is an extension of Newton's see Worrall (1989). Worrall denies that the passage is cumulative in the traditional sense, that is, in the ontological sense, and discuss the implications of such a kind of representative historical example for the convergentist epistemology.

nent of cumulativity like Laudan does not deny that cumulativity is "a worthwhile desideratum" (Laudan, 1976, p.593) for the explanation of the increasing success of science. Nevertheless, he points out that cumulativity cannot be highlighted in most of the cases of theory change in history. This because, coherently with the literature, Laudan considers that cumulativity, whenever obtainable, is of ontological nature. In Section 3.1, we have put forward the idea that if cumulativity is intended in a negative sense, it can be singled out even within revolutionary changes. Here we investigate the advantages of this negative characterization.

The negative perspective on cumulativity is an alternative to the convergentist one and to the non-cumulative one. It combines elements of the two perspectives while avoiding some major issues that traditionally challenge them. By preserving the idea that the progress of science involves cumulativity, it endorses the rationality of science. Without committing to ontological cumulativity, it makes cumulativity immune to the pessimistic meta-induction.

The idea that science is a rational endeavour has been seriously challenged by non-cumulative views such those of Kuhn and Feyerabend. As concisely pointed out by Laudan, these views have conveyed the idea that, since progress does not involve cumulativity, "either the bulk of science is irrational (because non progressive) or [...] that progress has nothing to do with rationality" (Laudan, 1976, p.587). Laudan's answer to Kuhn's and Feyerabend's challenge stands on the idea that the dismissal of the notion of cumulativity does not prevent from determining the progressive and rational character of science. Progress can be measured on the basis of the effectiveness in solving problems, with no need to commit to ontological cumulativity. Nevertheless, as Laudan admits, the abandon of the notion of cumulativity implies that we "weaken our notion of rationality and progress" (Laudan, 1977, p.127).

Undeniably, the very notion of progress suggests that something is accumulated in time so that it is possible to affirm both that the current phase of the scientific evolution is an advancement with respect to the past and that this advancement is not accidental. If after a revolution all the knowledge gained is lost and completely replaced, it is hard to make a rational sense of how the scientific community has significantly improved its skills, methods and understanding of natural phenomena. The intimate relation underlying cumulativity and scientific progress can explain why many thinkers are reluctant to abandon the notion of cumulativity and why those that have opted for abandoning it are aware of the major implications of this choice. In this respect, the negative approach to cumulativity is advantageous. By abandoning the "traditional connections between progress, rationality and truth" (Laudan, 1977, p.127) we do not conclude that we must also abandon the notion of cumulativity and, thus, that we must accept to weaken the idea of the rational progressiveness of science. Within the negative approach, cumulativity can be safely invoked because it is immune to the challenge that pushed many to reject it: the pessimistic meta-induction.

The peculiarity of the negative approach is that it draws a new relation between cumulativity and success. While in the traditional approach cumulativity and success are linked *via* the notion of truth, within the negative approach the

two concepts are linked *via* the notion of failure. This new system of links simply dissolves the attack of the pessimistic meta-induction since cumulativity is harmonized with its traditional enemy, that is, failure. Strictly speaking, the pessimistic meta-induction does not threaten cumulativity *per se*, but only ontological cumulativity. The observation that successful theories have been later abandoned as false does not question the idea that science accumulates knowledge, but only that science accumulates, and carries over, knowledge on truth. Since in the literature cumulativity has been tightly connected to truth, cumulativity has been rejected *in toto* in those philosophies of science that, on the basis of empirical counter-examples, have challenged the presumption that science is driven by truth. By characterizing cumulativity as an accumulation of knowledge about false, the negative approach frees this notion from the challenge of falsification. This allows one to consider the issue of failures in science in all its complexity while adopting the notion of cumulativity to explain the success of science.

To summarize, the focal point of the negative approach is twofold. On the one hand, the price to pay for obtaining cumulativity is to renounce to truth. The abandon of the notion of truth is the basic condition for obtaining an explanation of success that is safe from the pessimistic meta-induction. On the other hand, questioning truth does not imply to renounce to cumulativity, which is considered a "desideratum" (Laudan, 1976, p.593) also by the proponents of non-cumulative account of the success of science. What the negatively cumulative argument shows is that a cumulative interpretation of the success of science should not be considered as a prerogative of the convergentist epistemology, but that it could be rightly advocated within those dysteleological perspectives that traditionally reject cumulativity precisely on the basis of the pessimistic-meta induction and that, for their dismissal of cumulativity, are considered unable to account for the rational progression of science. If cumulativity is safe from the pessimistic meta-induction it is not only a *desideratum* but it becomes a feasible option.

4 Conclusions

In this paper, we have presented a novel argument to explain the increasing success of science. We named it the *negatively cumulative argument*. The negatively cumulative argument both describes science as a cumulative process and accounts for scientific success, which are two characterizing issues of the convergentist view of science. Nonetheless, contrary to the convergentist explanations proposed so far, the negatively cumulative argument is not affected by the pessimistic meta-induction. This because it does not appeal to the semantic feature of *being closer to truth* to explain the success of science. Rather, it assesses the relation between new theories and their predecessors in terms of *being farther from false*.

The main contribution of the analysis we have proposed in this paper is to have disengaged the notion of cumulativity from that of truth. This allows one to have the best of both worlds: to preserve the notion of cumulativity in the

explanation of success and to give to the issue of revolutionary changes its full weight.

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