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The discovery/justification context dichotomy within formal and computational models of scientific theories: a weakening of the distinction based on the perspective of non-monotonic logics

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ABSTRACT
The present paper analyses the topic of scientific discovery and the problem of the existence of a logical framework involved in such endeavour. We inquire how several non-monotonic logic frameworks and other formalisms can account for such a task. In the same vein, we analyse some key aspects of the historical and theoretical debate surrounding scientific discovery, in particular, the context of discovery and context of justification context distinction. We present an argument concerning the weakening of the discovery/justification context dichotomy based on the descriptive accent contained in the non-monotonic logic perspective together with its epistemological concerns.

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1. Introduction

One of the core concerns regarding the process of scientific discovery is the rationality of such process. That is, whether the process of such knowledge production is a rational one, or if it is beyond the realm of rationality and belongs to the mysterious genius of a few selected individuals. In the aforementioned dilemma, there lies a deep contradiction due to the fact that none of the historical figures in the field of science can be regarded as accidental figures with only luck on their side (this is something to which most, if not all, philosophers and especially scientist themselves would dispute), but if the reasoning process of scientific discovery occurs as a sophisticated reasoning process, then it should be rational and systematic procedure (Alai, 2004).

Hence, towards the problem of scientific discovery, one is able to find two key aspects. First, we have profound esteem and intellectual respect to the great minds which have proposed the great body of knowledge that is science and we also believe that these great minds did not achieve what they did on a mere account of luck. Second, there is a long list of philosophers and scientists who have disregarded the possibility that the process of scientific discovery has a specific logic or set of rules, which can account for such a rational

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endeavour. These two perspectives leave the door open solely to the mysterious geniality of some scientific minds as an explanation of the process of scientific discovery and the great achievements of it.

The aforementioned state of affairs leaves many doubts of whether this is necessarily the case. Furthermore, it seems that there is plenty of room to approach this debate through contemporary advances in long-standing disciplines such as logic, philosophy of science and even from novel disciplines such as computer science and cognitive science. In this paper, we analyse some advances and efforts within a specific debate concerning the problem of scientific discovery, namely, the problem of whether there exists or can exist a logic of scientific discovery. We frame this inquiry in the context of one of the most influential distinctions in philosophy of science, which is the dichotomy that contrasts and opposes two dimensions within scientific endeavour: the context of justification and the context of discovery. We will further analyse the impact this dichotomy has had in the construction of logic and computational models of scientific discovery. In virtue of the aforementioned survey, we propose an argument concerning the weakening of the discovery/justification context dichotomy based on the perspective of non-monotonic logics and similar non-classical logical formalisms. Before tackling our core object of inquiry, we provide a very brief historical sketch surrounding some of the relevant aspects of the debate regarding the problem of scientific discovery.

We start our survey recalling that during the seventeenth and eighteenth centuries, there was a positive attitude towards the existence of a logic of scientific discovery and/or a set of rules leading towards scientific discoveries, to this aspect, one could point a long and exemplary series of philosophers and scientists that like Rene Descartes (1596–1650) and Francis Bacon (1561–1626), all of which embraced the search for a formal and abstract systematisation of the crucial rules concerning the production of scientific knowledge. Nevertheless, during the nineteenth century, this optimism shifted towards the opposite side, in which the prevailing attitude was that scientific discovery is not and cannot be grasped by a set of mechanical rules, or logical principles (Meheus & Nickles, 1999). This latter period would ground the historical antecedent that led to the somewhat romantic view of scientific discovery as only available through insights and scientific genius.

In line with this historical antecedents of the problem of scientific discovery, Gottlob Frege (1848–1925) is one the most influential philosophers in analytical philosophy who portrayed and spread the view that there is no room for a logic of discovery and that the aim of logic itself is the problem of deduction, which has nothing to do with the intricate process of scientific discovery and/or its method. The impact Frege's view had on the topic of the logical method of scientific discovery was deeply rooted in his view towards the anti-psychological nature of logic and in virtue of that, Frege defers the study of scientific discovery to the field of psychology withholding its inquiry in logical terms (Cellucci, 2013). In the same line, Tarski (1994) held the view that there is no way of merging the study of logic and the procedure or methods employed in the process of scientific discovery.

One of the most influential movements that carried with the previously mentioned conviction was a highly influential group of philosophers and scientists established during the first half of the twentieth century known as the Vienna Circle. Among the various themes and concerns surrounding this intellectual group, the problem of scientific discovery was systematically left behind due to its elusive character and reinforced the 'fregean' towards the scientific method. This state of affairs prevailed over a long period of time and has been preserved into our current set of open debates through the analytical tradition of philosophy, which was undisputedly influenced by Vienna's Circle (Noé, 1998).

In the same context as the Vienna Circle, Karl Popper's view on philosophy of science has played a crucial role. Although Popper very much disputed a large array of tenets held by the logical positivists, he did help spread the perpetuation of the attitude towards scientific discovery that completely disregards the existence of any logic of scientific discovery (Cellucci, 2013). Hence, the view of scientific discovery as foreign to a logic has an overwhelming and boldly uncontested tradition in analytic philosophy.

Nevertheless, the whole attitude towards scientific discovery inherited by the logical positivists and Popper changed radically thanks to an emerging and opposing movement in the philosophy of science. In the 1960s, the prevailing trend in philosophy of science shifted somehow by the appearance of a critical movement within philosophy of science, which opposed the views entertained up to the moment by the logical positivists and Popper concerning the nature of scientific discovery. This opposing view, which was composed of authors such as Norwood Hanson, Thomas Kuhn and others, approached the sociological dimension of the topic of scientific discovery, which at the time was a whole new perspective that was historically unaddressed (Noé, 1998). This critical school of the previously established philosophy of science contested a long range of assumptions that both the positivists and Popper held regarding scientific endeavour. Among the new approaches to previous long-standing problems in philosophy of science was the treatment of scientific discovery.

Although this contesting movement of philosophy of science did not hold a positive view towards the existence of a logic of scientific discovery (they did not uphold the view that scientific discovery can be subject to some rules or sound logical heuristics) it did served the logic approach a great deal by reinstating the topic of scientific discovery and its method as an important subject within philosophy of science, which as we said before, was deeply unaddressed (Noé, 1998).

Be it as it may, the very succinct picture we have previously sketched somehow depicts in a broad sense a twofold approach towards the main topics and aspects of scientific discovery. One of the most important theoretical distinctions in philosophy of science emerges with the previous historical background. This matter will be the topic of the next section.

2. The discovery/justification context dichotomy in philosophy of science

In the twentieth century a very influential distinction regarding scientific inquiry emerged, such distinction was based on the existence of two different and opposing dimensions within scientific endeavour: the process of producing scientific theories and hypotheses on the one hand, and the aspects concerning the validation and/or justification of such findings on the other. According to this differentiation, proposed by Hans Reichenbach in his work of 1938 *Experience and Prediction* one dimension of science is the process of conceiving new ideas and theories, and a different dimension is the process of grounding and justifying those ideas. The former is denominated the context of discovery and the latter is the context of justification. As Reichenbach (1938) states it:

> There is a great difference between the system of logical interconnections of thought and the actual way in which thinking processes are performed. The psychological operations of thinking are rather vague and fluctuating processes; they almost never keep to the ways prescribed by

> logic and may even skip whole groups of operations which would be needed for a complete exposition of the subject in question. … It would be, therefore, a vain attempt to construct a theory of knowledge which is at the same time logically complete and in strict correspondence with the psychological processes of thought. […] The only way to escape this difficulty is to distinguish carefully the task of epistemology from that of psychology. Epistemology does not regard the processes of thinking in their actual occurrence; this task is entirely left to psychology. What epistemology intends is to construct thinking processes in a way in which they ought to occur if they are to be ranged in a consistent system; or to construct justifiable sets of operations which can be intercalated between the starting-point and the issue of thought-processes, replacing the real intermediate links. Epistemology thus considers a logical substitute rather than real processes. (p. 5)

This discovery/justification context dichotomy would boldly influence the field of philosophy of science, as it would shape out some of the key debates in philosophy of science such as whether there can be a logic of scientific discovery or what was the role of philosophy in regards to scientific endeavour. Furthermore, the distinction would be retaken from its conception in Reichenbach's works of 1938 all through contemporary philosophy of science. For example, Feigl (1965) underscored the irreducible and categorical differentiation among the different dimensions of scientific enterprise:

> There is a fair measure of agreement today on how to conceive of philosophy of science as contrasted with the history, the psychology, or the sociology of science. All these disciplines are about science, but they are 'about' it in different ways. … In the widely accepted terminology of Hans Reichenbach, studies of this sort pertain to the context of discovery, whereas the analysis pursued by philosophers of science pertain to the context of justification. It is one thing to ask how we arrive at our scientific knowledge claims and what socio-cultural factors contribute to their acceptance or rejection; and it is another thing to ask what sort of evidence and what general, objective rules and standards govern the testing, the confirmation or disconfirmation and the acceptance or rejection of knowledge claims of science. (p. 472)

Based on the previously historical formulations and precisions of the discovery/justification context dichotomy, one can point out that it grounded the view that there is no room for logic regarding the process of scientific discovery or its method, but only in the context of justification such discussions and methods were legitimate. Furthermore, epistemology and philosophy of science should only concern to the rational reconstruction of the context of justification, since its discovery counterpart would be an object of psychology or some other descriptive enterprise, but it would certainly not be an object of inquiry in the highly normative field of philosophy. In the same vein as Feigl, Karl R. Popper conspicuously reinstated the dichotomy in one of his most influential work concerning the very core discussion of the existence of a logic of scientific discovery, in which he stated the following:

> The initial state, the act of conceiving or inventing a theory, seems to me neither to call for logical analysis not to be susceptible of it. The question how it happens that a new idea occurs to a man – whether it is a musical theme, a dramatic conflict, or a scientific theory – may be of great interest to empirical psychology; but it is irrelevant to the logical analysis of scientific knowledge. This latter is concerned not with questions of fact (Kant's quid facti?), but only with questions of justification or validity (Kant's quid juris?). Its questions are of the following kind. Can a statement be justified? And if so, how? Is it testable? Is it logically dependent on certain other statements? Or does it perhaps contradict them? […] Accordingly I shall distinguish sharply between the process of conceiving a new idea, and the methods and results of examining it logically. As to the task of the logic of knowledge – in contradistinction to the psychology of knowledge – I shall proceed on the assumption that it consists solely in investigating the methods employed in those systematic tests to which every new idea must be subjected if it is to be seriously entertained. (Popper, 2002, pp. 7–8)

At this point, it's important to make a clear statement concerning the scope and limitations of the notions surrounding the discovery/justification dichotomy or distinction. Throughout this paper, we will make a difference concerning the terms 'dichotomy' and 'distinction'. In the sense of a discovery/justification *dichotomy*, both discovery and justification refer not only to different process and/or tasks but it also refers to different moments in scientific endeavour, which are ultimately irreducible. To the contrary, in the sense of a discovery/justification *distinction*, both dimensions would make reference to different processes involved in scientific inquiry but they would not imply the bold and irreducible differentiation of both dimensions. Up until now, we have presented in a very succinct manner the discovery/justification context debate, the two senses of such differentiation (i.e. 'dichotomy' and 'distinction') and its supposed mandate for different questions and methods concerning the different dimensions of scientific endeavour. Nevertheless, some of the basic presumptions are highly debatable in the context of philosophy of science, cognitive science and logic.

It's important to point out how one can read a strong sense of the discovery/justification distinction in the previously surveyed philosophers of science. For example, Reichenbach's stance is undoubtedly a strong version of the distinction, i.e. he would be placed among the authors who defend the dichotomy aspect of the distinction. This is due to his characterisations of the inner process of scientific reasoning as 'vague', 'fluctuating' and that it 'almost never keep to the ways prescribed by logic'. In the same quite strong and bold position, one can find Popper's view concerning the process of producing scientific knowledge which he characterises as being 'in contradistinction to the psychology of knowledge'. Therefore, one can arrive at the conclusion that in the context in which the dichotomy emerged, the prevailing approach to such distinction was grounded in the view that the two dimensions of the process of scientific inquiry were not only categorically apart but that they were opposing moments in the production of scientific knowledge and each dimension should be addressed with very distinct criteria and methods. Based on the above precisions, we can sketch such dichotomy as follows:

Context of Discovery	Context of Justification
1. Vague	1. Precise
2. Irrelevant to logical analysis	2. Relevant to logical analysis
3. Subject of psychology and/or other empirical sciences	3. Subject of Philosophy of science as a normative and prescriptive discipline
4. Does not follow any set of normative pattern or other formal rules	4. It follows a set of normative pattern or other formal rules
5. Involves historical, social and other ambiguous aspects	5. Does not involve in any form or manner historical, social and other ambiguous aspects

With such background, in the next section, we will address some basic problematic issues concerning the dichotomy of contexts presuppositions, and we will construct a taxonomical sketch of such dichotomy in the context of formal models of scientific knowledge.

3. Some general debates surrounding the discovery/justification dichotomy and the construction a taxonomy of such dichotomy in the context of formal models

First, we want to point out that one of the core topics concerning the aspects of the context of discovery lies in the comprehension of the nature of creativity in the context of scientific inquiry. This is due to the fact that the extent and limitations of understanding and – even more – modelling such a reasoning process can account for the acceptance or dismissal of the discovery/justification dichotomy. To this matter, it can be stated that creativity, in the context of scientific inquiry, can generate a myriad of plausible ideas but scientists as a norm do not take them up to inspection on a random or careless basis. Contrary to the above, there seems to be a decision-making process that rules some out and keeps others, by its very nature, this decision-making process of ruling hypothesis or ideas out and keeping others must have some sound criterion by which the process goes along no matter how creative the roots of those ideas can be (Cellucci, 2013).

In particular, the model of Ward, Finke, and Smith (1995) GENEPLORE, provides a framework under which such psychological creative process can be understood. According to the GENEPLORE model, the creative process is divided into two main phases. On a first phase, an individual generates an idea. To this aim, one only needs to search for simple cognitive processes such as recalling information from previous experiences or any other sort of elementary cognitive abilities. The outputs of this phase are the building blocks that are involved in the later phase. On the second phase, the individual explores the creative and combinatorial possibilities attached to the ideas previously produced. According to Picciuto and Carruthers (2014), this twofold model can shed light towards the emergence and development of creative processes in human infants and to the existence of such faculties in other non-human animals. Hence, in virtue of this framework of understanding the creative component in human reasoning, one can draw the thesis that, for the production of new hypotheses or theories, in the context of scientific discovery (a particular dimension of human creativity), there is no need to rule out any form of systematic rule following schema or rational approach, such as tree searches, conceptual frameworks, production systems, etc. This would leave the possibility for a rational approach to understand and model inferences involved in scientific discovery.

In line with the above, and despite the creative ingredient that might be involved in the production of knowledge – even in the realm of scientific knowledge – one can hold the acceptance of a rational scheme in this reasoning process based on the fact that even such creative components of scientific inquiry are subject to a problem-solving procedure that requires the proposal of inferences (Meheus, 1999). Hence, based solely one of the key ideas of this theoretical framework of cognitive psychology one finds grounds to question the boldness contained in the strong interpretation of the discovery/justification distinction (for example, Reichenbach's interpretation). This last thesis would be supported by the fact that even the creative dimension of scientific reasoning process would be subject to some form of rational and precise analysis, which stand in direct contradiction of what is stated in the classical and strong version of the distinction.

Leaving the 'discovery' side of the debate, there remains the important discussion concerning the context of justification in the studied dichotomy. One of the main topics of discussion regarding the problem of the justification in the context of scientific inquiry lies in the possibility of modelling this process, whether it is through the methods of classical logic or some other formal systems: or if this side of the scientific enterprise is doomed to be far beyond any rule-following, systematic and rational approach. To this matter, it has been pointed out that the process involves inferences in which a conclusion is derived or sought to derive on the basis of previous knowledge or evidence (Cherkassky, 2012). Furthermore, those inferences must be ground on some sound and valid procedure. Therefore, if at the core of the process of justification of scientific theories lies the production and manipulation of inferences and other human reasoning mechanisms, it follows that there has to be some kind of rule-following procedures or rational deliberation at least that lies beneath this inference process conducive to scientific discovery. Furthermore, one can point out that in the context of this debate, several frameworks such abduction and induction severely diminishes the strong and clear-cut dichotomy interpretation of the discovery/justification distinction. At this stage of our paper, we only point out the subject matter, in later sections, we shall undertake the issue with more detail.

Following the previous discussion, there is also the question of whether any set of mechanisms or rules involved in the context of justification is congruent with classical logic. To this matter, it has been pointed out by Meheus (1999) that classical logic does not provide the tools and resources to cope with the reasoning process involved in much of the scientific deliberation and this is in part due to the fact that information involved in this process is more often than not either incomplete or inconsistent and these two aspects are not fully approachable from the standpoint of classical logic. But, the fact that standard or classical logic is not sufficient in the context scientific inquiry, does not implies that any other logical formalism whatsoever will also fail to grasp this aspect of human reasoning or that scientific deliberation is foreign to logic at all. But if this is the case, then again, we find reasons and evidence that displace the bold sense and interpretation of the discovery/justification dichotomy. That is, if the justification process is restrained by contextual contingencies such as limited cognitive resources or some other form of knowledge constraints (due to some external or internal limitation), and even more, the presence of inconsistent information, then the ideal presented in the so-called strong interpretation of the distinction would be severely undermined, because from the strong interpretation of the discovery/justification distinction, the process of justification is not subject to such contingencies. Hence, if the non-classical logic frameworks better capture the deliberation process involved the context of justification, the sense of such dichotomy would be displaced in favour of a more tempered one.

In the context of the aforementioned debate concerning the nature of these systematic approaches to scientific deliberation, one crucial aspect lies in how one view the steps involved in the justification of scientific theories. If one regards them as rational procedures foreign to logic then one must question what kind of logic one has in mind to have such as stance. If one's view of logic is restrained to classical logic then various reasoning processes will be categorised as foreign to logic. Therefore, it stands out that one's view of logic is crucial to the methodological analysis of the process of scientific discovery (Meheus, 1999).

As example of the debate surrounding the context of justification within scientific inquiry, Popper (2002) did held the conviction that this aspect of scientific inquiry can be scrutinised in terms of logical procedures, specifically and according to Popper falsasionism can give an account of the process that lies at the core of the context of justification. Contrary to the above, one can point out how Kuhn (1970) held a very sceptical attitude towards the existence of a logic procedure concerning the comparison, contrasting and weighing of the different scientific theories, views or research programmes (i.e. aspects concerning scientific revolutions which can be said to belong to the context of justification). Kuhn (as other philosophers of science of with similar approaches) was more inclined towards historical and sociological explanations of the processes involved in scientific deliberation, which according to him would give a more rich and precise picture of what really happened in the process of scientific inquiry.

Following the aforementioned debate, one can point out that there is another alternative between the opposing views (Poppers defence of classical logic and Kuhn's sociological account) regarding the process of justification. For example, there are approaches to this aspect of scientific inquiry that although not belonging to sociological or historical accounts give a rational schema according to which this dimension of scientific inquiry can be scrutinised.

In line with the above, there are *rhetoric* approaches to deliberation that although do not fall under the procedures and method of classical logic, they do provide a rational and systematic framework for understanding such processes involved in the context of justification, that is, the stage of scientific discussion in which theories and statements concerning those theories are scrutinised in order to validate those theories. The deliberative or rhetoric approach towards the problem offers a halfway solution that lies between the logical/sociological dichotomy previously remarked.

One paradigmatic example of such rhetorical approaches to argumentative deliberation can be traced back to Aristóteles' *Rhetoric* (1990), in which the Greek philosopher undertakes the systematic study of the art and means of persuasion in a sound and demonstrative manner. In the aforementioned work, he posits the *enthymeme* as one of the core structures under which the persuasive enterprise is carried out (1354a1–4). Aristotle understands such deliberative and persuasive task as *rhetoric demonstrations* or *rhetoric syllogisms* (1355a4–8). Nevertheless, Aristotle himself points out the elusive nature of enthymemes from the perspective of a logical structure and how its value lies between the notions of truth and plausibility (1355a16), which is far apart from the exact nature the syllogism of the *Analytics*. Despite the elusive nature of enthymeme's Aristotle does not dismiss its theoretically demonstrative capability. Hence, one can characterise the deliberative task concerning the justification of the scientific enterprise with the same elusive character as Aristotle had towards the *rhetoric syllogism*, without sacrificing any form of systematic or rational foundation.

Once again, in light of the previous perspective, one can point out that the discovery/justification as *a bold dichotomy* seems diminished. Supporting evidence for such stance lies in the fact that this kind of rhetorical/argumentative approach to rational deliberation (even in the context of scientific inquiry) acknowledges being far from the kind of irrevocable and infallible nature of demonstrative knowledge, given space to some degree of retractability. That is, even the justification context of scientific knowledge is far from the depiction made in the classical interpretation of the discovery/justification distinction.

Lastly, it's of substantial importance to mention one of the core debates surrounding the discovery/justification dichotomy, and that is: the existence of a logic, a formal framework or any form of rule-following and systematic approach for tasks associated with each of the dimensions. As we mentioned earlier, it's traditionally held that one can apply such formal and logical methods to the context of justification, but such methods shall not be applied in the analysis and scrutiny of the context of discovery. Naturally, one key aspect of such stance lies in the extent and limitation of notions such as logic, logic framework and formal systems. Hence, before drawing the final remarks concerning the expositions of the dichotomy and some of the key aspects surrounding such distinction, we must mention some differences to be made regarding the notion of a logic framework and a formal system.

As Schickore (2014) has pointed out, there is a clear distinction between heuristic procedures and analytical algorithms. Examples of the former are statistical methods, production systems and in general, mechanisms to which, a precise solution to a given problem is far from being guaranteed, nevertheless this kind of tentative search and the problem-solving procedure is more efficient than the analytical algorithms counterpart. On the other hand, analytical procedures to problem-solving are much more exhaustive and furthermore, given a problem it will brute force all the possibilities in search for the appropriate answer. The downside of the analytical way is that its applicability if far narrower than the approach of heuristics. To this matter, it's necessary to point out the fact that a combination of heuristics plus analytical procedures can be combined to obtain far better results than any of the two approaches on its own. In spite of the aforementioned differences, both modes of problem-solving in the context of scientific discovery are rule following procedure that can be computationally implemented.

Based on the above distinction, there are two different senses of the concept of 'formal models'. The narrow sense of the term only includes a reduced and precise set of formal rules to conduct a deductive process in an analytical form. On the other hand, the broad sense of the term logic includes the narrow sense, plus any other form of heuristics or rule following procedure to tackle a given problem (Schickore, 2014). Examples of the narrow sense might include what is known as classical logic, relevant logic, etc. and concerning the broad sense of the term, we can take into account production systems or statistical models, etc. In this context, we will generally reserve the term logic framework to the narrow sense of the notion of logic and a computational system will be used in a way that can include a given set of heuristics to approach a specific problem.

Having in mind the above distinctions and the previous discussion of the dichotomy we sketch out in Figure 1. a taxonomy of the discovery/justification context dichotomy and how it relates to the logical and heuristic formalisation stance in connection with the various philosophical stances towards the same dichotomy.

The taxonomy of Figure 1 can be understood as follows: the root of the tree would be the notion or object of inquiry of science as a whole; from there we would locate on the one side the context of discovery and another branch to the context of justification.

In the case of the context of discovery, we would have two attitudes, one holding that such dimension of scientific endeavour cannot be modelled. Exemplar representatives of this stance would be K. Popper, P. Feyerabend (1993) and T.S. Kuhn with their sociological and historical reconstructions of scientific endeavour (although P. Feyerabend and T.S. Kuhn

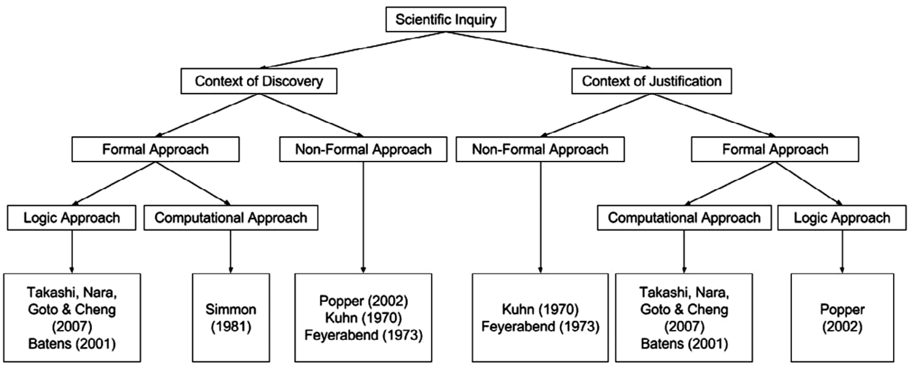

Figure 1. The justification/discovery dichotomy in the context of the formalisation of scientific inquiry.

would not conceive their stance in the terms of this dichotomy they would certainly not sustain the possibility of formalisation of scientific endeavour). On the other hand, within the context of discovery branch, we would have the positive assumption that this aspect of scientific endeavour can be formalised. Regarding this stance, we would further have two possibilities: the heuristics formalisation and the logical formalisation. Exemplars of the former would be Simon, Langley, and Bradshaw (1981) with his BACON computational framework and similar computational architectures devoted to the computational automation of scientific discovery, and of the latter would be Batens and Meheus (2001) with the *Adaptive Logics* research programme and Takahashi, Nara, Goto, and Cheng (2007) with their *EPLAS* epistemic programming language.

In the case of the context of justification, we would have two attitudes. The first position would hold that such dimension of scientific endeavour cannot be formalised. Exemplars of this position would be again P. Feyerabend and T.S. Kuhn. A second position within the context of justification branch would have the positive assumption that this aspect of scientific endeavour can be formalised. This stance further bifurcates towards the heuristic formalisation and the logical formalisation: Exemplars of the former would be K. Popper with his falsifiability which is based on the *modus tollens* logical schema and of the latter we can again place Batens and Meheus (2001) and Takahashi et al. (2007).

Based on the previous schematisation of the discovery-justification dichotomy, we proceed in the next section with the survey some logic frameworks that – as we will later argue – can give a satisfactory account of tasks associated with both dimensions of the distinction.

4. Research endeavours regarding the logical approach towards the process of scientific inquiry

It has been pointed out that scientific discoveries more often than not involve a kind of reasoning that has to deal with inconsistent information, and furthermore, this is not an isolated occurrence but the norm. This particularity can be attributed to the immense complexity of inferences in the context of scientific discovery, in which some parts have to be rejected, modified and/or replaced, all of which must involve a rational process. This further vouches for the idea that the manipulation of inconsistent data is necessary but it must be a logical, rational or rule-following kind of inconsistent information manipulation (Meheus, 1999).

Thus, it has become a common ground that the production of knowledge in the context of scientific inquiry is one of those many cases in which classical logic may not be suited for modelling this inference process (Meheus,1999). In light of this, there have been several proposals of what might be such a logic of scientific inquiry. On this latter topic, there is no clear consensus, and there are several proposals of how such a logic might look like. In the following subsections, we will survey some logical frameworks that have aimed to provide the foundations to the formalisation of the process of scientific inquiry.

4.1. Non-monotonic logics and the reasoning process within scientific theories

It's common ground that knowledge in the context of scientific theories is one of the most paradigmatic cases in which a set of beliefs in a given point of time may not remain firm with further advancement of the process of scientific inquiry. Furthermore, the process of gathering further information may further diminish a set of beliefs once held. This points to a more fundamental aspect of human reasoning, that is, besides the ability to make novel inferences we seem to also possess the ability to retract the derived information in light of new data or evidence. (Kraus, Lehmann, & Magidor, 1990).

In classical logic, there is a key property that contraries this view. The property that a belief cannot be withdrawn if it was it is derived at some earlier point in the inference process is known as the monotony principle. It has been pointed out that the property of monotony is too restrictive in the sense that although it prevents us from reaching to false conclusions (by having a strict restriction on the deducibility relation that guarantees that when one proposition is inferred it can no longer be retracted) this is really counterproductive in the context of everyday common sense reasoning in which we do not possess this kind of certainty nor is it beneficial and can represent an epistemic cost to restrain to engage in new knowledge that can be true (Nute, 2003). This monotony property may be one of the key factors that at some point favoured the view that the study of scientific discovery requires moving beyond classical logic (Meheus, 1999).

The non-monotonic mode of reasoning was largely dismissed and unattended in favour of deductive reasoning, at least the kind of (monotonic) deductive reasoning that infers propositions in an absolute and irrevocable way. This attitude has not been without cost in the epistemological realm in which we bluntly recognise the fallibility of our inferences and the revocability of our beliefs. There are historic and theoretic reasons of why this is the case, as Koons (2013) points out Aristotle's view of science was of an endeavour that constructs universal laws that hold no matter what. Nevertheless, a whole range of everyday inferences relies on common sense generalisations that do not follow the irrevocable character of classical logic.

The same epistemological concerns emerge in the context of the reasoning process involved in scientific inquiry, and to this aim there is a need for reasoning systems that can handle this process of making tentative inferences and correcting them in light of new evidence (Nute, 2001) since the process of manipulating inconsistent belief sets is a manoeuvre that cannot be undertaken in the context of classical logic, which render this inference process as insufficient within classical logic (McDermott & Doyle, 1980).

Hence, regardless of the specific logical framework to deal with the process of scientific endeavour, there is the conviction that this process is inherently non-monotonic. This is based on the fact that scientific theories may be inconsistent in a very specific way, one of which can be the addition of new data or evidence, which makes it necessary to be able to withdraw any belief at any given time based on the correct criterion. Therefore, the whole process of accepting or rejecting theories or beliefs in the context of tentative but scrutinised scientific theories has a rational or logical procedure to it, that is, this deliberation process is not a random or arbitrary one, and as such, we can establish and identify rules and reasons on which scientific theories are dismissed or upheld. Hence, the inference process and conclusions within scientific discovery are regarded as intrinsically non-monotonic.

4.2. Defeasible reasoning and defeasible logic

Defeasible reasoning is a model of deduction in which when we make an inference, the conclusions that we reach could be retracted later on. This kind of reasoning has the base presumption that at any given time we make inferences on a *ceteris paribus* clause, that is, all thing being equal we reach the conclusions we make, but there could exist a given situation that invalidates our *ceteris paribus* presumption (Nute, 1988).

In the same vein, Tohmé, Delrieux, and Bueno (2011) have pointed out that one of the key distinctive features of scientific reasoning lies not only in the less than absolutely certain inferences but the fact that those inferences or information can be further corrected. Based not only on the fallibility but also the necessity of correcting mechanisms, they argue that defeasible logic is the most suited framework to accomplish such a task. Hence, the use of defeasible modes of reasoning and their logical formalisms counterparts might offer a satisfactory foundation for logic and computational models of episodes in scientific inquiry.

In the context of defeasible reasoning, when an argument is strongly or at least sufficiently supported by its premises, we can defeasibly sustain the respective conclusions, but this connection between premises and conclusions is not definite or absolute in nature, it is just tentative (Koons, 2013). Now, it's important to underscore the fact that for a given proposition to be defeasibly inferred does not implies that the proposition is somehow false, it just means that the particular inference *could* be further defeated in light of new information or new rules connecting previously held information.

Defeasible logic is essentially a non-monotonic logic that deals with the problem of revising inconsistent sets of beliefs or information through the notion of defeasible inferences and defeasible rules, which by all means is one of the many cumbersome inconveniences contained in classical logic. In what follows, we will make a further exposition of the key aspects of defeasible logic based on an illustrative example given by Ewa Madalińska.

First of all, in defeasible logic we have the notion of *facts*, which state some proposition or known information. For example, we can state that fact that 'Marco is Italian' and the fact that 'Marco is a communist' as follows:

Italian(Marco) (1)
Communist(Marco). (2)

Now, the core idea of this logic framework is the existence various kinds of rules: strict rules and defeasible rules. Strict rules are the kind of monotonic rules that one can formulate in standard classical logic. For example, the rule that states, 'If *x* is Italian then *x* is European' would be formalised as follows:

Italian(x) → *European*(x). (3)

Contrary to these classical and standard rules, there is the case of defeasible rules. For this kind of rules the inference is only defeasible, meaning that other rules can further defeat this inference. For example 'If *x* is Italian then *x* is Catholic' and 'If *x* is Communist then *x* is not Catholic' would be formalised as follows:

r1: Italian(x) ⇒ *Catholic*(x). (4)
r2: Communist(x) ⇒ *Catholic*(x). (5)

The defeasible rules exhibit the non-monotonic properties that offer the flexible and revisable mechanism by which a set of beliefs can be revised and in which any particular belief can be further retracted at any given point in virtue of its defeasible nature. In the same vein, defeasible logic also provides a way to handle inconsistent sets of data and beliefs inasmuch that the beliefs that make up the system are not irrevocable; to the contrary, they can be revised and compared in virtue of defeasible rules. To this end, it posits the notion of *defeaters*. The role of defeaters is to defeat inferences (i.e. the deduction of a given atomic literal) that without the existence of the respective defeaters would be legitimately justified. For example, one can formalise the notion that 'If *x* is a communist then the conclusion that *x* is Catholic should be blocked' as follows:

$$Communist(x) \rightsquigarrow \neg\, Catholic(x). \qquad (6)$$

Hence, defeaters do not provide positive support for any inference; on the contrary, they can block the application of a given defeasible rule. In the above scenario, the defeasible rule (6) would prevent the inference stating that Marco is Catholic from the previously known fact (1) (i.e. the fact that state Marco is Italian).

In addition to the existence of defeasible rules, defeasible logic uses a superiority relation > concerning the available rules. Hence, solely based on our potentially contradictory set of defeasible rules (4) and (5), a decision of whether Marco is or is not catholic cannot be made. Therefore, if one establishes that $r2 > r1$ then some intended conclusion can follow in virtue of the primacy of some rule over other. In this case, with the specified superiority relation one is enabled to infer that Marco is not a catholic.

One final remark is to be made in connection with superiority rules within defeasible logic, and how this superiority relation has to be established. In particular, we point out the fact that a computational system can outsource this task. That is, to establish the different weights and levels of precedence among different defeasible rules (i.e. the details of the superiority relation >), a computational approach can be used. For example, statistical mechanisms can be used to determine with exact precision (and even with a dynamic nature) the details of the superiority relation in any given defeasible context. Hence, in such a setting, one can easily see how computational methods could be used to support a logical framework. In this sense, one could speak of hybrid models of the process of scientific inquiry, in which one or other approach could be used in the general framework to further optimise the model.

4.3. Adaptive logics

In congruence with the notion that within the process of scientific discovery one has to deal with a great amount of data and some pieces of information within that data can be inconsistent, it has been argued that paraconsistency is a necessary condition that any logic formalism must satisfy in order to model this process of scientific inquiry. In this context, paraconsistency should be regarded as a property concerning logic formalisms that allows the occurrence of contradictions without any arbitrary proposition being able to follow from such inconsistency, as is the case in classical logic. To this, there has been intensive work in a research programme devoted to the construction of a formal system that can provide the tools for this task. This formalism is denominated adaptive logics (Meheus, 1999).

Adaptive Logics restricts the applicability of the rules of inference, i.e. when a rule of inference is violated its applicability is restricted. In this way, one is not entitled to deduce any sentence from an inconsistency, rather its use and extent in virtue of such inconsistencies are restricted and limited. That is, when an inconsistency is found or involved in some step of the inference process, adaptive logic restricts the applicability to avoid triviality, but when no inconsistency is involved then rules of inferences are applied with their full-fledged strength. One of the most important aspects of adaptive logics, besides being a logic aimed at the proper manipulation of inconsistent information, is that it does so in a very precise way, in a non-monotonic way. This is important to point out due to the fact that simply paraconsistent logics only rules out some tenets contained in classical logic (most exemplary *ex falso quodlibet* among others) but this has been pointed out to be insufficient to explain inferences made in the context of scientific inquiry (Meheus, 1999). As such, adaptive logic is said to provide a much richer consequence relation than the ordinary monotonic paraconsistent logics (MPL) (Batens & Meheus, 2001).

One prominent example is in which the importance of this kind of adaptive logic is put in the context of scientific theories. If for a particular theory *T* we assume a classical logic (CL) as its grounding framework and, such a theory would produce an inconsistency (i.e. inferring *A* and *A* at the same time) then the original theory *T* should be fully disregarded as trivial in favour of some other theory *T'* that does not contain any inconsistency. But, if for the same scenario as described above we assume a MPL as its grounding framework, then the sole occurrence of an inconsistency in *T* is no longer a reason for the dismissal of this theory based on the fact that we now assume a logic framework that can handle such inconsistencies. Nevertheless, the monotonic property of such a paraconsistent logic would come at a price, namely, the fact that there are some rules of inference that are not accepted in the context of a monotonic paraconsistent logic, such as Disjunctive Syllogism. Hence, if the scientific theory *T* needed such a rule or any other that is available in classical logic (CL) but unavailable in a monotonic paraconsistent logic (MPL) then there would emerge a shortage of inference power in the formalised theory *T* (i.e. in this context it would no longer be the case that *B* follows from *A* and *A v B*). Thus, with this change in our logical framework, our former theory *T* would not be trivial anymore, but the downside is that some rules of inference would cease to be available. Therefore, the sole change from classical to paraconsistent logic comes at a significant cost. But if we push forward our grounding formalism to be a non-monotonic paraconsistent logic, we would not only be entitled to avoid the dismissal of *T* based on some particular inconsistency but we would also retain the inference power available in classical logic (for example, we would be able to work with rules such as the Disjunctive Syllogism. Hence, the change in viewpoint from classical logic to adaptive logics permits the reuse of the original theory *T* in such a way that all inference rules of classical logic are still available in the cases were those inference rules do not produce an inconsistent set of information (Batens & Meheus, 2001).

Meheus (1999) has pointed out, that adaptive logics can provide a logical formalism resource in the context of scientific inquiry, where some given inconsistency does not rule out a whole scientific theory, but scientists themselves only restrain the inconsistency to a particular fraction of the theory. That is, if from a given theory, a consistency might show up, that does not grant licence to produce or infer any arbitrary number of inferences with no bearing on the original theory; to the contrary, scientists only restrain the implications of an inconsistency as much as possible, ruling out any more trivial inferences to the broad extent of the theory. Hence, in light of this common schema in the context of scientific inquiry, adaptive logics can accommodate to the dynamics within the process of scientific discovery.

As an example of the above, Meheus (1999) points out the demonstration of Carnot's theorem carried out by Rudolf Clausius (1822–1888). The theorem was conducted in such a way that involved inconsistent belief sets regarding the production of work in heat engines. On one side, Sadi Carnot proposed that this work production was derived from the heat transfer from a hot to a cold reservoir, but the opposing view of James Prescott proposed that such work production in heat engines was a result of the conversion of heat into work.

Given this scenario, Rudolf Clausius developed two different proofs, both of which were conducted through *Reductio ad Absurdum*, that is, starting from the hypothesis that the negation of Carnot's theorem was true plus the corresponding premises he could reach a contradiction, so Carnot's theorem must be true, but Rudolf Clausius only considered his second proof to be valid. Now Meheus (1999) points out that, the first proof produces an inconsistency just from the premises, that is, the inconsistency at hand does not involve the hypothesis of Carnot's theorem, but the second proof, on the other hand, produces an inconsistency in such a way that such inconsistency does involve the statement of Carnot's theorem.

From the above scenario, Meheus (1999) remarks two key aspects. First, in the context of a monotonic paraconsistent logic, the rule of *Reductio Ad Absurdum*, is not admitted, therefore neither proof of Carnot's theorem would be valid. Second, and most importantly, assuming a non-monotonic paraconsistent logic, in which such rules of inference like *Reductio Ad Absurdum* are available, the question remains which of the two available proofs is valid. To this, Meheus notes that the second proof would be more relevant towards the demonstration of Carnot's theorem, due to the fact that it is in this second proof that the contradiction emerges not only from the premises themselves, but from the premises plus the hypothesis stating the negation of Carnot's theorem, whereas the first proof produces a contradiction but such contradiction emerges from the premises, and do not involve or use the statement regarding Carnot's theorem. Hence, only from this second proof, would be reasonable to infer that the negation of Carnot's theorem is false, i.e. Carnot's theorem is true. In light of this kind of episodes in scientific discovery, Meheus states that there is a need not only for a simple paraconsistent logic that can handle inconsistencies, because such framework would rule out important inference rules such as *Reductio Ad Absurdum* (as well as some others), but it would also need a non-monotonic paraconsistent logic that can handle inconsistencies without reducing the available inferences rules which could be needed in the context of scientific knowledge production.

It also pointed the need of such adaptive style of inferences for computational environments such as databases in which inconsistent information is an ongoing possibility but nevertheless rules of classical logic cannot be taken away in the global or general scenario (Batens & Meheus, 2001). The above naturally leads to the consideration of such a logical framework in the context of inferences in scientific inquiry.

4.4. Abduction

A final logical framework to be mentioned is the undoubtedly paradigmatic scheme to approach the topic of reasoning in the context of scientific discovery: abduction. In general terms, abduction is the mode of reasoning in which one infers possible hypotheses based on some given data or phenomena (Schickore, 2014). The abductive mode of reasoning is usually one of the three major modes of reasoning (the other two being induction and deduction), nevertheless, abduction is sometimes placed within the inductive category (Duoven, 2013).

Nevertheless, definitions as the above lack a precise nature than can render a clear-cut formal criterion (general o narrow). To this matter, Duoven (2013) notes that abduction can be defined as follows: given some set of evidence E and a list of possible explanations H_1, H_2, …, H_n regarding *E*, if some hypothesis H_i better explains the given data *E* than the other competing hypothesis, H_i is accepted as a satisfactory and appropriate explanation of *E*.

There are several historical examples of how abduction is the functioning reasoning process concerning some scientific discovery. For example, Duoven (2013) recalls how at the beginning of the nineteenth century the orbit of Uranus did not comply with Newton's theory of universal gravitation. At the time, it was held that Uranus was the seventh and last planet in our solar system. In this scenario, both Couch Adams (1819–1892) and Leverrier (1811–1877) instead of dismissing Newton's highly successful theory on the face of its poor explanation of Uranus orbit, proposed some other more parsimonious explanation (that there was an eighth planet: Neptune). In the context of the aforementioned scenario concerning the postulation of an eighth planet, one could see the Uranus' orbit irregularity, which departed in such a way that did not fully complied with predictions grounded on Newton's theory of universal gravitation as the available evidence set *E*, and the existence of an eighth planet as a hypothesis H_1 that better suits the state of affairs than the hypothesis H_2 that dismisses Newton's theory of universal gravitation. This abductive process was a more economical and precise explanation (than completely dismissing Newton's theory) and showed how intrinsic this mode of reasoning is to scientific endeavour.

Several shortcomings have been pointed out towards the abductive mode of reasoning. One of them consists in the fact that there are considerable number of hypothesis to explain a given phenomenon, in this sense, the sole fact of producing or proposing explanatory hypothesis towards a particular set of data or some phenomenon is not the whole story to scientific inquiry, and a further selection criterion is required to evaluate the hypothesis.

Furthermore, it's important to point out that although abduction has a long-standing tradition as an object of inquiry within contemporary logic and it can be sketched according to some general schema, it is 'logical' in an extremely broad sense of the term. Thus, it might be too ambiguous for a formal and precise definition as other logical systems can be (Schickore, 2014). Due to the ambiguity of its formal status, this reasoning framework can also be classified – and has been done so – within the family of heuristic processes. Despite the categorical debates of the abductive mode of reasoning, it is without a question that is has been a prominent mode of understanding the process of scientific discovery

In the same vein as the above, it's important to point out that, abduction as a logical framework further supports the case of the weakening between computational and logical systems distinction. That is, in terms of the general sketch of the logical/computational distinction within the discovery/justification dichotomy illustrated previously in Figure 1. We see that abduction would incur in the same elusiveness as to whether it could be exclusively belonging to either the logical or computational branch. This, we stress, is not a shortcoming of abduction as such, but to the contrary, the shortcoming would be placed on any attempt to sustain a hard set and hidebound dichotomy concerning the logic and computational distinction. Hence, as we previously stated, abduction further illustrates the elusive nature of the logical/computational distinction.

5. The weakening of the discovery/justification context dichotomy based on the non-monotonicity perspective of logic and other non-classical formalisms

In this section, we undertake a new approach to the previously surveyed discovery/justification dichotomy. In particular, we analyse such dichotomy and propose our argument supporting the weakening the aforementioned dichotomy, that is, declining the strong and bold interpretation of the discovery/justification distinction in favour of a moderate and tempered sense of such distinction.

To illustrate our stance, we recall Feigl's (as well as Reichenbach's and others alike) views on the distribution of the methods to approach the different tasks of the discovery and justification contexts. According to this perspective, which we will denominate the classical perspective on the subject matter, on the one hand, the context of discovery deals with the psychological, political and contingent aspects by which scientific theories and/or hypothesis are produced and on the other hand the context of justification deals with the rules, standards and procedures according to which some hypothesis and/or theories are accepted or rejected. Just as we mentioned earlier in this paper, this perspective makes a bold assumption according to which logic is of a prescriptive/normative nature while other empirical disciplines such as psychology are descriptive and deal with matters of contingent and elusive nature. This approach can be sketched as follows:

	Computational	Sociological
Validation	Justification *Moment*	–
Generation	–	Discovery *Moment*

We argue that such state of affairs is incorrect. First of all, as we previously remarked (in section 3) psychology possess the methods and instruments to undertake the study and analysis of deliberative processes involved in the context of justification. Second, the process of justification does not end nor it's exhausted in the logical dimension, that is, one can make descriptive remarks of the justification process, and furthermore aspects of the process of discovery can also be approached and undertaken in a prescriptive manner. Therefore, we argue that the tasks and processes involved both in the production and validation of scientific knowledge can be subject to a descriptive or prescriptive analysis (again, earlier in this paper we have reviewed several frameworks and theoretical stances that can accomplish such tasks). In virtue of the above, we decline the thesis according to which neither the discovery nor the justification context refers to different or opposing moments in the process of scientific inquiry.

To support our perspective, one can notice how the dispute over the logic of scientific discovery has had a significant shift towards its rationalisation as a rule following procedure (whether a heuristic or a logical one), which is a significant hallmark of contemporary philosophy of science. That is, the view that logic is beyond the realm of the descriptive process of human reasoning has been abandoned and to the contrary logic models have been investigated to explain human psychology (Garcez, Lamb, & Gabbay, 2008). For example, there has been an enormous shift towards the descriptive value of logical models in contemporary of logic, which has been largely ignited by the Artificial Intelligence community (Dix, Pereira, & Przymusinski, 1997). A particular example of the above, we point out precisely to some of the formalisms we have surveyed in previous sections, such as non-monotonic logics.

In the same vein, and as we previously stated, one of the core difficulties concerning the process of scientific endeavour is that this enterprise, more often than not, involves modes of reasoning that deal with inconsistent or incomplete information. The fact that scientific theories may be inconsistent in some way, one of which can be the addition of new data or evidence, makes it necessary for any formal framework to model such a phenomena to be able to withdraw any belief at any given time based on the correct criterion (Cheng, 2000). Furthermore, and in the same vein as Popper (2002), scientific beliefs are tentative conjectures, which can be further, diminished in light of new information. That is, a set of beliefs once held may be further diminished or revised by the process of gathering further information. According to these properties, one can easily see that classical logic is saliently insufficient to account in a comprehensive manner the distinct process and functions involved in the endeavour of scientific inquiry, given that, for example, if a belief is derived at some point, it cannot be further withdrawn. This is one of the crucial aspects or particularities of the family of non-monotonic logics, that is, they aim to construct a framework in which the addition of further information can interfere with previously held knowledge and/or handle inconsistent information can be captured. Scientific reasoning seems one of the paradigmatic cases in which the inference process loudly fails to satisfy this monotony requirement contained in classical logic. Hence, the family of non-monotonic logic is a case example of a formalism that can account for various aspects involved in the production of scientific knowledge, and in doing so supports our claim concerning the weakening of the hardcore dichotomy such the one expressed by Feigl.

As an example of the previous argument, one can imagine an instance of a logical model of a scientific discovery computationally implemented. If one takes as valid the justification/discovery dichotomy, then one would have to assume that the same scientific episode would require two separate descriptions and process to be satisfactorily modelled, one description and set of procedures concerning the processes of discovering and proposing new empirical laws, relations among the available data and generalisations, and on the other hand another set of processes that handle the evaluation and justification of the output produced by the first processes. In this sense, the discovery/justification dichotomy would provide an insightful and useful distinction.

Nevertheless, one could argue that in virtue of the loudly contested descriptive component present in non-monotonic logics, with the same specifications and with the same inference process the model would carry out not only the validation of inferences corresponding to the context of justification but also tasks strictly associated to the context of discovery, the reason being that non-monotonic logics is, after all, supraclassical (i.e. it extends classical logic without invalidating elementary inferences from classical logic). Hence, both the task of producing inferences and validating those inferences could be addressed within the same logical framework. That is, within a non-monotonic framework, the computational instance of such a model would not only produce new and unbeknown statements that can match and extend any given knowledge base (a discovery context related task), but it would also have the available mechanisms to compare contrast between two possible theories in the face of an specific set of data (a justification context related task). This multiplicity of resources would be grounded on the fact that, for the first set of tasks (the discovery dimension) the model would provide all the available tools and features contained in classical logic and in virtue of the non-monotonic nature of the logical framework, then it would provide the mechanisms to retract information in light of new data, premises or some other kind of information (the justification dimension).

In virtue of the above, if the logical framework one uses to model the episode has not only a normative but also a descriptive component –as it is the case for non-monotonic logics-, then tasks of both dimensions of the proposed dichotomy of discovery/justification context could be addressed with the same logical framework, further diminishing the value of such dichotomy. Hence, we argue that, if one assumes the non-monotonic view concerning inferences in the process of scientific endeavour one could be labelled to be working on the context of justification rather than on the context of discovery, nevertheless, if the logic behind the proposed framework is descriptively significant to the agents involved in the process of constructing such scientific theories, then a link between the two dimensions of scientific discovery (discovery and justification) is satisfied.

Having made a case against the strong interpretation of the discovery/justification distinction, we wish to further advance some more constructive remarks concerning the subject matter. To attend, this is important to recall that we previously distinguished two senses of the discovery/justification differentiation. Up until now, we have argued against the strong sense of the differentiation, that is, the *dichotomy* sense. Nevertheless, we will argue that there is much value in the differentiation, but we appreciate its value in the more temperate sense, i.e. in the distinction sense. That is, we do not see the existence of two distinct and separate moments (i.e. one of discovery and one of justification) we do see two different *approaches* concerning the endeavour of scientific inquiry.

On the one hand, we would have a *justification approach* to scientific endeavour. In line with this approach, what would be emphasised would be the analysis of the logical, rational or rhetorical reasons by which a given theory and/or scientific hypothesis is accepted, retained or dismissed. Exemplary frameworks that can serve the purpose of this approach can be the rhetorical deliberation of scientific knowledge or the means of inference validations contained in non-monotonic logics (such as defeasible or adaptive logics), with the much esteemed non-monotonic character of such logical framework. On the other hand, we would have a *discovery approach* to scientific endeavour. In line with this approach, the emphasis would be placed on the computational aspects and/or mechanisms by which a given theory and/or scientific hypothesis is generated and/or proposed. In this approach to scientific endeavour, further emphasis would be placed on computational models by which such processes can generate scientific theories and/or hypothesis. Some frameworks that would be of particular interest in this approach to the process of scientific endeavour can be Simmon et al. (1981) BACON series of computational discovery architectures and again, the non-monotonic logic framework, in that being an intrinsically non-monotonic family of logics, it can broaden the set of inferences and statements from classical logic to a much more dynamic and in doing so, extend the set of available scientific statements and hypothesis.

Based on our previous remarks, and in contrasts with the classical view (such as Feigl's and Reichenbach's) we would propose the following sketch of the discovery/justification differentiation:

	Computational	Sociological
Validation	Justification *Approach*	
Generation	Discovery *Approach*	

According to the previous scheme, some aspects of scientific endeavour that are labelled as belonging to the context of discovery would be in our terms aspects emphasised in a justification or prescriptive approach and aspects that are labelled as belonging to the context of discovery would only amount to a descriptive character. But in our terms, the existence of distinct approaches does not imply that any of the tasks and aspects involved in scientific endeavour belong to separate and distinct *moments*, but aspects of scientific endeavour are analysed through different *approaches*, whether a descriptive or prescriptive one.

6. Conclusions

In this paper, we have exposed some of the core controversies surrounding the discovery/justification context debate, and how it has shaped the philosophy of science as a discipline both in a methodological and theoretical sense. We have furthermore drawn a plausible taxonomy surrounding the discovery/justification dichotomy in the context of contemporary philosophy of science.

We have proposed, from the context of modern approaches to long-standing disciplines (such as logic and philosophy of science) and also from novel and evolving disciplines (such as computer science and cognitive psychology) several conceptual and theoretical frameworks to approach each of the dimensions conforming the dichotomy. In particular, we analysed the family of non-monotonic logics as a plausible basis for the reasoning process concerning inferences in the context of scientific discovery. We have argued that such approaches and frameworks can give a satisfactory account of tasks associated with both dimensions in the discovery/justification dichotomy. In doing so, we have not only provided what we consider substantial evidence of the contemporary shift towards the logical/formal approaches to the process of scientific discovery, but we take this aspect as supporting evidence concerning our thesis about the weakening of the bold and clear-cut distinction portrayed in the original dichotomy. As we have argued throughout our current work, it seems that such distinction under scrutiny only refers to two (but not opposite) descriptions levels and that they do not hold up to the trial of a categorical and irreducible differentiation. Nevertheless, we also sustained the thesis that this distinction in a tempered and moderate interpretation does offer some explicative and illustrative value.

Despite our critic of the discovery/justification dichotomy, it's important to underscore that we do not dismiss the distinction but what we argue against is the bold and clear-cut dichotomy. That is, the discovery/justification as a distinction between two different approaches to the same object of study is of great explanatory value, but the existence of two different moments in scientific inquiry does not hold such explanatory value. Much to the contrary, the bold dichotomy of the discovery/justification differentiation seems to obscure the study and analysis of scientific endeavour in philosophy of science.

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