ABSTRACT

An Examination of the Merit of Climate Science From the Perspective of Imre Lakatos' Methodology of Scientific Research Programs

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There is a great deal of disagreement in the United States regarding the role that human activity has played in precipitating climate change. While the scientific community is generally in agreement that humans have brought about the observed increases in temperature, the general public is far less unified. Given that there has been copious data given by scientists to justify their claims, there must be another reason besides insufficient evidence why people choose not to agree with them. While political and ideological motivations elucidate this rift to a certain degree, they do not seem to provide a sufficiently comprehensive explanation. A reasonable solution is that people do not trust the scientific merit of climate science. Therefore this paper will examine climate science from the perspective of Imre Lakatos, a 20th century philosopher of science. His theory of what constitutes legitimate science, and what distinguishes it from pseudoscience, will be explored and compared to the theories of some of his contemporaries such as Thomas Kuhn and Karl Popper. In short, Lakatos' emphasis on novel predictions, as the marker of progressive scientific research, will enable the debate over climate science to be viewed from a philosophical perspective. Rather than present answers to a myriad of individual facts, this approach provides standards for adjudicating methods and research programs more broadly. The indications are that climate science has made accurate and novel predictions about shifts in the climate and therefore would be regarded as a progressive research program by Lakatos.

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AN EXAMINATION OF THE MERIT OF CLIMATE SCIENCE FROM THE PERSPECTIVE OF IMRE LAKATOS' METHODOLOGY OF SCIENTIFIC RESEARCH PROGRAMS

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TABLE OF CONTENTS

PREFACE

I became interested in the history and philosophy of science while taking Dr. Eric Martin's Great Texts in Modern Science course. This course demonstrated to me that the line between science and pseudoscience is not only very important, but can often be ambiguous as well. I was most intrigued by Imre Lakatos' methodology of scientific research programs. Lakatos provides what I found to be the most practical method of analyzing the merit of scientific theories. Thus, I decided to apply Lakatos' methodology to the theory of anthropogenic global warming, because it is an area of science that has been mired in controversy in the United States for several decades. According to a 2016 Pew Research poll, "Roughly half of adults (48%) say climate change is mostly due to human activity; roughly three-in-ten say it is due to natural causes (31%) and another fifth say there is no solid evidence of warming (20%)" (Funk and Kennedy, 2016). Since it is often cited that 97% of scientists agree that humans are contributing to climate change, it seems that a large portion of the U.S population must either be unaware of, or distrust the scientific evidence supporting the anthropogenic global warming theory. According to a 2010 study conducted by Yale psychologist Dan Kahan it appears to be the latter. "He surveyed over 1,500 Americans, classifying each person's "cultural worldview" on a scale that roughly correlates with politically liberal or conservative. He then assessed each person's scientific literacy with questions such as "True or False: Electrons are smaller than atoms." Finally, he asked them about climate change. If the deficit model were correct, Kahan reasoned, then people with increased scientific literacy, regardless of worldview, should agree with scientists that climate change poses a serious risk to humanity" (Requarth, 2017). The results did not support the deficit model. In fact it was found that conservatives with more scientific knowledge were actually slightly less likely to be worried about climate change. This finding demonstrates that it is ineffective for climate scientists to merely explain their findings. People will not believe the results if they do not trust the source. Thus, a more effective approach is to provide people with a politically neutral framework that can analyze the merit of climate science. This approach will analyze the credibility of the anthropogenic global warming theory. If people can be reassured that climate scientists are a credible source of information, then this will hopefully make them more willing to accept the data that climate scientists present. This method will not convince people who put politics above reason at all costs. However, it could be effective for those who want to be rational, but do not know if they can trust the climate science community.

In order to provide some context for Lakatos' theory, the ideas of some of his key influences will be presented and examined in Chapter One. Logical empiricism, Karl Popper's falsification and Thomas Kuhn's paradigms will be explained and compared and contrasted with Lakatos' methodology of scientific research programs. The topics of induction, deduction, and verificationism, will also be examined.

Once the genesis of Lakatos' theory has been covered, a more in depth examination of Lakatos' concept of research programs will follow in Chapter Two. The essential aspects of a research program, such as the hard core, heuristics, and the protective belt of auxiliary hypotheses will be explained. It will be demonstrated how the protection of the hard core is necessary for the development of a research program.

In Chapter Three the key components of a research program will then be applied to the theory of anthropogenic global warming to assess whether it is progressing or degenerating according to Lakatos' criteria. If it is able to make novel predictions that are corroborated by empirical evidence then it will be considered progressive.

In Chapter Four a practical application of Lakatos' theory, by one of his students, will be presented in order to demonstrate some potential limitations and pitfalls of the methodology of scientific research programs. This will help to provide perspective on the degree to which Lakatos' theory can provide clarity to the anthropogenic global warming debate. Lakatos can not provide a definitive answer as to whether anthropogenic global warming is an accurate theory, but he can provide a helpful framework within which to examine the merit of the anthropogenic global warming theory.

CHAPTER ONE

Lakatos in Context

1.1 Introduction

In order to fully appreciate and understand the contribution of Imre Lakatos to the history and philosophy of science, it is necessary to be familiar with the context in which he wrote. Thus, some of the relevant social, political, scientific and philosophical figures and ideas of Lakatos' day will be discussed, since they had a profound impact on many of Lakatos' ideas. This historical information will elucidate the foundation from which Lakatos developed his theory and the ways in which his theory is a departure from past efforts to differentiate between science and pseudoscience. More specifically, logical empiricism, Karl Popper's falsificationism, and Thomas Kuhn's perspective on the structure of scientific revolutions will be examined. Finally, some of Lakatos' central ideas will be presented and compared with his predecessors. His Methodology of Scientific Research Programs will then be examined in greater detail in the following chapter.

1.2 Logical Empiricism

An important and extremely influential philosophical tradition that developed during the early 20th century is logical empiricism. Having an understanding of logical empiricism is essential for gaining insight into the philosophical atmosphere that influenced Lakatos and other philosophers of science of the 20th century. One of the catalysts for the development of logical empiricism (also known as logical positivism) was the branching off of the natural sciences from philosophy which enabled their independent development. As these sciences, such as biology, chemistry, and physics, became perceived as reliable sources of information, due to their empirical methods, philosophy was under pressure to embrace a method that would be perceived as more reliable and fact based. “One answer that was available at the time that logical empiricism flourished was that the genuinely philosophic remainder after the departure of the sciences is somehow deeper than the empirical sciences and gets at matters, perhaps cultural ones, that are more profound and important than anything that empirical science even can address” (Creath, 2011). This reliance on metaphysical explanations was what logical empiricists wished to abandon.

The logical empiricist rejection of metaphysical explanations of reality was influenced by the turmoil of the early 20th century, in which racism and war were prevalent. A reliance on metaphysics seemed to create a void of moral ambiguity that was filled by the wills of tyrants. “So to articulate a “scientific world conception” and to defend it against metaphysics was not just to express an academic position in the narrow sense. It was a political act as well; it was to strike a blow for the liberation of the mind. To articulate scientific methods and a scientific conception of philosophy was the essential first step in the reform of society and in the emancipation of humankind” (Creath, 2011). In short, logical empiricists wanted to counteract metaphysics with a more evidence based system. Such a system would hopefully help people find common ground and end conflicts over issues to which metaphysics could not provide a singular answer. Thus, logical empiricism was an effort to promote a more rational society that relied on observable facts rather than on unverifiable metaphysical explanations.

1.2a Induction vs. Deduction

An essential aspect of the logical empiricists' war on metaphysics was clearly defining the purviews of induction and deduction; by marginalizing the metaphysical use of deductive reasoning to logical tautologies, logical empiricists put a leash on metaphysical philosophers who were creating an unstable atmosphere that fostered the chaos that plagued the 20th century. More specifically, logical empiricists used verificationism, which is the principle that conclusions and theories can only be made and developed if they are based on publicly shared, observable data. This aspect of logical empiricism was influenced by Ludwig Wittgenstein's 1921 *Tractatus Logico-Philosophicus*, which enabled a distinction to be made between logical and illogical discussions. According to Wittgenstein, logical truths are tautologies, or statements that can be produced by logical deduction. Some important terms to be aware of in logical empiricism are a priori knowledge, a posteriori knowledge, analytic statements, and synthetic statements. Analytic statements, similarly to tautologies, are statements that are true in and of themselves, but do not provide information about the world. Synthetic statements provide information about a fact or facts after an observation has been made. A priori knowledge is able to be known without empirical investigation, while a posteriori knowledge can only be attained after empirical evidence has been gathered. Many logical empiricists held that, exclusively analytic a priori and synthetic a posteriori claims have substance. However, Kant believed that synthetic a priori statements, or descriptions of facts before empirical evidence has been gathered, were possible. However, this idea was not accepted by most logical empiricists because it was deemed impossible to describe something without empirical evidence. Only concepts that could be attained with certainty through logical deduction did not need empirical evidence.

Verificationism provided the intellectual building blocks for logical empiricists, but they needed a coherent system to utilize these building blocks. Bertrand Russell's "logical atomism" satisfied this need. "From atomic propositions more complex propositions can be constructed. By joining together atomic propositions with the operators "a n d" or "o r" we can construct propositions which Russell calls molecular. But there are no facts, Russell holds, that corresponds to molecular propositions. What makes the molecular proposition "This is brown and this is green" true, if it is true, is not a molecular fact but two atomic facts, that this is brown and that this is green. Thus, the truth or falsity of molecular propositions depends entirely upon the truth or falsity of the atomic propositions that compose them. In other words, molecular propositions are "truth functions" of atomic propositions" (McGuire, 1992). In short, logical empiricism is very careful to clarify what it can and cannot say for sure. Complex ideas are composed of the combination of simple facts. The complex idea is only valid if all of the simple parts are valid.

However, this system of "truth functional analysis" has its limits. For example, some concepts are too broad for individual facts to verify a larger whole, as is demonstrated by the statement 'all swans are white'. "For even were it possible to enumerate all swans, it is necessary to stipulate that the swans so enumerated are exhaustively enumerated. This of course reintroduces the generality and as such fails to provide an analysis of it" (McGuire, 1992). In other words induction is useful for developing a theory but can be constrained by an inability to obtain all of the necessary data.

1.2b The Vienna Circle

Logical empiricism had its roots in the Vienna Circle, which was formed in the 1920's "to reconceptualize empiricism by means of their interpretation of then recent advances in the physical and formal sciences" (Uebel, 2006). Logical empiricism stemmed from Auguste Comte's social philosophy of positivism, which stated that eventually theology and metaphysics would be replaced by science. He believed that all that could be known was what was observable. The Vienna circle "sought to account for the presuppositions of scientific theories by regimenting such theories within a logical framework so that the important role played by conventions, either in the form of definitions or of other analytical framework principles, became evident." (Uebel, 2006) While logical empiricism was produced to a large degree by the Vienna Circle, this group of thinkers was certainly not unified. In fact, "its members were by no means of one mind in all important matters; occasionally they espoused perspectives so radically at variance with each other that even their ostensive agreements cannot remain wholly unquestioned" (Uebel, 2006). Thus, many varying ideas and theories emerged from the Vienna Circle. "Despite the pluralism of the Vienna Circle's views, there did exist a minimal consensus which may be put as follows. A theory of scientific knowledge was propagated which sought to renew empiricism by freeing it from the impossible task of justifying the claims of the formal sciences" (Uebel, 2006). The Vienna Circle was a departure from the philosophical schools of thought that had come before it. "All members of the Circle hailed the end of distinctive philosophical system building. In line with the Tractatus claim that all philosophy is really a critique of language, the Vienna Circle took the so-called linguistic turn, the turn to representation as the proper subject matter of philosophy. Philosophy itself was denied a separate first-order domain of expertise and declared a second-order inquiry" (Uebel, 2006) Thus, the independent value of philosophy was greatly diminished and it was now seen as more of an assistant to empirical science. Those who disagreed with logical empiricism often took issue with this assistant role of philosophy, continuing to believe that it had "a separate disciplinary identity from science" (Uebel, 2006).

1.3 Karl Popper and Thomas Kuhn: The Development of Science Over Time

The logical empiricist focus on verification and strict adherence to observable facts destabilized many generally accepted notions about the progressive nature of science. A widely accepted view was that science improves over time by building upon and refining scientific theories from the past. Therefore, scientific revolutions were seen as merely an acceleration of this process of improvement. This common view of science was challenged by the likes of Popper and Kuhn. Kuhn was partially in line with the widely accepted view that science could make progress. He believed that science could make progress within a paradigm and account for some anomalies of the previous paradigm. However, he did not believe that there are super-paradigmatic standards that allow one to say that science progresses toward the truth between paradigms. As Dr. James Marcum points out, “For Kuhn, the progress of science is not a directed activity toward some goal like the truth. Rather, scientific progress is a developmental process … a process of evolution *from* primitive beginnings—a process whose successive stages are characterized by an increasingly detailed and refined understanding of nature. But nothing that has been or will be said makes it a a process of evolution *toward* anything” (Marcum, 2005). According to Kuhn science operates similarly to evolution. “Just as a species is adapted to its environment so a theory is adapted to the world” (Marcum, 2005). In fact, Kuhn felt that new paradigms could actually lose the ability to explain certain phenomena that past paradigms had elucidated (“Kuhn-loss”). Kuhn believed that the philosophy of science could be greatly influenced by a careful examination of history. In his groundbreaking book, *The Structure of Scientific Revolutions*, Kuhn explains, “History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed” (Kuhn, 1962). This emphasis on the history of science was a tremendous addition to the philosophy of science. “Kuhn's contribution to the philosophy of science marked not only a break with several key positivist doctrines, but also inaugurated a new style of philosophy of science that brought it closer to the history of science” (Bird, 2004). While Kuhn and Popper both advocated for the necessity of scientific revolutions, their reasons differed from the main stream. Popper supported revolutions “not because they add to positive knowledge of the truth of theories but because they add to the negative knowledge that the relevant theories are false” (Bird, 2004).

1.3a Criteria For Abandoning a Theory

In addition to differing on the value of scientific revolutions, Kuhn and Popper also disagree on what justifies abandoning a theory. Popper believed that science should be concerned with falsifying theories and that if a theory was not falsifiable then it could not be considered scientific. For example, Popper was adamant about the unscientific nature of psychoanalysis. "Psychoanalytic theories by their nature are insufficiently precise to have negative implications, and so are immunized from experiential falsification" (Thornton, 1997). Unlike psychoanalysis, Marxism was initially deemed scientific by Popper, in that it made predictions that could be falsified. However, once its predictions proved inaccurate, Marxism attempted to adjust its claims to fit to what had actually occurred. This effort rendered Marxism unscientific to Popper because adjusting a theory in order to make it comply with verified data removes its status as falsifiable. Popper's issue with this ad hoc maneuver of Marxism draws parallels to the research programs of Lakatos which deem a program progressive or degenerative based on its predictive ability. Lakatos believes that such retroactive changes to a research program render it degenerative because they reduce the programs empirical content. This concept will be expanded upon in the next chapter.

Unlike Popper who contends that effort should be applied to falsify a theory, Kuhn believes that scientists should concern themselves with "puzzle solving", which involves developing the content of a paradigm. While Kuhn believes that answers to these "puzzles" can be falsified, only several highly problematic anomalies should bring about a "crisis" and a subsequent revolution. Lakatos is more in line with Kuhn on this issue than with Popper. He does not believe that a few anomalies justify the rejection of a research program. In fact, he argues that accounting for anomalies can lead to the expansion and improvement of a program.

1.4 How to Choose Between Competing Theories

Another issue with scientific change is determining which theory to choose when there are competing theories. Rudolf Carnap, an important member of the Vienna Circle, provides insight on the criteria which scientists should use when choosing a theory. "Although Carnap never explicitly addresses the notion of scientific change, his work on probability, confirmation, and induction is relevant to the problem(s) of adducing criteria for theory choice. The issue here is how one theory can be shown to be cognitively and empirically better than another theory. In company with most of his contemporaries, Carnap agrees that if a theory is genuinely scientific, it must in some way be responsive to empirically determinable evidence, and that the better theory is comparatively more responsive to the evidence than the lesser theory. But how was this relation to be specified? For Carnap it is in terms of inductive support as spelled out in his probabilistic notion of degree of confirmation. Thus, on a given body of evidence, a theory is better grounded than another if its inductive probability is higher" (McGuire, 1992). This approach to choosing a theory based on its merit draws comparisons to Lakatos' reasoning behind choosing one research program over another. According to Lakatos, a research program is progressive if it makes accurate predictions about future observable events and is degenerative if it does not. Carnap's criteria for choosing a theory seem to address the fact that the distinction between degenerative and progressive may not be clear cut. He introduces inductive probability to deal with this uncertainty.

1.5 Demarcation Between Science and Pseudoscience

Another way of characterizing the tension between properly conducted scientific efforts and improperly conducted scientific efforts is by describing it as science versus pseudoscience; Lakatos discusses the difference between science and pseudoscience and illustrates the tremendous significance of this distinction. He points out that strong convictions do not constitute knowledge, as there have been many firmly held beliefs that turned out to be misguided. He points out that some of these misguided beliefs have had very serious consequences. Lakatos describes the attempts of others to clarify what constitutes science and what brings about scientific revolutions.

One significant figure whom Lakatos mentions is his mentor Karl Popper. As the head of the Department of Logic and Scientific Method at the London School of Economics, Popper was a significant figure for Lakatos. However, Lakatos and Popper differ on the issue of induction vs deduction. Popper rejects induction and contends that it is pointless to try to verify a theory through empirical evidence because it is not possible to know for sure that all of the possible evidence has been gathered and therefore a theory can never be confirmed but can be disproven through one exception to the rule. Popper feels that deduction is the method science should employ. He believes that scientists should establish a falsifiable theory and attempt to find evidence that opposes that theory. Lakatos offers another perspective in pointing out that history demonstrates that scientific theories tend not to be rejected at the first sign of fallibility. "They do not abandon a theory [merely] because facts contradict it. They normally either invent some rescue hypothesis to explain what they then call a mere anomaly and if they cannot explain the anomaly, they ignore it, and direct their attention to other problems. Note that scientists talk about anomalies, [recalcitrant instances,] and not refutations" (Lakatos, 1973). His argument is based on the actions of scientists throughout history and does not actually refute Popper's theory. Just because historically people have not followed Popper's deductive method of falsification does not mean that the theory of falsification is invalid. This is essentially a prescriptive vs descriptive debate. Just because scientists have been acting a certain way does not mean that they should be acting that way.

1.6 The Evolution of Falsificationism

1.6a Neojustificationism

Lakatos further explains his differences with Popper in *Criticism and the Growth of Knowledge* by examining several different approaches to falsificationism. Lakatos describes the struggles that justificationists faced, in order to provide some context for his discussion of "Fallibilism versus Falsificationism". He describes probabilism ("neojustificationism") as an attempt to deal with the inability of science to prove theories. However, he states, "But even this retreat turned out to be insufficient. It was soon shown, mainly by Popper's persistent efforts that under very general conditions all theories have zero probability, whatever the evidence; all theories are not only equally unprovable but also equally improbable" (Lakatos, 1965). This led to a seemingly disastrous situation for science, as it appeared that science was only capable of speculation. "Falsification was, in a sense a new and considerable retreat for rational thought. But since it was a retreat from utopian standards, it cleared away much hypocrisy and muddled thought, and thus, in fact, it represented an advance" (Lakatos, 1965).

1.6b Dogmatic Falsification

Lakatos states that falsification provides science the ability to state with certainty when something is false. Dogmatic falsificationists contend that empirical facts cannot be used inductively to prove a theory but can be used to disprove a theory. "Scientific honesty then consists of specifying, in advance, an experiment such that if the result contradicts the theory, the theory has to be given up" (Lakatos, 1965). Lakatos sees two important issues with dogmatic falsificationism. The first is the demarcation between theoretical and observational propositions. He uses the example of Galileo's apparent use of observation to disprove the theory that celestial bodies are smooth. Galileo used technology to observe the surface of the moon and therefore his observations "depended on the reliability of his telescope and of the optical theory of the telescope which was violently questioned by his contemporaries" (Lakatos, 1965). Since the telescope only provided accurate information in theory, it could not be relied upon for empirical support. Additionally, he goes on to explain that even the apparently objective senses can not provide a demarcation between theory and observation, due to their inevitable "expectations". The second issue which Lakatos has with dogmatic falsificationists is their confidence in the ability of experiments to prove a “proposition”. He states, “propositions can only be derived from other propositions, they cannot be derived from facts” (Lakatos, 1965). This apparent weakness of falsification leads him to the conclusion that propositions can neither be proven nor disproven. “If factual propositions are unprovable then they are fallible. If they are fallible then clashes between theories and factual propositions are not ‘falsifications’ but merely inconsistencies… all propositions of science are theoretical and, incurably, fallible.”

Lakatos goes on to say that, in addition to these two problems, dogmatic falsification also does not deal with the concept that a theory is not isolated, but is guarded by “a *ceteris paribus* clause” (Lakatos, 1965). This clause can be adjusted to incorporate the empirical evidence and thus the theory is not falsified.

In summary, Lakatos refutes dogmatic falsificationists by pointing out the inability of the senses to make pure observations, the error of trying to falsify propositions through facts, and the immunity that “*ceteris paribus* clauses” provide for theories. He admits that this conclusion makes it appear that science can neither prove nor disprove anything.

1.6c Methodological Falsification

In an effort to address the issues of dogmatic falsificationism, Lakatos goes on to discuss methodological falsificationism. However, he first describes the various forms of conventionalism in order to explain how methodological falsification developed. He begins his discussion of conventionalism by explaining that, “There is an important demarcation between ‘passivist' and activist theories of knowledge. ‘Passivists’ hold that true knowledge is Nature’s imprint on a perfectly inert mind: mental activity can only result in bias and distortion. The most influential passivist school is classical empiricism. Activists’ hold that we cannot read the book of Nature without mental activity, without interpreting them in the light of our expectations or theories. Now conservative ‘activists’ hold that we are born with our basic expectations; with them we turn the world into ‘our world’ but must then live forever in the prison of our world” (Lakatos, 1965). Thus, the way in which we perceive the world is dependent upon the “conceptual framework” through which we see the world. While conservative activists believe that we are trapped within our personal frameworks, “revolutionary activists” contend that we can discard and improve upon these frameworks. Lakatos explains that this ability to discard or improve upon frameworks eventually led to conservative conventionalism, in which “after a considerable period of initial empirical success scientists may decide not to allow the theory to be refuted” (Lakatos, 1965). Thus, new theories that have not been rigorously tested can be abandoned if anomalous data is presented, but well established theories can reach a point where they are heavily guarded against falsification. Criticism that “there comes a time when these frameworks turn into prisons” led to the “methodological falsificationism" of Popper. Popper differed from proponents of dogmatic falsificationism in that he believed that individual empirical observations were not reliable enough to lead to the rejection of a theory. “The methodological falsificationist separates rejection and disproof, which the dogmatic falsificationist had conflated.” Basically, methodological falsificationism is an attempt at practicality. If the evidence is strongly against a theory then it should be discarded due to its scientific uselessness. It cannot be categorically disproven, because empirical evidence is not reliable enough to do so, but it can be shown to lack scientific fruitfulness. Additionally, while methodological falsificationists did not try to verify theories they did believe that certain theories provided “unproblematic background knowledge” that could be used to expand the scope of scientific examination. As Lakatos puts it, “The methodological falsificationist uses our most successful theories as extensions of our senses and widens the range of theories which can be applied in testing far beyond the dogmatic falsificationist’s range of strictly observational theories” (Lakatos, 1965). Additionally, this method of falsification provides a very clear criterion for what is scientific. To be scientific, a theory must simply be capable of being disproven.

1.7 Paradigm Shifts

Despite refuting Popper’s claim that falsification should lead to the instant rejection of a theory, Lakatos does not believe as Thomas Kuhn does that theories are chosen without a rational basis. Kuhn contends that, when a scientific revolution occurs, scientists can choose which school of thought they want to operate within. Scientists cannot operate between paradigms due to the issue of incommensurability. Additionally, progress can be made within a paradigm through the “puzzle solving” endeavors of “normal science”. However, because there is no overlap between paradigms, progress occurs only within a paradigm and not in a constant progression throughout history from inferior to superior science.

1.8 How Science is Conducted Historically

Lakatos emphasizes the importance of examining science from a historical perspective rather than a purely philosophical perspective. Lakatos believes that the enduring theories throughout history have not been rejected at the first sign of falsification because they are protected by other features, which combined with the central theory, make up a "research program". He states, "this hard core is tenaciously protected from refutation by a vast 'protective belt' of auxiliary hypotheses. And, even more importantly, the research program also has a 'heuristic', that is, a powerful problem-solving machinery, which, with the help of sophisticated mathematical techniques, digests anomalies and even turns them into positive evidence" (Lakatos, 1973). He claims that certain research programs have objective merit (progressive research programs) and should be chosen over other "degenerating" research programs. This merit comes from a research program's ability to make "novel" and accurate predictions about future events rather than adjusting to past occurrences. Lakatos comes to the conclusion that, "On close inspection both Popperian crucial experiments and Kuhnian revolutions turn out to be myths: what normally happens is that progressive research programs replace degenerating ones" (Lakatos, 1973). The structure and dynamics of scientific research programs will be examined in more depth in the next chapter.

CHAPTER TWO

Methodology of Scientific Research Programs

2.1 Introduction

Lakatos' methodology of scientific research programs is an attempt to provide a clear picture of how science operates and how to differentiate between science and pseudoscience. He was motivated by a desire to demonstrate the rational nature of science which was in need of a stronger defense than had been provided by his predecessors including those mentioned in Chapter One. He differed from Kuhn and Popper in a very fundamental way on how he approached the philosophy of science. The unit of appraisal for Kuhn is the paradigm, and for Popper it is the theory. For Lakatos the unit of appraisal is a series of related theories. Regarding the issue of how science operates, Lakatos provides guidelines for how to go about dealing with many of the issues that science frequently encounters. First, he addresses the criteria for determining whether a theory is scientific. Second, he explains how to determine whether a scientific theory is progressive or degenerative.

Having discussed the intellectual background from which Lakatos' theory emerged, the following description of the methodology of scientific research programs should be easier to understand and it should be clear in which ways Lakatos has generated improvements. First, the structure of a research program will be examined. Next, Lakatos' demarcation criteria for science vs. pseudoscience will be discussed. Finally, his method for determining when a theory should be abandoned for another will be explained.

2.2 Structure of a Scientific Research Program

Before explaining the dynamics of a research program it will be helpful to discuss the structure of a research program and to clearly define its essential components. While the specific nature of these components varies, there are several components common to all research programs. There is a hard core, a positive and negative heuristic, and auxiliary hypotheses.

2.2a Hard Core and Auxiliary Hypotheses

The hard core is the part of a research program that is accepted as true. It is protected by a negative heuristic which discourages attempts to find data that conflicts with the hard core. For example, "In Newton's program the negative heuristic bids us to divert the modus tollens from Newton's three laws of dynamics and his law of gravitation. This 'core' is 'irrefutable' by the methodological decision of its protagonists: anomalies must lead to changes only in the 'protective' belt of auxiliary, 'observational' hypothesis and initial conditions" (Lakatos, 1965). Lakatos believes that for a program to progress it is important to have this protective measure in place for the hard core. If there were no negative heuristic, then whenever anomalous data appeared the hard core would be in jeopardy. Putting the hard core off limits to scrutiny, allows scientists to come up with new hypotheses that account for anomalies. Consequently, anomalies can be beneficial to a research program, because by coming up with a corroborated auxiliary hypothesis the program increases its empirical content and progresses. Protecting the hard core does not however completely immunize a theory from falsification. “Together with the hard core these auxiliary hypotheses entail empirical predictions, thus making the theory as a whole —hard core plus auxiliary hypotheses—a falsifiable affair” (Musgrave & Pidgen, 2016). Additionally, as Musgrave and Pigden point out, “the hard core theses by themselves are often devoid of empirical consequences. For example, Newtonian mechanics by itself—the three laws of mechanics and the law of gravitation—won’t tell you what you will see in the night sky. To derive empirical predictions from Newtonian mechanics you need a whole host of auxiliary hypotheses about the positions, masses and relative velocities of the heavenly bodies, including the earth” (Musgrave & Pigden, 2016). Thus, a hardcore needs auxiliary hypotheses not only to protect it from anomalies but also to contribute practical value.

This strong commitment to the hard core draws parallels to Kuhn’s highly protected paradigms, and contrasts with Popper’s emphasis on the falsification and rejection of theories. “Kuhn's view is that during normal science scientists neither test nor seek to confirm the guiding theories of their disciplinary matrix. Nor do they regard anomalous results as falsifying those theories. (It is only speculative puzzle-solutions that can be falsified in a Popperian fashion during normal science.) Rather, anomalies are ignored or explained away if at all possible. It is only the accumulation of particularly troublesome anomalies that poses a serious problem for the existing disciplinary matrix” (Bird, 2004). This protection of the core of a scientific discipline is necessary to allow scientists to progress within a paradigm. If scientists are constantly questioning the principles upon which they are conducting their research, their efforts will be greatly inhibited. Kuhn acknowledges that paradigm shifts are sometimes necessary when a paradigm experiences a crisis. However, scientists should focus their efforts on developing a paradigm rather than trying to generate a new paradigm. On the other hand, Popper disagrees with Lakatos and Kuhn. Popper believes that all theories are falsifiable. Therefore, the goal of science is to focus on falsifying theories. Falsification clears away “bad” theories, and in this way science progresses towards truth. Popper argues that their are critical tests that can lead to the rejection of a theory. However, Lakatos believes that when science is examined historically these critical tests do not actually exist.

Lakatos’ reluctance to reject a theory was influenced by German philosopher Georg Wilhelm Friedrich Hegel’s dialectic philosophy. “Non-dialectical logic (induction as well as deduction) concerns itself with relations of inference between propositions, whereas dialectical logic studies the development of concepts.” (Larvor, 1998) Thus, dialectical logic is not a single jump to a conclusion but involves a stepwise process of adjustment and improvement. In other words, it is possible to learn from mistakes. Making a mistake doesn’t automatically mean that someone should give up. That experience can be used to improve in the future. Lakatos believes this gradual process of refinement to be an accurate representation of how science has developed throughout history.

2.2b Positive Heuristic

Dealing with anomalies is by no means an easy process but is made simpler by having what Lakatos calls a positive heuristic. As Lakatos puts it, “the positive heuristic consists of a partially articulated set of suggestions or hints on how to change, develop the ‘refutable variants’ of the research-program, how to modify sophisticate, the ‘refutable’ protective belt. The positive heuristic of the program saves the scientist from becoming confused by the ocean of anomalies” (Lakatos, 1965). The positive heuristic allows scientists to not only deal more efficiently with empirical anomalies, but also enables them to come up with auxiliary hypotheses for theoretical anomalies. A good example of this principle of gradual refinement is seen in the development of Newtonian physics. “Most, if not all, Newtonian ‘puzzles’, leading to a series of new variants superseding each other, were foreseeable at the time of Newton’s first naive model and no doubt Newton and his colleagues did foresee them: Newton must have been aware of the blatant falsity of his first variants… This shows once more how irrelevant ‘refutations’ of any specific variant are in a research program: their existence is fully expected, the positive heuristic is there as the strategy both for predicting (producing) and digesting them. Indeed, if the positive heuristic is clearly spelt out, the difficulties of the program are mathematical rather than empirical” (Lakatos, 1965). Although all research programs will encounter anomalies, highly effective programs can account for these issues preemptively instead of trying to catch up after receiving anomalous empirical data.

2.3 Demarcation Between Science and Pseudoscience

Having discussed the essential structural components of a research program, Lakatos' criteria for a theory to be scientific will now be explained. Lakatos agrees with Popper that for a theory to be scientific it must make claims that can be falsified. Theories such as psychoanalysis are dismissed as pseudoscience because it is not possible to empirically falsify them. According to Lakatos and Popper, the predictions that psychoanalysis makes accommodate every human behavior. Thus, while psychoanalysis makes predictions, these predictions are designed to always be corroborated. As Alexander Bird explains, "physics, chemistry, and (non-introspective) psychology, amongst others, are sciences, psychoanalysis is a pre-science (i.e., it undoubtedly contains useful and informative truths, but until such time as psychoanalytical theories can be formulated in such a manner as to be falsifiable, they will not attain the status of scientific theories), and astrology and phrenology are pseudo-sciences" (Bird, 2004). However, the demarcation is not always this clear cut. For example, Marxism was initially deemed scientific, but after adjusting its predictions to fit anomalous data, it diminished its empirical content (the amount of falsifiable predictions a research program makes). This technique is referred to as an ad hoc maneuver and is a sign that a research program is in decline. It is a sign of decline because a progressive program is able to explain anomalies in a way that doesn't diminish the programs empirical content.

2.4 Progressive vs. Degenerative Research Programs

In addition to determining whether a theory is scientific, Lakatos also provides detailed guidelines on when a theory can be considered progressive or degenerative. He believes that anomalous data is not enough to warrant abandoning a theory. There must be a new theory that is capable of explaining the anomaly and that adds empirical content while accounting for all of the corroborated aspects of the previous theory. He states, "let us call a problem shift progressive if it is both theoretically and empirically progressive, and degenerating if it is not. We 'accept' problem shifts as 'scientific' only if they are at least theoretically progressive; if they are not, we 'reject' them as 'pseudoscientific'. Progress is measured by the degree to which a problem shift is progressive, by the degree to which the series of theories leads us to the discovery of novel facts. We regard a theory in the series 'falsified' when it is superseded by a theory with higher corroborated content" (Lakatos, 1965). The theoretical progress that he refers to is the novel predictions that a theory makes, and the empirical progress is the predictions that are supported by evidence. Thus, Lakatos does not believe that theories can be examined in isolation. It is necessary to view theories in relation to their predecessors to determine if they are progressive or degenerative. An example that Lakatos thinks exemplifies a progressive research program, "is the predicted return of Halley's comet which was derived by observing part of its trajectory and using Newtonian mechanics to calculate the elongated ellipse in which it was moving. The comet duly turned up seventy-two years later, exactly where and when Halley had predicted, a novel fact that could not have been arrived at without the aid of Newton's theory (S&P: 5). Newton's theory delivered far more precise predictions than the rival heliocentric theory developed by Descartes, let alone the earth-centered Ptolemaic cosmology that had ruled the intellectual roost for centuries. That's the kind of spectacular corroboration that propels a research program into the lead. And it was a similarly novel prediction, spectacularly confirmed, that dethroned Newton's physics in favor of Einstein's" (Musgrave & Pigden, 2016). This is a perfect example of a progressive theory because it made a novel prediction that was confirmed. A theory can be initially progressive if it makes a novel prediction but is in jeopardy of becoming degenerative if the prediction is falsified.

Despite proposing that progressive research programs tend to replace degenerating research programs, Lakatos does not believe that science is on a straight path towards truth. "Lakatos did not imagine that every change in scientific orthodoxy is progress. He liked to cite the cases in which theories were adopted under political pressure from totalitarian governments. In these cases he was sure that change was for the worse. Moreover, he did not think that any change in the scientific outlook could be proven beyond all doubt to be a step in the direction of truth. The scientific community is capable of going astray all by itself, without the assistance of a Stalin-figure" (Larvor, 1998). Thus, Lakatos believes that science is based in reason and that it is possible to progress from an inferior theory to a superior theory. However, because humans are imperfect and are responsible for the development of science, it is possible for science to regress and appear irrational at times.

2.5 Problem For Lakatos

While Lakatos' methodology of scientific research programs has many positive attributes and is very helpful in distinguishing between progressive research programs and degenerative research programs, it does have a drawback. Lakatos admits, "As opposed to Popper the methodology of scientific research programs does not offer instant rationality. One must treat budding programs leniently: programs may take decades before they get off the ground and become empirically progressive" (Lakatos, 1973). Thus, the drawback of Lakatos' view is that it can take an extended and indefinite period of time to determine whether a research program is progressing or degenerating. The distinction between developing, and requiring more time, and stagnating can be ambiguous.

2.6 The Utility of the Methodology of Scientific Research Programs

That having been said, Lakatos still provides a useful framework for analyzing contested areas of science. Without clear guidelines of what to look for when discussing the merit of a particular theory, it can be difficult to come to any logical conclusion. It is also very easy to fall into the trap of allowing judgements to be influenced, and directed by political or other biases. A current scientific discipline that has been under a great deal of scrutiny is climate science. More specifically, the theory of anthropogenic global warming is a theory that has created a great deal of discord among U.S politicians and the American public as well. The methodology of scientific research programs can provide a more rational way of examining this controversial topic. It can help to identify markers of progress or degeneration.

CHAPTER THREE

Examining Climate Science From a Lakatosian Perspective

3.1 Introduction

Now that Lakatos' methodology of scientific research programs has been explained it is possible to apply it to climate science. More specifically the essential components of a research program, the hard core, the auxiliary hypotheses, and the heuristics will be used to describe important aspects of anthropogenic global warming. First it will be determined whether the anthropogenic global warming research program meets Lakatos' scientific criteria. Then it will be decided whether this research program is progressive or degenerative. This determination is very important because lawmakers and the general public need to know whether they should put their trust in the climate science community. First however, it will be helpful to be familiar with some fundamentals of global warming.

3.2 Climate Science Fundamentals

3.2a Climate vs. Weather

It is important to understand the distinction between climate and weather. "Climate is generally defined as average weather, and as such, climate change and weather are intertwined. Observations can show that there have been changes in weather, and it is the statistics of changes in weather over time that identify climate change" (IPCC, 2007).

Thus, short term extremes in temperatures do not constitute climate change. However, if these extremes persist over time then they will tend to impact the average temperature and consequently alter the climate. It is very difficult to predict weather, because it is highly variable from week to week. It is easier to predict climate because it is less susceptible to random events. This distinction is similar to predicting the price of a stock. It is easier to predict how a stock will perform over the course of several years than it is to predict how the stock will do on any given day.

3.2b Climate Forcings

The Earth's temperature is determined by the balance between incoming and outgoing radiation. This balance is influenced by external forcings (factors that impact the climate) such as solar variations, volcanic eruptions, aerosols, green house gases, and cloud cover. Some of these forcings reduce the amount of radiation reaching the Earth and others increase the amount. "There are three fundamental ways to change the radiation balance of the Earth: 1) by changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself); 2) by changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation); and 3) by altering the longwave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations). Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms" (IPCC, 2007). The climate science community is very focused on greenhouse gases because this is the forcing

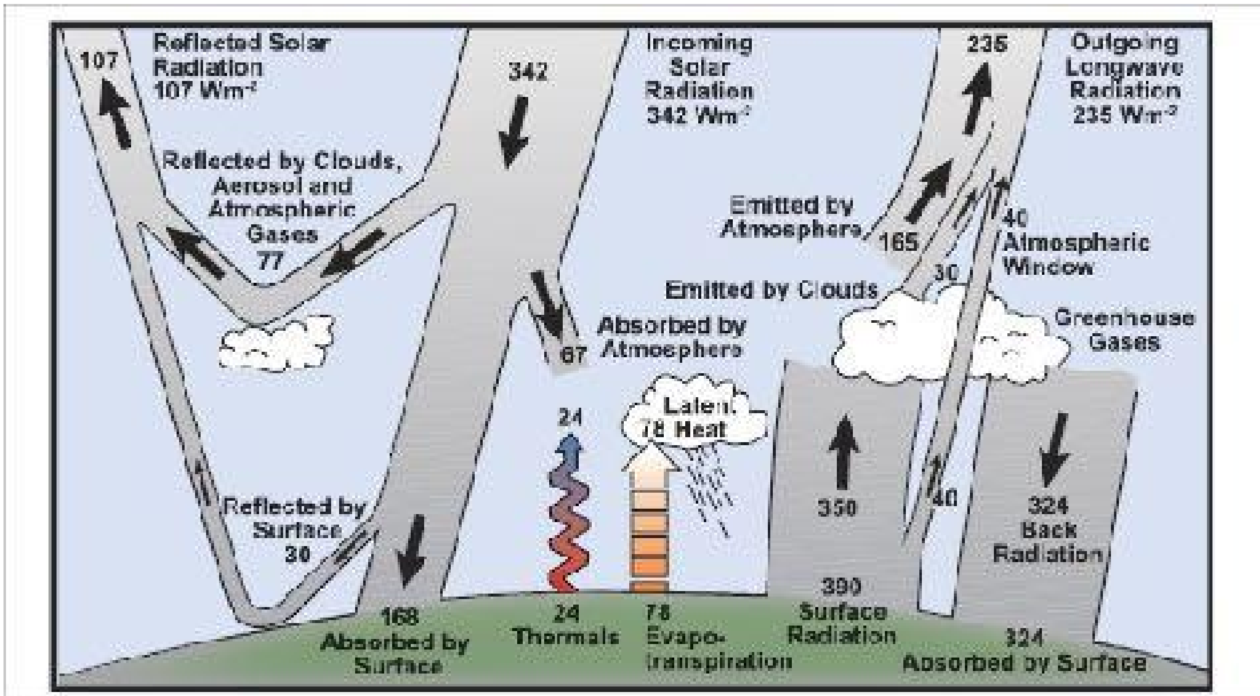

Figure 1: Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. (Kiehl and Trenberth, 1997).

that humans have been contributing to at an unprecedented rate over the past century. Greenhouse gases are necessary to keep the Earth's temperature from dropping too low, but an excess of green house gases can lead to more heat entering the atmosphere than leaving the atmosphere. "Water vapour is the most important greenhouse gas, and carbon dioxide (CO2) is the second-most important one. Methane, nitrous oxide, ozone and several other gases present in the atmosphere in small amounts also contribute to the greenhouse effect" (IPCC, 2007). As CO2 levels rise the the Earth's surface temperature increases, which leads to more water vapor. This additional water vapor produces even warmer surface temperatures by trapping outgoing radiation. This positive feedback mechanism is very concerning to climate scientists because it amplifies the warming effect of green house gases.

3.2c Anthropogenic Global Warming

While there is controversy regarding the degree to which human generated forcings are leading to global warming, there is little doubt that humans are having an impact. Since the time of the industrial revolution CO2 levels have increased at a dramatic rate. In fact, "The concentration of CO2 is now known accurately for the past 650,000 years from antarctic ice cores. During this time, CO2 concentration varied between a low of 180 ppm during cold glacial times and a high of 300 ppm during warm interglacials. Over the past century, it rapidly increased well out of this range, and is now 379 ppm" (IPCC, 2007). Since CO2 is one of the most important green house gases, increases in CO2 will lead to an increase in long wave radiation being trapped and returned to the surface of the earth. According to the IPCC's Fifth Assessment Report (AR5),

> Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally (high confidence). In most scenarios without additional mitigation efforts (those with 2100 atmospheric concentrations >1000 ppm CO2-eq), warming is more likely than not to exceed 4°C above pre-industrial levels by 2100. The risks associated with temperatures at or above 4°C include substantial species extinction, global and regional food insecurity, consequential constraints on common human activities and limited potential for adaptation in some cases (high confidence) (IPCC, 2014).

The report did state that reductions in CO_2 emissions could help to control this ominous situation.

3.3 Is the Anthropogenic Global Warming Research Program Scientific?

Lakatos' criteria for a theory to be scientific is that the theory must be falsifiable. It will now be examined whether the theory of anthropogenic global warming meets this criteria.

The most important element of anthropogenic global warming is that an increase in CO_2, and other human produced green house gasses will lead to an increase in surface temperature, if all other forcings remain constant. If it is demonstrated that an increase in human generated green house gasses does not lead to global warming or actually leads to global cooling then the theory will be falsified. Thus, it appears that the theory of anthropogenic global warming is falsifiable and therefore scientific. However, it may not be that simple. Since, climate science is heavily reliant upon models that make predictions relatively far in the future, it is difficult to know when enough time has passed to falsify anthropogenic global warming. Thomas Curtis, the Managing Director and Global Co-Head of DB Climate Change Advisors, believes that, "Because AGW is a complex theory with many auxiliary hypotheses, it is difficult to develop "crucial tests", i.e, any individual test that will show it to be false. In fact, in the very short term it is impossible. What we can do is develop "crucial tests" for important elements of the theory, but not for the whole theory at once" (Curtis, 2014). Thus, not only does time present an obstacle for falsification, but so to does the elaborate and extensive protective belt of auxiliary hypotheses that surround the core of anthropogenic global warming. However, these challenges do not change the fact that there is a prediction in place that is open to contradictory evidence. Thus, while it is difficult and requires an unspecified period of time, it is possible to falsify the theory of anthropogenic global warming.

3.4 Issue of Time For Lakatos

However, as was mentioned in the previous chapter this is a significant problem with Lakatos' demarcation between what is scientific and what is pseudoscientific. Lakatos wants to provide a rational way to examine a theory, but is unable to specify how long a theory should be allowed to persist before a final decision is made. Thus, it could be decades, centuries, or longer before it can be definitively stated whether the theory of anthropogenic global warming was falsified or not.

3.5 Is the Anthropogenic Global Warming Research Program Progressive?

Now that the anthropogenic global warming theory has been shown to meet Lakatos' criteria for being scientific, it will now be determined whether or not it is progressive. As was explained in the previous chapter, the criteria for whether a research program is progressive are more demanding than merely the ability to be falsified.

> It must meet two conditions. Firstly it must be theoretically progressive. That is, each new theory in the sequence must have excess empirical content over its predecessor; it must predict novel and hitherto unexpected facts. Secondly it must be empirically progressive. Some of that novel content has to be corroborated, that is, some of the new "facts" that the theory predicts must turn out to be true. As Lakatos himself put the point, a research program 'is progressive if it is both theoretically and empirically progressive, and degenerating if it is not'. Thus a research program

is degenerating if the successive theories do not deliver novel predictions or if the novel predictions that they deliver turn out to be false (Musgrave and Pigden, 2016).

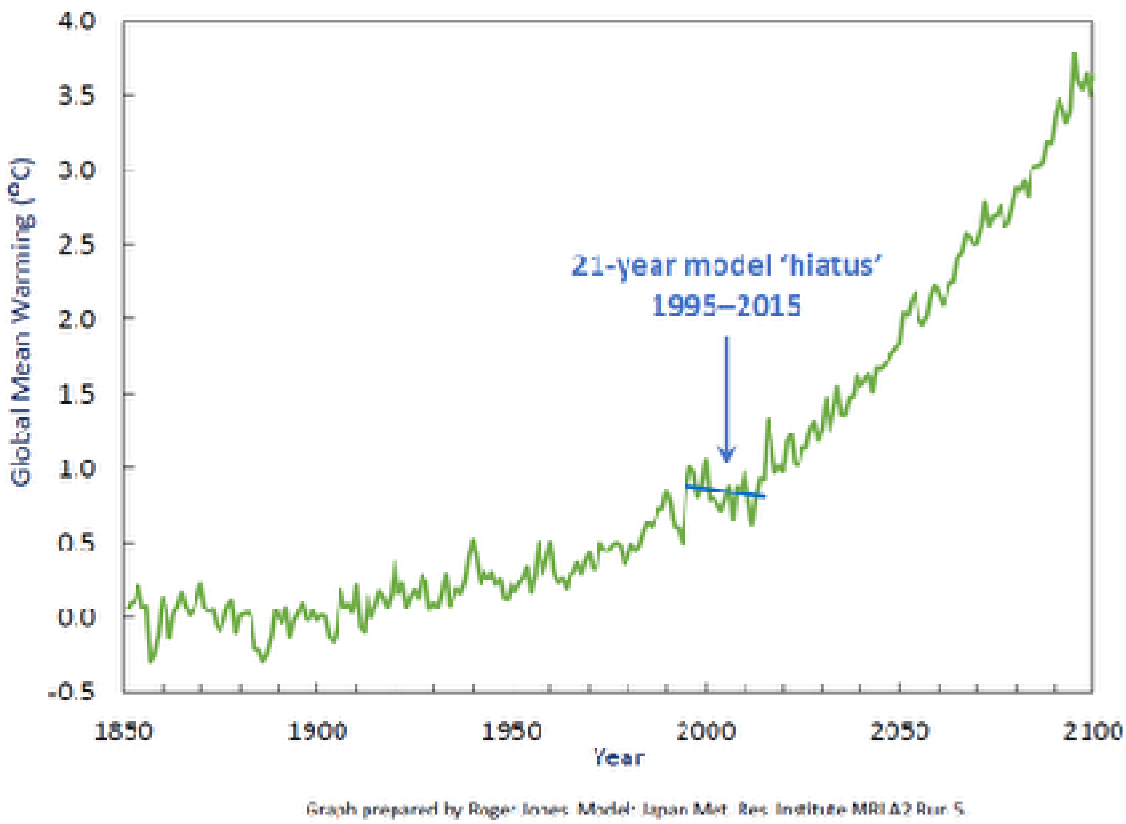

Figure 2: Warming Hiatus

A critical prediction for anthropogenic climate change theorists is that there is a direct, positive correlation between CO2 levels and global surface temperatures.

3.5a The Hard Core

The hypothesis that CO2 levels and increases in temperature are directly correlated has been strongly supported. In the last decades of the 20th century global temperatures steadily rose. Since natural forcings such as solar variations could not account for this increase in temperature it appeared that it must be the amplification of CO2 levels that was causing the temperature increase. As CO2 levels continued to rise in the 2000's it was anticipated that the global temperature would continue to rise as well. However, instead a pause in temperature increases was observed. This anomaly could have led scientists to reject the theory that humans are causing global warming.

Scientists did not reject their theory of anthropogenic global warming because it can be argued that it is the hard core of their research program. As explained in the previous chapter, the hard core is not subject to refutation.

3.5b Auxiliary Hypotheses

Therefore, scientists needed to find an alternative reason that temperatures had not continued to rise as CO2 levels rose. The auxiliary hypothesis that they came up with is that the deep water of oceans is storing the heat that otherwise would be leading to warming of the surface. "Armed with a unique model that simulates the world's oceans using historical weather data on temperature, humidity, and wind, Drijfhout and his colleagues calculated how much heat is moving between the oceans and the atmosphere, as well as where it first enters the ocean. The model revealed that the oceans were trapping more than 80% of the missing heat" (Kollipara, 2014). While this discovery would seem to account for a large portion of the missing heat, some believe that it only accounts for a relatively small fraction of the problem. "There is a difference between finding some warming in the Indian Ocean and justifying the proposition that the amount of heat storage explains what is needed to account for the global hiatus. [We] not only calculated the heat storage in the Indian Ocean in the upper 700 meters but…calculated it down to 1500 meters and showed that it was not enough" (Reed, 2015). Thus, while auxiliary hypotheses have been proposed to try to account for the hiatus in surface temperature warming there has not been a definitive and highly corroborated explanation. Additionally, the auxiliary hypotheses used to try to explain the missing heat seem to be ad hoc maneuvers according to Lakatos' criteria. They did not emerge from the positive heuristic (climate models) of the research program but were proposed in hindsight to account for a problematic anomaly. Therefore in this instance the anthropogenic global warming research program appears to be degenerative. According to Lakatos ad hoc maneuvers are problematic but in isolation are not enough to completely reject a theory. "The discovery of an inconsistency—or of an anomaly—[need not] immediately stop the development of a program: it may be rational to put the inconsistency into some temporary, ad hoc quarantine, and carry on with the positive heuristic of the program" (Lakatos, 1965). Lakatos believes that an ad hoc hypotheses is a potential problem but that it is only when ad hoc hypotheses are continually employed to explain anomalies that they become a significant issue and the research program is deemed degenerative. In order to determine whether this ad hoc maneuver is a rare occurrence or a recurring problem for the anthropogenic global warming research program, more examples of climate predictions and results will be investigated.

3.5c Climate Models as a Positive Heuristic

While it is not possible to corroborate current predictions about what global temperatures will be centuries from now, it is possible to analyze past predictions about where temperatures would be currently, or at least in the not so distant future. "In 1990, the Intergovernmental Panel on Climate Change (IPCC) — a group of the world's top climate scientists — released its First Assessment Report, predicting global warming of about 1.1 degrees Celsius between 1990 and 2030" (Creagh, 2013). The half way point between 1990 and 2030 is 2010. Thus, according to the IPPC the global temperature should have increased by approximately half of the predicted 1.1 degrees Celsius (0.55 degrees Celsius). "In fact, the world has now warmed by about 0.39 degrees Celsius, coming very close to the prediction despite several unforeseen historical events, such as the collapse of the Soviet Union, the Mt Pinatubo volcanic eruption and the rise of China" (Creagh, 2013). The difference between the predicted increase in temperature and the actual increase may seem to be a cause for concern. However, climate models used to make such predictions are intended to predict trends over time and do not account for extreme events that may skew the data in the short term. Thus, 1990-2010 is a relatively short time period for climate models to accurately predict. "Climate models are mathematical representations of the interactions between the atmosphere, oceans, land surface, ice – and the sun. This is clearly a very complex task, so models are built to estimate trends rather than events. For example, a climate model can tell you it will be cold in winter, but it can't tell you what the temperature will be on a specific day – that's weather forecasting. Climate trends are weather, averaged out over time - usually 30 years. Trends are important because they eliminate - or "smooth out" - single events that may be extreme, but quite rare" (Nuccitelli, 2016).

This raises the question of how we can know if climate models are reliable without being able to look into the future. The solution is that climate models can be used to predict changes in the climate that occurred in the past.

> So all models are first tested in a process called Hindcasting. The models used to predict future global warming can accurately map past climate changes. If they get the past right, there is no reason to think their predictions would be wrong. Testing models against the existing instrumental record suggested CO_2 must cause global warming, because the models could not simulate what had already happened unless the extra CO_2 was added to the model. All other known forcings are adequate in explaining temperature variations prior to the rise in temperature over the last thirty years, while none of them are capable of explaining the rise in the past thirty years. CO_2 does explain that rise, and explains it completely without any need for additional, as yet unknown forcings. (Nuccitelli, 2016)

The ability to calibrate climate models based on how they perform with inputs from the past is a valuable tool. However, Lakatos would likely not view this aspect of climate science as progressive because the ability to model past events is not the same thing as novel prediction.

This may seem similar to what Lakatos took issue with within Marxism of using past events to adjust their theory. However, this would only be the case if models were calibrated to fit future data. The theory of anthropogenic global warming will be supported or opposed based on how well climate models predict the future of the climate. Thus, using the past to calibrate models is not an ad hoc maneuver, but merely a way to strengthen the positive heuristic of the research program. Climate models are a very strong positive heuristic for climate science. They show scientists which forcings have the greatest impact on temperature changes and allow them to focus their efforts on what is most relevant.

Lakatos makes it very clear that a strong positive heuristic is a hallmark of a progressive research program. A positive heuristic should be able to deal with novel occurrences without comprising the hard core of the program. Climate models meet this criteria. “For example, the eruption of Mt. Pinatubo allowed modellers to test the accuracy of models by feeding in the data about the eruption. The models successfully predicted the climatic response after the eruption. Models also correctly predicted other effects subsequently confirmed by observation, including greater warming in the Arctic and over land, greater warming at night, and stratospheric cooling” (Nuccitelli, 2016). Thus, in this instance anthropogenic global warming appears to be progressive. As explained earlier the ad hoc maneuver utilized to account for the warming hiatus is concerning but in general climate models have been reliable in the predictions that they have made.

CHAPTER FOUR

Limitations for the Methodology of Scientific Research Programs

4.1 Introduction

The application of Lakatos' philosophy to contemporary climate science indicates that it is a progressive research program. It has made novel predictions, and some of these predictions have been corroborated. However, it has also encountered some unexplained anomalies. This coexistence of anomalies and accurate novel predictions within a research program does seem to present another limitation for the methodology of scientific research programs. Lakatos is correct that theories historically do not tend to be rejected due to a small number of anomalies. If certain theories such as Newtonian physics had been abandoned when they first encountered problems, the world would have been deprived of tremendous scientific developments. However, Lakatos' willingness to allow a theory to continue to be deemed progressive despite encountering anomalies presents a problem. In this chapter a practical application of Lakatos' theory, by one of his students, will be presented and critiqued in order to demonstrate the obstacles that can occur when trying to differentiate between progressive and degenerative programs. This analysis will help provide insight into the potential strengths and weaknesses of the application of the methodology of scientific research programs to climate science. Lakatos' methodology provides a helpful framework for analyzing the merit of climate science, but can be limited by its lack of clear guidelines regarding the significance of anomalous data, and by the challenge of correctly identifying the hard core, auxiliary hypotheses and heuristics.

4.2 Unclear Demarcation Between Progressive and Degenerative

As has been discussed previously, Lakatos contends that if a research program predicts novel facts that are corroborated then it is progressing. Lakatos also believes that the build up of unexplained anomalous data is problematic and is an indication of a degenerating research program. Thus, it becomes unclear how to determine whether a research program is degenerating or progressing, when that research program contains both corroborated novel predictions and unexplained anomalous data. Do multiple accurate predictions render inaccurate predictions insignificant? This brings to mind the phrase "a broken clock is right twice a day". The problem is what tips the balance between degenerative and progressive. Do you merely need to have more corroborated novel predictions than anomalies? Does one monumental accurate prediction outweigh many anomalies? It can be argued that Lakatos did not specify these details because it is not possible to do so. Thus, Lakatos helps us to make strides toward a rational way of analyzing the merit of theories, but does not fully achieve his goal because it is impossible to specify an exact number of anomalies that would cause a theory to become degenerative.

4.3 IQ Science: An Early Application of MSRP

In order to further analyze the utility of Lakatos' method, and the degree to which he achieved his goal of rationality, a practical application of MSRP will now be presented.

There are not many instances of this, but one of Lakatos' students Peter Urbach applied Lakatos' theory in a manner that is helpful in understanding the utility of the methodology of scientific research programs and some of its short comings. In Progress and Degeneration in the 'IQ Debate' Urbach examines the hereditarian and environmentalist theories of intelligence. Urbach utilizes Lakatos's methodology of scientific research programs in order to analyze the merit of each theory. He desires to "detach the debate from the political positions with which they are falsely associated in the public mind" (Urbach, 1974).

According to Urbach, the conflict between environmentalists and hereditarians is whether intelligence is genetically determined, or whether it is purely a result of an individual's surroundings. Both hereditarianism and environmentalism meet Lakatos' criteria of a research program. They have a hard core, heuristics, auxiliary hypotheses, and make claims that can be falsified. Urbach explains, "Each of the two series can be characterized by a set of assumptions ('hard cores') common to all the terms. Moreover, each of the series is associated with certain 'heuristic' machinery guiding the construction of successive hypotheses in the series" (Urbach, 1974). An example of this "heuristic machinery" is IQ tests. These tests can be adjusted in order to account for anomalies and are the means by which auxiliary hypotheses can be evaluated. For example, if a particular IQ test does not support a given hypothesis, then the test can be adjusted to account for things such as the educational, or cultural background of the participants taking the test.

Urbach focuses on the ability of each program to make novel predictions and to account for anomalies without using ad hoc maneuvers. He realizes that most if not all research programs will face challenges. However, this only becomes a problem if the heuristic is unable to account for these anomalies in a way that does not compromise the empirical content of the research program. Stated another way, “it is relatively easy for any program to deal with (that is, make its theories consistent with) any given anomalies. In appraising the programs, the question is whether they do this in a progressive or in a degenerating manner. The shift within a research program from one theory to another is progressive if the new theory not only deals with its predecessor's anomalies but also makes extra predictions, some of which are tested and confirmed. On the other hand, if the new theory does nothing more than accommodate the anomalies, the shift is ad hoc and the program degenerating” (Urbach, 1974).

Urbach provides several examples of anomalies that the hereditarian and environmentalist research programs have had to deal with. In most cases it is illustrated that the hereditarian program handles these anomalies in a progressive manner, while the environmentalist program is unable to do so. One topic that each program attempted to explain is the similarity in IQ between relatives. “In predicting family similarities in IQ, the hereditarian and environmentalist programs differ in two respects. First, the hereditarian program makes precise quantitative predictions while its rival predicts only the relative values of some correlations between relatives and, secondly, the two programs make several conflicting predictions” (Urbach, 1974). Urbach emphasizes that the hereditarian program makes concrete novel predictions because in doing so it is opening itself up to falsification. For example, the hereditarian theory predicts that there is a 100% positive correlation between the IQs of monozygotic twins. This prediction was well supported by the data for monozygotic twins raised in the same household and in separate households.

There were certain instances when monozygotic twins raised apart scored very differently on IQ tests. However, the hereditarian program was able to come up with a good explanation for this anomaly. It was hypothesized that the differences were due to differences in education and that when a non-verbal test was utilized instead of a verbal test the twins would receive similar scores. This prediction was shown to be true in a case of twins that had been raised apart. These are characteristics of a progressive research program.

On the other hand, according to Urbach, the environmentalist program appears degenerative in its efforts to account for the data. While the argument can be made that monozygotic twins raised together have similar IQs due to a shared environment, that argument falls apart for monozygotic twins raised in different surroundings. Urbach points out that environmentalists have tried to explain this anomaly by claiming, "that the environments of the separated twins which were studied were more similar than had been assumed" (Urbach, 1974) However, this explanation is not satisfactory for a progressive research program. According to Urbach "These assumptions can only be made testable by specifying the precise (hidden) factors which made the environments alike in the first case and unalike in the second. But this has not so far been done and the explanations are consequently ad hoc" (Urbach, 1974) Thus, Urbach argues that the environmentalist program lags behind the hereditarian program because it is not able to utilize its heuristic to come up with a satisfactory explanation for the anomaly.

After offering many examples of the hereditarian program providing novel and accurate predictions while also being able to account for anomalies, Urbach concludes that it is a progressive research program. As he puts it, "in appraising a program using the

standards of this methodology, the crucial task is not to see whether it has run up against any anomalies-nearly all programs are anomaly-ridden-but rather to see whether it is dramatically confirmed, that is whether it has predicted any novel facts" (Urbach, 1974). Thus, Urbach believes that despite being faced with anomalous data, the hereditarian program is progressive because it has made
new predictions that were corroborated. All research programs encounter anomalies but only progressive research programs experience an increase in theoretical and empirical content.

4.4 Problems For Urbach

Urbach's analysis of the IQ debate is a useful tool for examining the practical application of Lakatos' theory. He provides a valuable model for how to identify the hard core, heuristic, and auxiliary hypotheses of a research program. He also helps elucidate the characteristics of a progressive and a degenerative program. However, there are some major flaws in his paper that have been pointed out.

4.4a Conceptual Critique of Urbach

For instance, psychologist, Jack Tizard provides conceptual, methodological, and statistical critiques of Urbach's paper. Conceptually Tizard takes issue with the way in which Urbach tries to simplify a complex issue. For example, Urbach makes it seem as though there are two clear cut opposing theories of IQ. However, as Tizard points out,

> No psychologist therefore acts as though there were two hard core research programs-the one 'hereditarian' and aiming to show that intelligence is entirely determined by 'a large number of genes which segregate in accordance with Mendelian principles and which each produce a small, similar and cumulative effect', the other 'environmentalist', asserting that every individual 'inherits identical innate mental capacities'. Instead it would be generally agreed that, as Eysenck ([I973])-whom Urbach quotes but dismisses-has put it, there is 'a single research program' the aim of which is ‘interactionist'. Observed differences in IQ are always the result of genetic factors interacting with environmental ones. (Tizard, 1976)

Thus, the study of IQ tends to center around the ways in which genetics and environment work together to influence intelligence. It would have been more fruitful for Urbach to describe a single research program that attempted to explain the inseparable relationship between nature and nurture, rather than trying to pit nature and nurture against each other. This example demonstrates that it can be difficult to correctly identify and individuate a research program. However, the accurate identification of a research program is essential, because it is the foundation from which further analysis is conducted.

4.4b Methodological Critique of Urbach

In addition to the conceptual issues that Tizard points out, he also notes issues with the data used by Urbach to support his claims. One methodological area that he calls into question is the use of data from Cyril Burt. Cyril Burt was a mid-twentieth century educational psychologist. His work on IQ has largely been discredited due to fabricated correlations and dishonest data. As Tizard explains “It should be noted that Burt's ([1956]) twin studies on which much of the evidence for very high within-groups heritability rests, must be discounted (Jensen [1974]; Clarke and Clarke [1974]; Kamin [1975]); they are so full of inconsistencies as to make me at least wonder whether the data from the studies which he claims to have carried out, were in fact ever analyzed in the way he purports to have done. Heritability estimates of intelligence arrived at by other writers (see Clarke and Clarke [1974]; Rutter and Madge [1975]) have varied considerably" (Tizard, 1976). The reliance on Burt's data is another serious mark against Urbach's paper.

4.4c Statistical Critique of Urbach

A third area that Tizard takes issue with in Urbach's work is his misuse of statistics. Urbach makes the claim that high heritability of IQ within a group leads to the conclusion that the differences in IQ between groups can be attributed to genetics. However, this is illogical because heritability is the degree to which a characteristic within a population is due to inherited genes. Heritability can not be applied between different populations because environment is not held constant and therefore observed differences could be due to environmental differences instead of exclusively genetic variations. Tizard explains, "we cannot draw any firm conclusion as to the extent to which genetic differences are responsible for phenotypic differences between groups growing up in different environments"(Tizard, 1976). In order to test to see if differences in IQ between groups is genetic in origin, environment for the different groups would need to be homogenized.

4.4d Empirical Critique of Urbach

According to a 2016 article written by Alan Musgrave and Charles Pigden, Urbach's work was actually a step back for Lakatos' Methodology of Scientific Research Programs.

> Urbach's paper, which was written with Lakatos's active collaboration and encouragement (F&AM: 348–34), represents something of an "own goal" for the MSRP. Urbach argued that the environmentalist program in IQ Studies, which tries to explain intergroup differences in tested intelligence as due to environmental causes, was a degenerating research program. At least it was degenerating when compared to its hereditarian rival which puts these differences down to differences in hereditary endowments. The tables were dramatically turned just thirteen years later with the discovery of the Flynn effect (1987) which showed massive differences in intergroup IQs which simply could not be explained by hereditary differences. (Musgrave & Pigden, 2016)

Thus, the environmentalist theory of IQ which Urbach had characterized as degenerative has since been shown to be progressive. The article admits that Lakatos does believe it is possible for a degenerating program to become progressive. So this development does not condemn Lakatos' theory. However, it is discouraging for Lakatos' theory that in the rare instance that it was practically applied it did not yield convincing results.

4.5 Theory vs. Application

Urbach's disappointing application of MSRP may not be as much a negative reflection on Lakatos' theory as it is on Urbach's knowledge of IQ science. This stresses the importance of philosophers having a solid understanding of the area of science that they are examining. In order to accurately characterize the various aspects of a research program one must fully understand what constitutes the hard core, what the heuristic is and what auxiliary hypotheses have been put forth. It does not matter how helpful Lakatos' MSRP is, if it is applied in an incorrect manner.

When using Lakatos' methodology to analyze the theory of anthropogenic global warming it is important to keep these potential stumbling blocks in mind. It was argued in the previous chapter that the hard core of the anthropogenic global warming theory is the causal relationship between CO_2 levels and surface temperatures. As CO_2 levels rise surface temperatures will rise as well. If it is demonstrated that this is not the hard core, then this analysis will have suffered the same fate as Urbach. Thus, it is essential to accurately select the appropriate hard core. Additionally, it was proposed that climate models are a reliable positive heuristic that play a pivotal role in allowing the theory of anthropogenic global warming to be progressive. If climate models are demonstrated to be unreliable, then this would indicate a degenerating program rather than a progressive program. Thus, Lakatos' method is vulnerable to the non-static status of certain aspects of a research program. In short, it is important to use Lakatos' theory very carefully when applying it to a scientific discipline. However, even if it is applied appropriately there will still be unavoidable obstacles to absolute rationality.

CONCLUSION

While Lakatos believes that reason provides the ability to differentiate between science and pseudo-science, he does not think that there is any single full proof criteria that will solve the demarcation problem. As Brendan Larvor explains, "given any statute of law there will always be hard cases in which the application of the rules requires some judgement (and if we make rules to govern the exercise of such judgement, the same point applies to these rules and so on to an infinite regress)" (Larvor, 1998). Lakatos provides a method of determining whether a research program is progressive or not. If the heuristic of the program is able to account for novel data then the program is progressive. However, there is not a clear cut system in place to determine whether the heuristic is achieving this goal. This decision needs to be made on a case by case basis. This condition in Lakatos' theory appears frustrating at first glance because there is not a universal formula for determining whether a program is progressive or not. However, his approach does seem to accurately reflect the way in which science has been conducted throughout history. While it is reliant to a degree on human judgement, it does provide a very valuable means of determining whether a theory should be abandoned or not.

According to Lakatos' criteria it has been demonstrated that the theory of anthropogenic global warming is progressive. It has made predictions about temperature rises that in many cases have been supported by empirical evidence. However, it has also encountered a major anomaly. The warming hiatus that occurred in the 2000's was not predicted. It was anticipated that as CO_2 levels rose the surface temperature would continue to rise. According to Lakatos such an anomaly can be tolerated as long as the research program as a whole is still able to generate novel accurate predictions. It appears that the prediction about the 1.1 degrees Celsius warming between 1990 and 2030 will be supported based on the overall warming that has occurred from 1990 to the halfway point of 2010.

It is important to clarify what this progressive label signifies and what it does not signify. The progressive nature of the anthropogenic global warming theory does not mean that this theory is infallible or that it is immune to degeneration in the future. It does mean that it is worthwhile for scientists to continue working within this research program. They should work to fine tune climate models to help make further accurate predictions, and account for unexplained anomalies.

Some would argue that Lakatos has not had a significant impact on the way the philosophy of science is conducted. “The methodology of scientific research programs has attracted many admirers but few followers” (Larvor, 1998). Larvor believes that this is likely because Lakatos does not provide a straightforward method that can be easily applied to new theories. However, to think that there is a one size fits all solution to the demarcation problem would be overly simplistic and would not account for the complexity of scientific theories. Thus, Lakatos provides guidelines for us to operate within, but is humble enough to realize that he can’t provide a simple solution to a complex problem.

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