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Lakatos' Modification of Popper's falsificationism

By

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Contents

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Part Ⅰ Introduction

In the research of science, different people play different roles. Scientists establish their theories by conjectures resulted from the investigation and exploration of nature or universe, and thereafter test them. Sociologists research how science influences human society and what the influence is. For example, with the development of science, our life is improved, and it is possible that our value theory will take place a corresponding change. The change of value theory may be a subject researched by socialists. Philosophers of science try to explain what on earth science is and research what method guides the progress of science. In fact, from the historical point of view, the history of human being is also the history of science. With the development of human being, science also makes progress. From the history of science, we can see strong points and weaknesses in different development stages and learn some experiences and lessons. Consequently, historical research is helpful to study the progress of science.

In general, before doing a scientific research, we may have an elementary idea and set an explicit goal. Upon this basis, we construct a practical scheme to achieve the goal. However, these are not enough. Effective and rational methods are also needed. Without the guidance of methods, it is impossible to achieve a goal. Thus, methods play an important role in scientific research. Many philosophers of science devote themselves to the research about the methodology of science. The idea of this thesis just originates from my interest in the methodology of science. Science attracts me all the while, because it not only makes us know the world in which we live and the universe space out of our world, but also gives our lives great changes. Without science and scientific progress, we may still live a primeval and uncivilized life. Then, what method has such power to specify a criterion to demarcate science from pseudoscience and to guide the progress of science? It motivates me to study the methodology of science. It is well-known that Karl Popper makes great contributions

in the aspect of the methodology of science. And Imre Lakatos further develops and modifies Popper's theory. Consequently, it is very necessary to understand Popper's and Lakatos' arguments comprehensively in order to study the methodology of science research. Popper advocates a deductive method rather than an inductive one and replaces the confirmation criterion of demarcation with his falsification criterion of demarcation. Lakatos' main contribution to the philosophy of science is an effort to harmonize the disagreement between Popper's falsificationism and Kuhn's structure of scientific revolutions. In Popper's view, once a theory is falsified, it has to be replaced; and scientists actively seek falsifying observations. However, for Kuhn, the falsification does not play an important in normal science and a decision to reject a theory can be made by a group of social and non-rational factors. After carefully reviewing the history of science as well as analysing Popper's and Kuhn's theories, Lakatos proposes his methodology of scientific research programmes. Actually, Popper's falsificationism has much more and deeper influence on Lakatos. Just as Lakatos said in his *The Methodology of Scientific Research Programmes*, he tried to develop Popper's programme a step further in order to escape Kuhn's stricture. Actually, both of them pursue a necessary rational reconstruction of scientific practice. This thesis mainly concerns Lakatos' modification of Popper's falsificationism, not Kuhn's theory.

This thesis aims to understand Popper's falsificationism and Lakatos' methodology of scientific research programmes right and to grasp why and how Lakatos modifies Popper's falsificationism to be the methodology of scientific research programmes. Firstly, it sets forth a background in which Lakatos makes the modification. The background is a basis on which we study why Lakatos modifies Popper's falsificationism. In order to understand Lakatos' motivation for making the modification better, the section will be described according to Lakatos' view. It briefly reviews some methodologies of science before Popper, and then explains the two phases of Popper's methodological falsificationism--naïve methodological falsificationism and sophisticated methodological falsificationism--and makes a comparison between them. Secondly, this thesis states Lakatos' comments about

Popper's methodological falsificationism, and then explains why and how Lakatos makes the modification and what his modification is. Moreover, it also makes a comparison between Popper's falsificationism and the modification. Thirdly, having made comments about the influences of their theories, this thesis shows some criticisms raised by contemporary philosophers of science and discusses some of their potential problems. Finally, it makes a brief summary about the whole discussion and draws a conclusion that Lakatos modifies Popper's falsificationism effectively and improves it more sophisticated.

Although Lakatos tries to solve the conflict between Popper's falsificationism and Kuhn's theory by the modification, I do not attempt to describe the conflict in detail or compare these two theories. Instead, I seek to discuss how Lakatos modifies Popper's falsificationism and ultimately establishes his methodology of scientific research programmes. By reviewing, analysing and comparing them, we can further understand how the methodology of science makes progress. Additionally, this study admits that Lakatos' modification is significant and that it is more progressive and more consistent with the history of science than Popper's falsificationism, nevertheless, it also offers some potential problems of Lakatos' methodology of scientific research programmes. They may be topics of discussion in future research.

Part Ⅱ Background and the basis of the modification

2.1 Methodology research before Popper

In the philosophy of science, many philosophers devote themselves to research about what science is or what the criterion of demarcation is. According to Lakatos' summary, before Popper, there were several influential views as follows.

Firstly, justificationists identify scientific knowledge with proven propositions. Lakatos classifies them as classical intellectualists who hold that intellectual intuition or experience can make extra logical "proofs" and classical empiricists who hold that only a few "factual propositions" with "proven facts" are self-evident and that their

truth-value is determined by experiences. In order to prove theories based on experience, classical empiricists extend to inductive reasoning from deductive reasoning of classical intellectualists. Both believe that scientific theories should be proven by empirical facts. Generally, deduction and induction are two distinct reasoning methods in logic. The difference between them is that in deduction, the premises can entail the conclusion and the inference is from the general to the particular; and whereas in induction, the premises cannot entail the conclusion and the inference is from the particular to the general. It is owing to their different characters that people think that induction can provide us with something new, not deduction. For example, in a deductive reasoning, from two premises: all husbands are married and Tom is a husband, it follows that Tom is married. In effect, the conclusion has been implied in premises. However, in an inductive reasoning, if all ravens you have ever seen are black, you might then say 'all ravens are black'. People think that induction is more important than deduction in science since it supplies more information to us. However, in the eighteenth century, David Hume raised "the problem of induction" that induction is not justified. That is, it is not justified to infer to a future unobserved statement from a series of observed singular statements. So, the reliability of inductive reasoning is shaken. It may be problematic that a theory should be proved by empirical facts. In order to avoid the problem, probabilists make an attempt to modify the view of justificationism.

Probabilists try to use probability to reduce the problem of induction. They believe that theories may have a certain degree of *probability* relative to the empirical evidence, even if theories cannot be proven thoroughly. Theories with a higher degree of probability are better, and closer to science than theories with a lower degree of probability. However, according to the view, scientists cannot make a sharp distinction between science and pseudoscience. It just provides them with a fuzzy scope, not a clear criterion. Popper raises his objection to the view of probabilism. Firstly, he thinks that this view cannot effectively avoid the problem of justification of induction. He points out that

> "if a certain degree of probability is to be assigned to statements based on inductive inference,

> then this will have to be justified by invoking a new principle of induction, appropriately modified. And this new principle in its turn will have to be justified, and so on. Nothing is gained, moreover, if the principle of induction, in its turn, is taken not as 'true' but only as 'probable'. In short, like every other form of inductive logic, the logic of probable inference, or 'probability logic', leads either to an infinite regress, or to the doctrine of *apriorism*". (Popper, the 5th edition, p30, italics in original)

Secondly, he indicates that the view of probabilism results from a confusion of psychological with logical questions. So-called degree of probability is simply a kind of psychological tendency. In other words, the degree of probability comes from the degree of belief which scientists hold. It changes in the light of new evidence. When scientists discover new evidence to support a theory, their degree of belief in the theory will improve. The degree of probability of the theory will also improve accordingly. However, theories are either true or false in logic. There is no "middle of the road". From the point of logical view, the probability of a theory is zero if it is not one. So, zero or one may not correctly measure scientists' degree of belief in a theory. Thirdly, Popper holds that the view of probabilism does not work for the demarcation of science because the mathematical probability of all theories is zero under the specific account of evidence. In his opinion, no matter how many experiments can support a theory, comparing with infinite number of possible experiments, the probability of the theory is zero. By above arguments, Popper indicates that the view of probabilism is irrational. At the same time, he overturns the traditional empirical view that theories must be proven by facts. He proposes that the criterion of demarcation is not concerned with facts, but rather the *potential falsifiability* of a theory. This will be discussed in detail in the following text.

Generally speaking, Popper's falsificationism is divided into two phases by later philosophers: dogmatic (or naturalistic) falsificationism and methodological falsificationism. The notion of "naturalistic" comes from Popper. In *The logic of scientific discovery*, Popper said that "this view, according to which methodology is an empirical science in its turn—a study of the actual behaviour of scientists, or of the

actual procedure of 'science'—may be described as '*naturalistic*'".[1]However, Lakatos objects to the above division. In *The Methodology of Scientific Research Programmes*, he explicitly indicates that Popper never actually puts forward dogmatic falsificationist view and it is really just Ayer and some philosophers who attribute this view to Popper.

2.2 Dogmatic falsificationism

Popper's falsificationism is based on the criticism and modification to *dogmatic falsificationism*. Thus, dogmatic falsificationism can be considered as background information to understand Popper's falsificationism. Dogmatic falsificationists declare that all scientific theories are fallible except their empirical basis which consists of a set of "potential falsifiers"--observational propositions which may disprove a theory. Lakatos thinks that dogmatic falsificationism is *the weakest brand of justificationism* since "it is strictly empiricist without being inductivist: it denies that the certainty of the empirical basis can be transmitted to theories".[2] It claims a different criterion to demarcate science from pseudoscience. According to dogmatic falsificationism, empirical fact is still a tool to test and judge theories, nevertheless, it is not used to confirm but falsify a theory. That is, a theory is regarded as "scientific" as long as it can be falsified or potentially falsified by empirical facts. This particularly stresses the decisive function of empirical counterevidence to judge a theory.

As for dogmatic falsificationism, Lakatos points out that it is untenable because of its two false assumptions and a narrow criterion of demarcation between scientific and non-scientific.

The first assumption of dogmatic falsificationism is that "there is a natural, *psychological* borderline between theoretical or speculative propositions on the one hand and factual or observational (or basic) propositions on the other".[3] That is, it

[1] Karl R. Popper, The Logic of Scientific Discovery, Hutchinson of London, the 5th edition, 1968, p52.
[2] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p12.
[3] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p14.

separates observations from theories completely. It indicates that observations which falsify theories are existent independently of theories. However, it is evident that observations are actually based on theories and guided by theories. That is, observations are theory-dependent. Let us imagine that, if we do not apply any theory when we observe an event, how can we interpret it or express the observation? We even cannot say its colour and shape. Once we get a result, we have applied (previous) theories to directing the observation. Neither theories nor observations can be isolated. Without observations, theories are fancies. Without theories, observations are just images. Although dogmatic falsificationists apply observations to the test of theory, these observations are still based on previous theories and observations. So, it is impossible to separate observations from theories thoroughly.

The other assumption is that "if a proposition satisfies the psychological criterion of being factual or observational (or basic) then it is true; one may say that it was *proved* from facts".[4] Lakatos holds that logic can destroy this assumption since "*no factual proposition can ever be proved from an experiment*. Propositions can only be derived from other propositions, they cannot be derived from facts: one cannot prove statements from experiences".[5] Popper also proposes the similar view that "*statements can be logically justified only by statements*".[6] In other words, we cannot decide the truth-value of an "observational" proposition by experiences, so we fail to prove it factual from experiences. Then, it may be concluded that factual propositions are fallible (since they are unprovable). If so, it is problematic to use a fallible factual proposition to test and falsify a theory. Therefore, the contradiction between a theory and a factual proposition is simply regarded as an inconsistency, not falsification.

The narrow criterion of demarcation made by dogmatic falsificationism is that "only those theories are 'scientific' which forbid certain observable states of affairs and therefore are factually disprovable. *Or a theory is 'scientific' if it has an empirical*

[4] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p14.
[5] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p16.
[6] Karl R. Popper, The Logic of Scientific Discovery, Hutchinson of London, the 5th edition, 1968, p43.

basis".[7] It seems to imply that the theory will have certain logical implications, which can be tested by observations. However, as mentioned before, experiences cannot prove a theory. Lakatos takes an imaginary story to explain the problem of this criterion of demarcation[8]. The story shows that a physicist of the pre-Einsteinian era adopts Newton's mechanics and Newton's law of gravitation, (*N*), the accepted initial conditions, *I*, to calculate the orbit of a newly discovered small planet, *p*. But the actual motion of *p* is inconsistent with the calculated orbit. According to dogmatic falsificationism, once the inconsistency is established, it will refute the theory *N*, since the inconsistency is forbidden by Newton's theory. However, the Newtonian physicist does not do that but rather proposes that an auxiliary hypothesis such as a planet *p'* which is unknown until now may bother the motion of *p*. He makes a careful calculation about the mass and orbit of *p'* and requests an experimental astronomer to help him to test his hypothesis. It may take them a lot of time and money to do it. If the final result shows that the unknown planet *p'* does exist, it will be regarded as a success of Newton's theory. If it is not, the physicist will continue making a further suggestion to explain the inconsistency until it is solved; or it is left aside and never remembered by anyone.

Popper tries to solve the above problems with the help of convention. In general, this is called "methodological falsificationism".

2.3 Popper's methodological falsificationism

Actually, Popper was inspired to research the problem of demarcation of science when Einstein's prediction about gravitation was successfully verified by the findings of Eddington and it shook the stable status of Newton's theory. He aims to clarify the method of empirical sciences and describe the objective scientific growth. Lakatos divides Popper's *methodological falsificationism* into naïve and sophisticated methodological falsificationism.

[7] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p14.
[8] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p16-17.

2.3.1 Naïve methodological falsificationism

In general, *naïve methodological falsificationism* is thought as the initial form of Popper's falsificationism. It is the introduction of methodological decisions which replace the assumptions of dogmatic falsificationism. Popper explores empirical science within the framework of logic. By advocating deductive reasoning instead of inductive reasoning, Popper bypasses the traditional problem of justification of induction effectively. He thinks that only deductive method is valid in logic. In deduction, the truth of premises *entails* the truth of the conclusion. According to "the *modus tollens* of classic logic", once people find *a singular statement* which is contradictory to *a universal statement*, people can falsify the universal statement. One counterexample is enough to falsify the universal statement. For example, once we observe one non-black raven, we can falsify the proposition "all ravens are black". If the contradictory statement is not observed, the universal statement will be simply retained, not regarded as being true or even more likely to be true. The problem of induction does not exist in above reasoning.

Here, Popper calls a statement as a premise in an empirical falsification a "basic statement" or a "basic proposition". He claims that "basic statements are accepted as the result of a decision or agreement; and to that extent they are conventions".[9] Generally, they are regarded as *unproblematic background knowledge* to test a theory. Background knowledge is changeable over time. And it is possible that, with the progress of science, previously unproblematic background knowledge becomes problematic and is replaced by new convention. Comparing with dogmatic falsificationism, naïve methodological falsificationism may make more theories be applied in testing with the help of unproblematic background knowledge.

Popper applies the logical and conventional argument to the discussion of scientific theories. He proposes that a singular observation or statement cannot affirm a theory but falsify a theory, and he admits that scientific theories must be falsifiable. "Falsifiable" is not equal to "false". It simply means that a theory is capable of being

[9] Karl R. Popper, The Logic of Scientific Discovery, Hutchinson of London, the 5th edition, 1968, p106.

falsified, not that it has been falsified. In other words, a falsifiable theory means that there must be a possibility that an observation may show the theory to be false, even if it has not been made yet. Falsifiability becomes the basic condition of scientific theory and the criterion to judge a theory good or bad. Falsifiability requires a theory to have two features: clarity and precision. That is, clearer and more precise theories are more falsifiable. For example, Popper thinks that Marxian theory cannot be falsified because it is not clear and precise, thus, it is not scientific.

Falsification in naïve methodological falsificationism is different from that in dogmatic falsificationism. According to dogmatic falsificationism, falsification and rejection are conflated. If a theory is falsified, it is rejected immediately. However, according to naïve methodological falsificationism, falsification is separated from rejection. If a theory is "falsified", it may be not false and it is not rejected at once, since a theory is not only constructed by hypotheses, but also affected by auxiliary hypotheses, such as experimental conditions and background theories. It is difficult to determine which one of them results in a final falsification. This point is just the difficulty of naïve methodological falsificationism. Consequently, falsification does not necessarily lead to rejection.

For the objective scientific growth, Popper envisions that science originates from problems about world or universe; and scientists make speculative and tentative conjectures in order to solve problems. It is just these conjectures that construct theories. Once conjectures are proposed, they will be strictly tested by experiments and observations. The theory which is not tenable in the face of experimental and observational tests is "falsified" and may be rejected. Only theories which succeed to stand up to tests can survive. However, at this time, the process is not finished. Survival is just *tentative* and it will be still tested by experiments or observations, since it is possible that a theory which has survived so far will be falsified in the future. When it is finally falsified, a new problem appears. The process may proceed infinitely. Consequently, Popper believes that science never reaches the truth and it only approaches to the truth (because of the infinity of experiments and observations). According to this view, the growth of science seems to be a process of scientific

evolution.

The naïve methodological falsificationism, although it is more liberal than dogmatic falsificationism, raises a relevant problem. As far as a basic statement is concerned, if scientists accept it by a convention, why can scientists not also "prove" a hypothesis through "induction" based upon a convention?[10] In other words, Popper admits that a basic statement is a convention to the extent, and that the basic statement is open to change—for example, when Einstein's statement that the mass of an object becomes less when it moves is accepted by scientists agreement, one basic statement of Newtonian physics that the mass of a moving object is constant would be changed. Then, it is also possible that with the help of a convention, scientists stipulate that a universal statement is inductively confirmed by observations. This problem is worth considering.

2.3.2 Sophisticated methodological falsificationism

Sophisticated methodological falsificationism is an advance on naïve methodological falsificationism. Popper realizes that although naïve methodological falsificationism is valid in logic, it is rather limited and raises some problems, such as that some scientific theories seem to be irrational according to it. Lakatos takes the example of Mercury's perihelion[11]. Although it was regarded as an anomaly of Newton's theory, it was not generally regarded as a falsifier. So Popper attempts to improve naïve methodological falsificationism to be sophisticated.

According to sophisticated methodological falsificationism, a scientific theory T1 is falsified iff another theory T2 comes along and satisfies the following three conditions:

1) T2 has "excess empirical content" over T1; in other words, T2 can predict novel facts which T1 does not or cannot explain;

2) T2 includes "all the unrefuted content" of T1; in other words, T2 can explain the previous success of T1;

[10] Alexander Bird, *Philosophy of Science*, UCL Press, 1998, p242.
[11] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p30.

3) Some of the excess content of T2 is confirmed by experiment or observation.

Here, excess and confirmed empirical content replaces experimental evidence to falsify a theory among a series of theories. A theory cannot be abandoned as falsified before a better one is found. Although we might find that a number of experiments or observations are contradictory with a theory, all of them are not enough to falsify or reject the theory. We can do nothing but waiting until a better theory comes out. This better theory should subsume not only the content of the old one, but also novel predictions. This feature tells us how a theory grows or develops. It shows that falsification is a multiple relation among rival theories and experiments, not a two-side relation between a theory and experiments. It is more compatible with history of science than previous falsificationisms. For example, why is Einstein's theory of relativity "better" than Newton's theory? The reason is not that one is falsified, whereas the other is not. The real reason is that the former can explain not only phenomena which the latter explains, but also facts about electromagnetic waves which Newtonian laws of motion fail to explain.

For the objective scientific growth, sophisticated methodological falsificationists think that science is composed of bold conjectures and cautious conjectures. Scientists adopt different attitudes to falsification according to different conjectures. Cautious conjectures have lower degree of risk, so the falsification of them can provide us with more information. However, in general, bold conjectures have higher degree of risk. It shows that bold conjectures predict some novel facts which are inconsistent with existing scientific theories. The falsification of them is pretty much what we would probably expect to happen, whereas the confirmation of them may be informative. Consequently, only the confirmation of bold conjectures and the falsification of cautious conjectures are helpful to the prediction of novel facts. It is obvious that bold conjectures play an important role in the objective scientific growth and that a better theory has bold conjectures. It is worth clarifying that both "bold" and "novel" are relative notions. They are changeable over time. Once a conjecture is confirmed to be a part of scientific theory, it will not be bold any more. For example, Copernican theory is bold and novel relative to Ptolemaic theory, but it is not relative to Kepler's

theory.

Sophisticated methodological falsificationism has two main characters:

Firstly, sophisticated methodological falsificationists recognize the continuity of scientific knowledge and specify a series of theories rather than a particular theory as the basic research unit of science. By the replacement, they make falsifiability a *comparative* or *relative* matter, since it is difficult for us to be sure what the degree of falsifiability of a particular theory is, but we can make sure which one is more falsifiable by comparing two theories. For example, in general, a theory with higher degree of falsifiability will be capable of testing in a greater number of circumstances. It is stricter than naïve methodological falsificationism in this point.

Secondly, sophisticated methodological falsificationists clarify the influence of auxiliary hypotheses on theories. Popper affirms that "saving a theory with the help of auxiliary hypotheses which satisfy certain well-defined conditions represents scientific progress; but saving a theory with the help of auxiliary hypotheses which do not, represents degeneration".[12] Linguistic adjustments and hypotheses which fail to be tested in any way are regarded as *ad hoc* and removed from the convention of auxiliary hypotheses. Based on this division, Popper further proposes *progressive problemshifts* and *degenerative problemshifts*. In his opinion, every new theory includes the previous theory and some auxiliary hypotheses dealing with anomalies. If a new theory has excess empirical content which predicts novel facts over its antecedent, then, we can say that such a series of theories is *theoretically progressive*. And, if some of the excess empirical content is confirmed by experiments, then, we can say that the theoretically progressive series of theories is also *empirically progressive*. If the series of theories is both theoretically and empirically progressive, it is *progressive*, and it is *degenerating* if it is not. Sophisticated methodological falsificationists hold that problemshifts are scientific if and only if they are at least theoretically progressive. The evaluation of theories is shifted to the evaluation of series of theories. Lakatos inherits the division between progressive and degenerative

[12] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p33.

problemshifts in his discussion of methodology of scientific research programmes[13].

Even though sophisticated methodological falsificationism is more broad-minded and more reasonable than previous falsificationism, it is still problematic. It is still involved with convention in order to save theories from refutation. Popper's methodological falsificationism does not get rid of convention.

2.3.3 Contrast between naïve and sophisticated methodological falsificationism

Having discussed naïve and sophisticated methodological falsificationism, it may be helpful to contrast them. Lakatos concludes the following differences:

At first, their research objects are different. Naïve methodological falsificationists only research and test particular theories. However, sophisticated methodological falsificationists research and test a series of theories. By comparison, they may make sure of a different degree of falsifiability between rival theories.

Secondly, they make different criterions of demarcation. According to naïve methodological falsificationism, the criterion of demarcation is the falsifiability of theory. That is, only theories which can be falsified by experiments or observations are scientific. However, sophisticated methodological falsificationism emphasizes the comparison between competitive theories. So their criteria of demarcation are *excess* and *confirmed empirical content* (which is mentioned above). That is, newer theories not only have the content of old theories, but also have excess empirical content which old theories do not have or cannot explain. And the excess content can deal with refutations which old theories encounter. This difference also induces another difference—the difference of a crucial element in falsification; the "falsifying" or "refuting" evidence of a theory. In naïve methodological falsificationism, since the progress of science is motivated by the falsification of a theory, so, it is a *passive* process. However, in sophisticated methodological falsificationism, its crucial element is the confirmed evidence of excess information which predicts novel facts.

[13] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p48.

And the progress of science results from the competition between rival theories, so, it is an active process.

Moreover, their methods to deal with a falsified theory are different. Naïve methodological falsificationism rejects it, whereas sophisticated methodological falsificationism replaces it by a better one. The better one has "all unrefuted content" of the previous theory. So, sophisticated methodological falsificationism is more tolerant.

Finally, their understandings about the components of science are different. According to naïve methodological falsificationism, science consists of conjectures and scientists' attempts to simply falsify them, whereas, according to sophisticated methodological falsificationism, science consists of cautious conjectures but also bold conjectures and scientists attempt to falsify cautious conjectures and confirm bold conjectures.

In summary, falsificationism developed in different forms, but it is still insufficient either to *describe science* or to *solve the demarcation problem*. It suffers from a series of logical and philosophical difficulties that should perhaps give us pause if hoping to find a single answer to what makes good science and what does not. Lakatos also realizes the weaknesses of Popper's theory raised by contemporary philosophers. I will discuss this in the next section.

Part Ⅲ Lakatos' modification of Popper's methodological falsificationism--the methodology of scientific research programmes

Lakatos' methodology of scientific research programmes can be considered as the *modification* of Popper's falsificationism. It is inspired by the conflict between Popper's theory and Kuhn's theory. It aims to save Popper's falsificationism from Kuhn's criticism by "reconstructing scientific progress as proliferation of rival

research programmes and progressive and degenerative problemshifts".[14] Lakatos particularly applies historical case study in the modification. We can see lots of examples of scientific theories and scientific experiments in his *The Methodology of Scientific Research Programmes*. He also emphasizes that

> "*In writing a historical case study, one should, I think, adopt the following procedure: (1) one gives a rational reconstruction; (2) one tries to compare this rational reconstruction with actual history and to criticize both one's rational construction for lack of historicity and the actual history for lack of rationality. Thus any historical study must be preceded by a heuristic study: history of science without philosophy of science is blind"*. (Worrall and Currie, 2001, p53, italics in original)

Before discussing the methodology of scientific research programmes, we should make clear the weaknesses of Popper's theory.

3.1 Lakatos' comments about Popper's methodological falsificationism

For Popper's methodological falsificationism, Lakatos firstly admits that naïve methodological falsificationism solves "the problem of combining hard-hitting criticism with fallibilism" by regarding conventional theories as unproblematic, and that it saves not only falsification from fallibilism, but the rule of dogmatic falsificationism—"scientific honesty consists in specifying, in advance, an experiment such that, if the result contradicts the theory, the theory has to be given up".[15] He also summarizes that

> "*Sophisticated methodological falsificationism* blends several different traditions. From the Empiricists it has inherited the determination to learn primarily from experience. From the Kantians it has taken the activist approach to the theory of knowledge. From the conventionalists it has learned the importance of decisions in methodology". (Worrall and Currie, 2001-p38, italics in original)

[14] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p92.
[15] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p13.

However, Lakatos sees that some issues for Popper's methodological falsificationism from the history of science. In the first place, it fails to solve the problem whether a theory itself or its auxiliary hypothesis leads to falsification yet. So a theory cannot be "conclusively falsified". In the next place, it does not realize that it is uncertain in factual history of science that experimental anomalies or "refutations" falsify a theory. In most of historical cases, scientists leave them aside and do further research.

3.2 Lakatos' methodology of scientific research programmes

After knowing above problems and difficulties of Popper's methodological falsificationism, Lakatos commences establishing his methodology of scientific research programmes. He inherits the continuity of science from Popper's sophisticated methodological falsificationism and proposes that it is just the continuity that shifts the discussion of scientific theories to the discussion of scientific research programmes. All individual theories in a series of theories are connected together by the continuity to form a research programme. Science is composed of neither singular theories nor a series of theories but rather research programmes. Even science itself can be regarded as a huge research programme (see figure 1). A scientific research programme (see figure 2) consists of "*hard core*" and "*protective belt*".

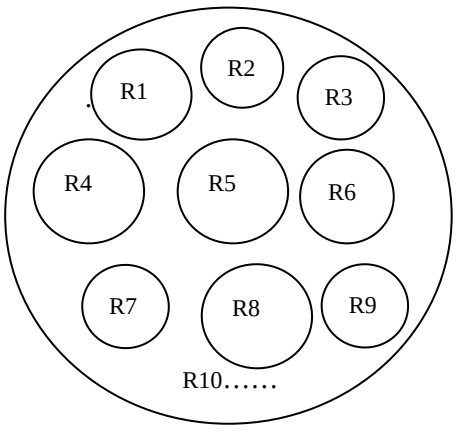

Figure 1: Science as a huge research programme

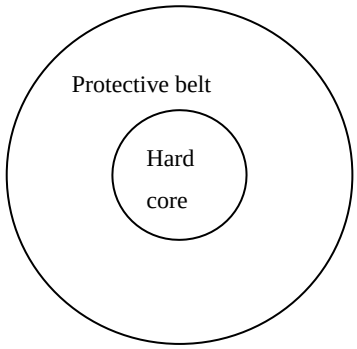

Figure 2: A research programme

3.2.1 "Hard core" and "protective belt"

Lakatos thinks that some parts of a scientific research programme are more foundational than others. Generally speaking, they are basic theoretical hypotheses. It is only these hypotheses that compose the hard core of a research programme. They are also necessary constituents of a research programme. For example, Newton's three laws of motions and his law of gravitational attraction compose the hard core of Newtonian physics. This hard core is presupposed to be certainly essential and "irrefutable". With the development of science, a hard core may be supplemented by adding some new laws, auxiliary hypotheses, and even experimental and mathematical techniques because, according to Lakatos, "if the positive heuristic is clearly spelt out, the difficulties of the programme are mathematical rather than empirical".[16]

Outside of this hard core, there are a variety of auxiliary hypotheses to support and protect the hard core in the face of anomalies. These hypotheses compose the protective belt of a research programme. Although a research programme may change sooner or later, its hard core usually stays constant. Change and adjustment always happens in the protective belt. In Lakatos' view, when an observation or experiment is inconsistent with a programme, it as an anomaly will point to the protective belt of a research programme, not to the hard core. It seems to solve above first problem of Popper's methodological falsificationism. The hard core of a theory is exempt from falsification. Consequently, it is possible that a series of theories have the same hard core but have different protective belts in a research programme.

3.2.2 Negative heuristic and positive heuristic

Besides above two theoretical parts—hard core and protective belt, scientific research programmes have two methodological rules which guide the research of science: *negative heuristic* and *positive heuristic*. Lakatos thinks these two rules are the main work of scientific research programmes. A negative heuristic helps to

[16] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p51.

determine what procedures scientists should not follow, what entities they should not accept, and so on. It dictates that *modus tollens* is inapplicable to the hard core and forbids that the hard core is rejected or adjusted[17]. Counterevidence is powerless to the hard core. Scientists should pay attention to how to adjust the protective belt of a research programme instead of the hard core. If scientists try to adjust the hard core in a research programme, they deviate from this program[18]. For example, the assumption of *heliocentricity* (that the Earth goes around the Sun) is the "hard core" of Copernican astronomy. The job of scientists is simply limited to the adjustment of peripheral protective belt of the system under the guidance of the hard core. As a result a hard core is generally not falsified and rejected in the face of anomalies. Negative heuristic provides a hard core with a principle guarantee.

In the discussion of negative heuristics, Lakatos also introduces a criterion to judge whether a research programme is successful or has failed. As mentioned above, he derives it from Popper's division between progressive and degenerative problemshifts. If the process of protecting a hard core causes a progressive problem-shift, then the research programme is successful. If it causes a degenerative problem-shift, then the research programme has failed. For progressive problem-shift and degenerative problem-shift, Lakatos clarifies that, if a problem-shift can account for a refutation and predict novel facts, then it is *progressive*; and if a problem-shift fails to predict *novel facts* but only accounts for refutation, it is just *ad hoc*, and then it is *degenerative*. Here, "novel facts" is different from the "novel facts" of sophisticated methodological falsificationism. According to the latter, a prediction is regarded as "novel" only if the facts predicted by it have never been observed before it. Here, "novel facts" also means those facts observed before, but they were not explicitly explained by previous theories, or they are also the already-known anomalies in previous theories. Lakatos further points out that if a research programme is progressive, it is rational to adjust and change auxiliary hypotheses of its protective belt in order to defend its hard core from anomalies; and if a research programme is

[17] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p48.
[18] A. F. Chalmers, *What Is This Thing Called Science?* Open University Press, 3rd Edition, 1999, p133.

degenerative, it will be falsified by the replacement of a better one. Lakatos instances Newton's gravitational theory as a successful research programme. He points out that:

> "When it was first produced, it was submerged in an ocean of 'anomalies' (or, if you wish, 'counterexamples'), and opposed by the observational theories supporting these anomalies. But Newtonians turned, with brilliant tenacity and ingenuity, one counter-instance after another into corroborating instances, primarily by overthrowing the original observational theories in the light of which this 'contrary evidence' was established. In the process they themselves produced new counter-examples which they again resolved. They 'turned each new difficulty into a new victory of their programme'…If we analyse it, it turns out that each successive link in this exercise predicts one new fact; each step represents an increase in empirical content: the example constitutes a *consistently progressive theoretical shift.* Also, each prediction is in the end verified; although on three subsequent occasions they may have seemed momentarily to be 'refuted'". (Worrall and Currie, 2001, p 48, italics in original)

In addition, Lakatos holds that "the programme as a whole should also display an *intermittently progressive empirical shift*". That is, novel facts are not always produced at once. Scientists can leave anomalies aside until a better theory with novel facts appears. From above statement, negative heuristic seems to be the view of convention. But, Lakatos emphasizes an exception--it is allowable that the hard core is rejected iff the research programme cannot predict novel facts any more. It weakens the weight of convention.

Positive heuristic is the other methodological rule of scientific research programmes. It suggests what scientists should try to do in a research programme and provides a protective belt with guidance on how to produce new explanations to fight with anomalies. For empirical anomalies, scientists generally leave them aside as long as they have no influence on the progress of a research programme. Sometimes they may be solved with the development of the programme. Anomalies may be just some trivial by-products of scientific research. They can get more attention only if a positive heuristic cannot motivate scientists. That is, scientists will turn their attention into anomalies when the research programme cannot predict novel facts any more. What scientists should evaluate and test is a research programme, not a singular

theory or a series of theories. Anomalies never can be regarded as evidence which eliminates a research programme, since "no accepted basic statement alone entitles us to reject a theory".[19] Positive heuristic gives a research programme more space to survive and develop. Lakatos takes the example of Newton's programme of a planetary system to account for positive heuristic and concludes that the existence of refutations is expected and positive heuristic is just the strategy both for predicting and digesting these refutations[20].

Additionally, Lakatos addresses that the methodology of scientific research programmes explains the "relative autonomy" of theoretical science which is not discovered by earlier falsificationisms. According to earlier falsificationisms, the problems researched by scientists mainly result from the falsification of previous theories by empirical evidence or the empirical confirmation of novel facts of a better theory. However, in the methodology of scientific research programmes, Lakatos holds that scientists do not pay much attention to anomalies. What they focus on researching is the problems specified by the positive heuristic of a research programme, rather than by "psychologically worrying (or theoretically urgent) anomalies".[21] Scientists will turn their attentions to anomalies only if the motivating power of the positive heuristic weakens. Consequently, theoretical science is relative autonomy.

3.2.3 Lakatos' criterion of demarcation

Having stated main content of Lakatos' methodology of scientific research programmes, we should sum up his criterion of demarcation in order to make this clearer.

Lakatos proposes "an amended demarcation criterion" in order to modify Popper's definition of science. He tries to shift the problem of evaluating "theories" to the

[19] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p150.
[20] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p50-60.
[21] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p52.

problem of evaluating “research programmes”. In his opinion, a research programme has a hard core with convention and a protective belt which can predict anomalies and shift them to supporting evidence successfully. A research programme can be retained only if it can predict novel facts. Once it cannot do so any more, a new research programme may appear as an alternative. The new one must be progressive. It replaces the old one only if its novel prediction is confirmed. From this point, it seems to be proper to say that Lakatos’ methodology focuses on the demarcation between progressive and degenerative research programmes rather than the demarcation between science and pseudoscience. The criterion of demarcation is relatively moderate. It is more consistent with the history of science. According to it, some classical scientific theories which may be rejected in earlier falsificationisms can get back to scientific status. Moreover, it should be noticed that scientists can perform the replacement with hindsight, since it may take scientists several decades to confirm that the prediction of the new research programme is novel. Lakatos holds that both “refutation” and “crucial experiment” are also known and accepted several decades later.

For different research programmes, Lakatos adopts different attitudes to treat them. Lakatos is tolerant toward a new or young research programme. He explicitly proposes that

> “*we must not discard a budding research programme simply because it has so far failed to overtake a powerful rival. We should not abandon it if, supposing its rival were not there, it would constitute a progressive problemshift. And we should certainly regard a newly interpreted fact as a new fact, ignoring the insolent priority claims of amateur fact collectors. As long as a budding research programme can be rationally reconstructed as a progressive problemshift, it should be sheltered for a while from a powerful established rival*”. (Worrall and Currie, 2001, p70-71, italics in original)

For a developed research programme, Lakatos adopts a quite different attitude. A developed research programme must have been tested many times. Its protective belt is improved and the research programme tends to be more powerful in predicting and explaining phenomena. Accordingly, Lakatos believes that it is reasonable that a

developed research programme can be retained as long as its rivals predict novel facts less than it, since an enduring programme has developed a certain resistance to immediate rejection.

In the amended criterion, the significance of falsification seems to be weakened, whereas the significance of confirmation which is refused by Popper is re-emphasized. Lakatos realizes that confirmation seems to play a more important role than falsification in positive heuristic, since the confirmation of a recent theory may be equal to the falsification of a previous theory. In addition, no matter whether a research programme has been falsified or not, it can be replaced by a more progressive one. The mark of progress is *the confirmation of novel facts* predicted by a new research programme rather than the falsification of an old research programme. As a result, we can see that falsification plays a less important role in Lakatos' theory than it does in Popper's theory.

3.3 Compare Popper's methodological falsificationism with Lakatos' methodology of scientific research programmes

Having discussed Popper's methodological falsificationism and Lakatos' methodology of scientific research programmes, it is necessary to summarize the similarities and the differences between them.

From what we have discussed thus far, we can see that both Popper and Lakatos are concerned with the demarcation between science and pseudoscience and the growth of knowledge. Both of them consider the function of auxiliary hypotheses in science. Although they apply auxiliary hypotheses by different methods, both of them have the different degree of convention. And they realize that the progress of science is a process that a better theory or research programme replaces the old one. The better one not only predicts novel facts, but also accounts for the content of the previous one, and some of these facts can be confirmed. Moreover, both of them emphasize the importance of "novel facts" in the progress of science.

Although Lakatos' methodology stems from Popper's falsificationism, there are

many differences between them.

Firstly, their basic units of scientific research are different. Popper's basic unit of scientific research is falsifiable theories, and later a series of theories. However, Lakatos' basic unit of scientific research is research programmes.

From the above difference, a second one follows. Their descriptions about the progress of science are different. As mentioned above, according to Popper's sophisticated methodological falsificationism, a series of theories are composed of bold conjectures and cautious conjectures. The progress of science relies on the confirmation of bold conjectures and the falsification of cautious conjectures. All bold conjectures or cautious conjectures will be either confirmed or falsified over time. Once a bold conjecture is confirmed, it is possible that it becomes a cautious conjecture over time—for example, the heliocentricity is a bold conjecture for Ptolemaic followers, whereas it is a cautious conjecture for Copernican followers after being confirmed; and once a cautious conjecture is falsified, it may produce a bold conjecture—for example, the geocentricity is a cautious conjecture for Ptolemaic followers. When it is falsified by Copernicus, a bold conjecture--the heliocentricity is proposed. Consequently, conjectures changes with the progress of science and they are considered in historical terms. However, in Lakatos' methodology of scientific research programmes, the progress of science relies on the inside adjustment of a research programme and the replacement of a degenerative research programme by a progressive research programme. Although both adjustment and replacement seem to be historically based, Lakatos' division of research programmes into hard core and protective belt is not a historical division. Both of them will be present simultaneously in a given research programme.

Finally, they apply different research methods. The dominant principle of Popper's theory is logical. He even calls the method of empirical science the logic of scientific discovery. Logical analysis can be seen throughout his whole theory. For example, by shifting inductive reasoning into deductive reasoning, he bypasses the problem of induction and proposes his falsification criterion. However, Lakatos' arguments stress the historical aspect of scientific progress more than Popper's. He uses a lot of

historical examples to test Popper's methodological falsificationism, and modifies it according to the history of science. Although, as mentioned above, hard core and protective belt are not considered in historical terms, the result of Lakatos' modification makes science more consistent with historical facts. Historical method guides Lakatos to modify Popper's methodological falsificationism.

Part Ⅳ Comments

When Popper and Lakatos research the progress of science, their respective theories also similarly compose the progress of philosophy of science. It is very significant for us to know and evaluate them. From above statement and comparison, we have gained a general understanding about them. Evaluations about them will be discussed in following parts.

4.1 The influences of Popper's methodological falsificationism and Lakatos' methodology of scientific research programmes

Popper's methodological falsificationism is generally acknowledged to be Popper's great and influential contribution to philosophy of science. His discussion about the logical asymmetry between confirmation and falsification forms the core of his philosophy of science. In his view, confirmation from induction is invalid in logic, whereas falsification from deduction is valid in logic. Actually, the distinction is firmly rooted in the nature of confirmation and induction respectively. Of its very nature, induction is an *ampliative* inference; i.e. one where there is more contained in the argument's conclusion than can be validly deduced from the premises. Popper establishes his falsificationism by a logical shift--from inductive reasoning to deductive reasoning. The shift shakes the dominant status of traditional inductive reasoning in scientific research. It also bypasses the problem of induction which has puzzled philosophers of science since Hume. Popper's falsification criterion provides people with a totally new set of standards by which to judge whether an investigation

is *scientific*. As Lakatos noticed, in the background of a major epistemological research programme, it can be concluded that Popper's criterion of demarcation gives a new function to experience in science: "scientific theories are not based on, established or 'probabilified' by, 'facts' but rather eliminated by them".[22] This is a far stricter standard than the confirmation criterion of inductivism in logic.

As far as Lakatos' methodology of scientific research programmes is concerned, it inherits some views of Popper's sophisticated methodological falsificationism, such as the continuity of science, the confirmation criterion of novel facts and so on. He makes some modifications to these. In the first place, Lakatos replaces a series of theories of sophisticated methodological falsificationism with the idea of research programmes. This modification turns scientific research from traditional linear discussion (simple replacement of theories), to include a broader set of systematic concerns, because a research programme includes not only theoretical content but also methodological rules. This provides scientists with more ways in which to do scientific research.

In the second place, besides logical method, Lakatos lays more stress on historical method in scientific research. Under the guidance of the history of science, he probes the progress of science and modifies Popper's methodological falsificationism to be consistent with the historical facts of science.

In the last place, the division of a research programme into a hard core and a protective belt solves the problem of why some classical scientific theories in history of science can develop in the face of anomalies, and bypasses the attack of empirical anomalies to the central tenet of a research programme. It also explains "*the relative autonomy of theoretical science*".[23] The growth of science relies on the development of scientific research programme itself and the replacement between progressive and degenerative research programmes, rather than solution of difficulties from empirical anomalies. This view is not realized by previous falsificationists, such as naïve

[22] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p141.
[23] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p52.

methodological falsificationists. What is more; Lakatos particularly pays attention to how to treat a new or young theory when it faces empirical anomalies. Lakatos gives it more tolerant conditions to benefit its growth. He even points out that "*some of the most important research programmes in the history of science were grafted on to older programmes with which they were blatantly inconsistent*".[24] It seems to be a progress, since it offers a research programme more chances to grow.

4.2 Criticism raised by contemporary philosophers

Popper's methodological falsificationism and Lakatos' methodology of scientific research programmes raise many debates among contemporary philosophers of science.

For Popper's methodological falsificationism, besides Lakatos' criticisms mentioned above, there are some powerful criticisms raised by other contemporary philosophers. The most influential criticism may be Duhem-Quine thesis that there may be uncertainty in the falsification of a theory because it is difficult to say whether *the theory itself* or *other test conditions* that is responsible for the falsification. Under different test conditions, empirical results may be different. Falsifying and refuting a theory simply by experiments may, therefore, be unreasonable.

Another fundamental criticism comes from Kuhn's *The Structure of Scientific Revolutions* which argues that scientists work within a series of *paradigms* that determine how scientists know the world. It is different from Popper that Kuhn offers a historical picture of science and tells us how scientists actually behave. Kuhn realizes that traditional explanations of science, whether inductivism or falsificationism, are not consistent with the historical evidence. He suggests that social, psychological and other non-rational factors should be also considered in explaining theory-change. Although he advocates the important of these factors, he severely denies that he is an irrationalist or relativist about the progress of science.

For Lakatos' methodology of scientific research programmes, the most critical may

[24] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p57.

be Feyerabend's view. He completely denies the methodological research of scientific progress. In his opinion, what the progress of science relies on is *anything goes* rather than any other prescriptive methodologies.

An influential criticism mainly focuses on his arguments of hard core and the criterion of scientific progress. Through reviewing and analysing the history of science, Lakatos suggests that a research programme has a hard core unaffected by empirical anomalies. Nevertheless, in the history of science, sometimes scientists do modify the hard core of their research programme to solve problems, such as Copernicus' modification concerning the position of the sun[25].

Another criticism concerns Lakatos' "methodological decision". Lakatos only tells us that a hard core is "irrefutable" by "the methodological decision of its proponents", but he does not explain that this decision is a historical reality or a figment of his imagination[26]. He does not suggest any evidence and method to answer this question. For the positive heuristic of a research programme, Lakatos' methodology claims that it suggests and predicts reasonable instructions of how to develop the research programme, but this is impossible because "not every potential anomaly could be foreseen and a strategy for dealing with it planned"[27].

Additionally, it has been noticed that Lakatos does not give a specific rule to eliminate a research programme, even if he makes the criterion between progressive and degenerative research programme in the growth of science[28]. Critics point out that it is possible and rational that scientists remain a degenerative research programme and expect that it may revive. They think that Copernican theory which gains an ultimate victory a century later is a good example. As a result, they conclude that, for instance, it may be rational for Marxists to stick to historical materialism[29]. Now that Lakatos has allowed that falsification and refutation are not instant, why does not he give more time to Marxism and other sociological research programmes?

Another problem arises from the dependence of Lakatos' methodology on the

[25] A. F. Chalmers, *What Is This Thing Called Science?* Open University Press, 3rd Edition, 1999, p145.
[26] A. F. Chalmers, *What Is This Thing Called Science?* Open University Press, 3rd Edition, 1999, p145.
[27] Alexander Bird, *Philosophy of Science*, UCL Press, 1998, p253.
[28] A. F. Chalmers, *What Is This Thing Called Science?* Open University Press, 3rd Edition, 1999, p146.
[29] A. F. Chalmers, *What Is This Thing Called Science?* Open University Press, 3rd Edition, 1999, p146.

history of physical science. Critics point out that Lakatos lays particular attention to the research of physical science in his discussion of methodology. He uses cases study of physical science to measure research programmes of other field, such as Marxism or astrology[30]. This may be unreasonable, because it is just an unreliable assumption that the criterion of physical science is applicable to all study fields.

4.3 Some attempts at further discussion

Having recounted some contemporary philosophers' criticisms of Popper's and Lakatos' theories, I will attempt to offer my own discussion of the two.

Popper insists that inductive reasoning is invalid for a scientific theory in logic. He objects to inductive confirmation as the criterion of demarcation between science and pseudoscience. However, in his argument about falsificationism, he does not avoid inductive reasoning and confirmation entirely. For example, he indicates that scientists may try to use *ad hoc* hypotheses to save their theory from empirical falsification. It is just with the help of induction that he draws the conclusion from the analysis of many previous scientific theories and the summary of them. As a consequence, both deductive and inductive reasoning may play important roles in the discussion of scientific demarcation. The neglect of either one must be justified. It is impossible to get rid of induction absolutely.

Secondly, it seems to be also impossible that falsification gets rid of confirmation totally. Even Popper's theory may presuppose some degree of confirmation. For example, both experiments and novel facts are used to falsify a theory, but both first need to be confirmed or supposed to be confirmed. Without their confirmation, falsification would lose its reliability. Consequently, the neglect of confirmation needs to be justified. Here, falsificationism leaves a problem that the fact of past success up to now is not warrant for future reliability.

In addition, Popper tries to eliminate the psychological factors from the research of science. However, in fact, both scientific discovery and technical invention stem from

[30] A. F. Chalmers, *What Is This Thing Called Science?* Open University Press, 3rd Edition, 1999, p147.

human activities. The demarcation of science about which we are talking is not exceptional in this aspect. We establish a theory with bold conjectures, and then test it by experiments or observations. The whole process involves psychological factors. Comparing with those speculative conjectures, experiments and observations are simply relatively natural. Actually, they are also judged by human. As a result, it seems to be impossible for scientists to evade the influence of psychological factors completely.

For Lakatos' methodology of scientific research programmes, it certainly leads the demarcation of science and the progress of science to enter a more comprehensive and complicated research field. By means of historical research, the problem of demarcation is no longer a static logical problem but rather a dynamic historical problem. With the development of science, the viewpoint about the demarcation of science also changes. With the help of the notion of "research programmes" rather than that of "a series of theories", the progress of science is also no longer a linear process of replacement of theories, but rather a systematically modificatory and alternative process between rival theories and experiments. What is more, by specifying a hard core and a protective belt rather than merely "basic statements", the degree of convention is higher, but the progress of science is really more consistent with the history of science.

Besides, Lakatos' attitude is relatively tolerant of induction. He does not deny induction absolutely, and he admits "thin" induction in his methodology of scientific research programmes. He thinks that "with a *positive* solution of the problem of induction, however thin, methodological theories of demarcation can be turned from arbitrary conventions into rational metaphysics".[31] The rationality of this view seems to be worth further discussing.

In the end, both Popper's methodological falsificationism and Lakatos' methodology of scientific research programmes aim to clarify the problem of demarcation between science and pseudoscience, so as to offer a clear and effective

[31] I. Lakatos, *The Methodology of Scientific Research Programmes*, Philosophical Papers Volume1, Cambridge University Press, 2001, p165.

criterion to help people know science and guide further scientific research. However, can this aim be achieved? Popper proposes falsification as the criterion of demarcation between science and pseudoscience. And then, he requires that scientists should follow this criterion to establish and test theories. It shows that logical method guides the progress of science. In Lakatos' opinion, it is rational that we know science not only by logical method but also by historical method. In other words, the methodology of science should be not only valid in logic, but also consistent with the history of science. However, there seems to be a problem with the fact that both Lakatos' and Popper's views are known with hindsight. That is, the progress of science may be influenced by other uncertain factors besides logical and historical factors in reality, such as social and political conditions. So, it is possible that the replacement of a degenerative research programme by a progressive one may be realized by scientists several decades later. However, it should be noticed that, just as Hume argued, we cannot offer a non-circular rational justification for our inductive inferences. In reality, we can, and indeed should, use induction but we cannot offer a justification of induction that does not ultimately rest on induction itself. Then, it seems to be problematic to guide the future research of science by the criterion with hindsight.

Part Ⅴ Conclusion

As mentioned in the introduction, the purpose of this thesis was to explain why and how Lakatos modifies Popper's falsificationism into his methodology of scientific research programmes. Now, let us make a brief summary of this study to assess whether this purpose has been achieved.

Firstly, a review of research methodology before Popper finds that the early demarcation criteria of science result from different schools of thought about science --justificationism, probabilism and dogmatic falsificationism. The former two claim that the empirical confirmation of theories is the demarcation criterion of science.

That is, scientific theories must be able to be confirmed by empirical facts. And the latter regards the falsification of theories as the demarcation criterion of science. That is, scientific theories must be able to be falsified by empirical facts.

Popper refutes these earlier criteria and proposes his methodological falsificationism based on a logical method. As far as the confirmation criterion is concerned, Popper thinks that it is unreliable since it brings in the problem of induction, and so it may be problematic to demarcate science from pseudoscience by means of this criterion. Popper offers an explanation of scientific practice which rejects the need for induction and instead proposes that science proceeds by deduction. Upon this explanation, he proposes his falsification criterion. At the same time, he also amends dogmatic falsificationism. As for Popper's methodological falsificationism, Lakatos divides it into naïve methodological falsificationism and sophisticated methodological falsificationism. Briefly, the argument of naïve methodological falsificationism is relatively rigorous in science demarcation, whereas the argument of sophisticated methodological falsificationism is more tolerant and readily applicable to historical facts. For example, the latter holds that science consists of "a series of theories" instead of "individual theories" of the former, and replaces "reject a previous theory" of the former with "replace a previous theory". The sophisticated form lacks the rigidity of the naïve form.

However, Popper's methodological falsificationism still has some problems, even if there is some improvement to be seen in its development. These problems raise some criticisms from philosophers of science. The purpose of Lakatos' modification is to save Popper's methodological falsificationism from the most influential criticism--Kuhn's stricture (which is briefly mentioned in the introduction section). Lakatos modifies Popper's methodological falsificationism by establishing his methodology of scientific research programmes with the help of the history of science. On the whole, Lakatos' methodology of scientific research programmes is more consistent with the history of science than Popper's methodological falsificationism. By replacing "a series of theories" with "research programmes" as components of science, Lakatos turns science from a series of static theories to a complicated

dynamic system. By specifying hard core and protective belt, Lakatos solves the failure of Popper's methodological falsificationism to explain why some classical theories were still retained in the history of science, even if they faced some experimental anomalies. Moreover, Lakatos offers a criterion which demarcates progressive research programmes from degenerative research programmes, and further explains under what condition a research programme can be regarded as degenerative and *replaced* by a progressive research programme. Although it is generally known that Lakatos modifies Popper's methodological falsificationism according to the history of science, Lakatos' division of a research programme into a hard core and a protective belt seems not to be historical.

From the whole study, we can see a clear development line of the methodology of science--from original empirical confirmation to dogmatic falsification, and then to naïve methodological falsification and sophisticated methodological falsification, and finally to the methodology of scientific research programmes. In the process of development, the methodology of science is constantly being improved. It proceeds from merely emphasizing an individual criterion to considering both confirmation criterion and falsification criterion so that the degree of its rigor gradually falls. In early stages, philosophers of science only claim *either* confirmation, *or* falsification as the demarcation criterion of science, and must exclude the other. For example, justificationists advocate confirmation, whereas falsificationists advocate falsification. However, the emphasis of each one seems not to be sufficient to explain the progress of science in the history of science. Lakatos does not excessively stress one of them. He admits that empirical facts can falsify hypotheses of protective belt in a research programme, but he more emphasizes the function of confirmation. He explicitly indicates that the confirmation of novel facts is the mark of progress. Lakatos' tolerant attitude makes his methodology of scientific research programmes more applicable than Popper's methodological falsificationism in the factual history of science. Moreover, by replacing theories with research programmes, Lakatos modifies Popper's methodological falsificationism to consider the complexity and the tenacity of science and makes it more sophisticated and consistent with the factual history of

science. Consequently, we can see that Lakatos modifies Popper's methodological falsificationism effectively.

Finally, this study shows some potential problems of Lakatos' theory which are worth further discussing.

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