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SCIENTIFIC REALISM: A DEFENCE AGAINST PESSIMISTIC META-INDUCTION AND UNDERDETERMINATION OF THEORY BY DATA

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Declaration

I, Getahun Belay Meheretu, declare that this thesis is my original work and has not been presented for a degree in any other university and that all source materials used for the thesis have been fully acknowledged.

Declared by Getahun Belay

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Abstract

In this thesis, I will argue for scientific realism against pessimistic meta-induction and underdetermination of theory by data. Scientific realism argues that the entities and mechanism of scientific theories literal exist in the world. The inference from the impressive explanatory and predictive success of scientific theories has been the main reason for taking such claims seriously. Detection and corroboration of one and the same scientific entities by different instruments of disparate working mechanism has been the second core reason for scientific realism. Pessimistic induction objects to scientific realism for in the history of science there have been many successful scientific theories that were taken as true which turned out to be false after a while. Underdetermination argues that there is more one scientific theory that is compatible with a body of evidence. As such there is no reason to think one scientific theory as true but not others. However, confirmation methods like subjective Bayesian confirmation and Bootstrapping hypothesis testing are competent to select a scientific theory that is best supported by evidence. Inference of existence only to the essential components of successful scientific theories will block pessimistic meta-induction. Entity realism is able to meet the above objections by limiting scientific realism only to entities that have causal warrant. Structural realism resolves the threat of the two objections since what successful scientific theories capture is the fundamental structural relation between entities. Thus, I conclude that scientific realism has potent defences against pessimistic induction and underdetermination.

Keywords: scientific realism, pessimistic meta-induction, underdetermination of theory by data, entity realism, structural realism, Bayesian confirmation and Bootstrapping hypothesis testing

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Introduction

Since the rise of modern science, there have been debates and controversies about what science tell us about the world. On one hand, it is claimed that science describes the true features and structures of the world. In addition the entities and mechanism posited by scientific theories are things that are found in the real world independent of human constructs. It is the view that is called scientific realism. The foremost argument in favour of scientific realism has been the impressive empirical success of modern science. Accordingly, science has become hugely successful in predicting and explaining the phenomena of natural world because scientific theories are true and their entities are real. On other hand, those who are doubtful about the truth and the metaphysical status of scientific theories and scientific entities claim the otherwise. Although various mechanisms and entities of scientific theories have evidently enabled science to predict and explain myriad of empirical phenomena, it doesn't mean they are real features of the world. Rather, they are just tools and constructs of scientist that helped them to control, organize and predict the observable phenomena. As a result, scientific theories and their entities don't tell us the truth and the fundamental constituting entities of the natural world. It is such view that is called scientific anti-realism.

It is the project of this thesis to defend and develop the claims of scientific realism against two central anti-realist objections. I will argue for scientific realism against pessimistic meta-induction and underdetermination of theory by data.

According to pessimistic meta-induction the history of science is a grave house of past scientific theories that were accepted as true and as referential in their claim about the world but got subsequently rejected. Science is full of past scientific theories that were accepted as true and as referential but later these theories were discarded on the ground that they were found to be false and non-referring theories. As a result, it is highly likely that the currently accepted scientific theories (as true and referential) will face the same fate and will be discarded as false and non-referring theories. On other hand, Underdetermination of theory by data argues against scientific realism on the ground that evidence is impotent to limit theory choice. That is, there is more than one possibly infinite number of scientific theories that are inconsistent with each other, which can be compatible or entail a body of evidence. Due to this, it is an error to claim that a scientific theory is true and referential just because it is compatible or entails the empirical evidence.

I will defend scientific realism from the above two objections in two ways. In The first one I will develop direct counter response to pessimistic meta-induction and underdetermination of theory by data. As such I will contest the claims of these objections various ways. The underdetermination proponents err in conflating deductive compatibility or entailment of a body of evidence by scientific theories with equal level of support or confirmation. In claiming underdetermination of theory choice, they relied on the incapacities of deductive methods to filter out competing scientific theories. However, Bayesian confirmation and hypothesis testing by Bootstrapping are the two methods that enable us to solve the deductively underdetermined rival scientific theories or hypotheses.

In response to pessimistic meta-induction argument from the history of science, scientific theories success getting at the true features and entities of the world I contend that it is only partial and approximate. That is, only some of the essential entities and mechanism that drive the success of scientific theories are true and extant in the world. The non-essential parts of scientific theories have no truth or ontological implication. And it is the latter parts of past successful scientific theories that get discarded subsequently. On other hand, it is precisely the essential parts of past successful scientific theories that get preserved in later successful theories. The relation between past and current successful scientific theories is explicated with notion of approximate truth or truth-likeness. Supplanting scientific theories are more truth-like or closer to the truth compared to the ceded past scientific theories.

To me, when looked at closely, pessimistic meta-induction is a weak inductive argument and commits at least two kinds of fallacies. Proponents of pessimistic induction when selecting historical evidences of rejected successful past scientific theories, it wasn't systematic and methodical. Rather, they purposely selected discarded scientific theories that illustrates there point. Such cherry picking methods will not enable us to know if the selected scientific theories are representative of the general predicament of successful past scientific theories. Due to this, it is difficult to take seriously pessimistic induction as strong inductive argument. Pessimistic meta-induction commits the turn over fallacy and base rate fallacy as well.

In the second way, I will defend scientific realism against the two objections is through selective scientific realism that includes entity and structural realism. Entity scientific realism puts a stringent demand on the evidence for taking scientific entity to be real. In particular, it is only scientific entities involved causal explanation of events and with demonstrated experimental causal properties and powers from parts of scientific theories that are taken to exist in the world. That is, I will argue to limit scientific realism to the entities with demonstrated causal warrant. As I see it, pessimistic induction is not a problem for entity realism since on its account demonstrated causal warrant not inference to best explanation grounds scientific realism. The strict demand for experimentally demonstrated causal properties will eliminate as well most of the candidate scientific theories that could pose a threat of underdetermination.

Structural scientific realism, on other hand, the fundamental ontological feature of the world is the structure relations between entities not the entities. On epistemic variant structuralism, human science can only have knowledge of the structural relation between entities while internal properties of those entities are forever foreclosed from human reach. The continuity between successive scientific theories is that of structure not content. On ontic variant of structural realism scientific entities are either reducible to the structure or have only relational properties. For both kinds of structural realism, scientific theories are model of the existing world rather than syntactic account of it. As a result one scientific theory is more truth-like than another theory if it has better modelled the structural relation between entities. In my view, these fundamental shifts of structural scientific realism make the bite of pessimistic meta-induction and underdetermination of theory by data insignificant.

The above themes of this thesis will be addressed in the coming chapters with the following structure. In chapter one, I will present the historical background of scientific realism. In chapter two, I will outline what scientific realism is, its two central concepts and the main arguments in its favour. In chapter three I will present and explicate pessimistic meta-induction and underdetermination of theory by data that threaten scientific realism. In chapter four I will present the direct counter response of scientific realism to the two attacks. Chapter five I will deal with modified or selective kinds of scientific realism. In chapter six, I will appraise and conclude the strength of the defences of scientific realism against pessimistic meta-induction and underdetermination.

Chapter One

Historical Background

1.1 The 19th Century Debate

Controversies about the reality and truth of scientific entities and theories started with the birth of modern science.[1] However, it reached into the main stream level of discussion during the 19th century. The debates prominently were about the existence and the reality of atoms and atom based molecules. This debate about the existence of atoms and the truth of atomic theory lasted until the first decade 20th century. It involved many actors from chemistry, physics and philosophy. During early 19th century chemists like William Dalton conceived atom as physical entities of various size and weight.[2] Atoms of various elements like gold or carbon were thought to differ in their relative weight. And these atoms combine in fixed relative proportion to form compound molecules. In physics atom was thought as hard micro entity that is the ultimate unit of matter. At that time, they were thought as indivisible and indestructible basic unit of all matter. Kinetic theory and the associated mechanical theory of heat that hypothesized the reality of atoms gained host of new empirical predictions like the Avogadro number and diameter of gas molecules.

However, Subsequent difficulties to ascertain the precise number and weight of each atom in chemicals lead some chemists to abandon the idea of atom as physical quantities.[3] They wanted to replace them with equivalent unit of gas volumes that are observational and within the limit of experience. Fierce criticism intensified over the physical reality of atoms during the second half of 19th century that are grounded mainly over the lacking experimental support for determination various properties atoms including their weight, number and size. Of these two were prominent. The first formulation of atom as inelastic hard matter was contradicted by experimental evidence and the atomists shifted atom into elastic spherical structures. Second was the atom based kinetic theory inconsistency with second law of thermodynamics. That is, time

[1] Martin Gardner, "Realism and Instrumentalism in 19th Century Atomism", *Philosophy of Science* 46, no. 1(1979),3

[2] Mary Jo Nye, "The Nineteenth-Century Atomic Debates and the Dilemma of an 'Indifferent Hypothesis'", *Studies in History and Philosophy of Science* Part A 7 , no. 3 (1976):247

[3] Gardner, "Realism and Instrumentalism in 19th Century Atomism, 9 & 19

asymmetry and time directed increment of entropy in thermodynamics was inconsistent with time reversibility of kinetic theory. Compared to the atomic theory of matter, the energy based thermodynamics view of matter as continuous entity was gaining traction. The proponents of such theory viewed their theory of matter as constrained by the limit of experience in contrast to atomic theory of matter. Furthermore they attacked that atomic theory is unverifiable and there was no practical reason to keep its model of matter. As a result atomic entities were not seen real and fundamental feature of matter.

Some of the most prominent philosophers of the time concurred with non-reality of atoms. To Ernst Mach positing unobservable entities like atoms by a theory is acceptable, if it helps the theory to make prediction and discovery of empirical phenomena.[4] However, it doesn't mean atomic entities are genuine metaphysical entities that exist in the world. He argued, at best, atoms were instrumental and organizing devices for success of scientific theory but not real entities of the world. To Henri Ponicare the atomic theory and atom based kinetic theory were indifferent hypothesises that cannot to true or false because of the lack of means to test the theories.[5] He also doubted the heuristic value of maintaining such theories.

The growing sceptical attitude to the existence of atoms started to change by closing of years of 19th century and the reality of atoms for most scientists got firmly established by the end the first decade of 20th century.[6] The myriad of independent experimental results that support the existence of atoms and sub atomic particles played the decisive role. It started with Stanislao Cannizzaro developing mechanism to measure the weight of atoms. The discovery that cathode ray are constituted by negatively charge subatomic particles which we now call electrons was another. The detection and measurement of atoms of elements with different weight (i.e. isotopes) further substantiated the reality of atoms. Most importantly, it was the precise determination Brownian motion of atoms and molecules that changed the tide. That is, experimental confirmation of an earlier prediction about the distribution and random movement of particles (atoms and molecules) suspended in fluid made the reality of atoms overwhelming. The same experiment confirmed the precise number of molecules per unites volume that is called

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[4] Nye, "the Nineteenth Century Atomic Debates", 264
[5] Nye, "the Nineteenth Century Atomic Debates", 256
[6] Nye" the Nineteenth Century Atomic Debates ",266

Avogadro number as well. As a result by 1911 to most scientists the evidence for the existence of atoms has been firmly established.

1.2 Logical Empiricism

The philosophical heirs to the antirealist attitudes of 19th century scientists and philosophers presented above were the logical positivists or logical empiricists.[7] These were scientifically minded philosophers who formed the Vienna circle in the 1920's. Their primary concerns were making philosophical inquiry in sync with the contemporary science. As a result they strived to demarcate the proper area of philosophical investigation and amend the fault lines of past philosophers. In addition, they were philosophers who inherited the linguistic turn into philosophical inquiry from Frege, Russell and Wittgenstein.[8] That is, the solution to philosophical questions lies in the analysis and construction language (natural and artificial).

All propositions, for them, are either analytic or synthetic.[9] The truth of analytic propositions is gotten from studying the syntax and convention of a language. A synthetic proposition, on other hand, has its source in empirical phenomena. For logical empiricists any claim about the empirical world to be cognitively meaningful, it has to be verifiable. That is, any synthetic claim about the world has possibility of being true or false, if it can only be verifiable. For a statement to be verifiable there has to be inter-subjectively accessible observational phenomena that can be used to assess the truth condition of its claims. Accordingly, any non-verifiable claims about the world are senseless pseudo claims that have to be discarded from the world of philosophy. In light of this criterion, most of traditional metaphysical claims like the reality of external world and meta-ethical claims about the reality of absolute ethical values became pseudo problems. The main reason for such strong pronouncement is that the above metaphysical and meta-ethical claims lack any observational condition on which to evaluate the truth or falsity of their claims. As a result it is precisely from this point that their suspicion about existence of non-observable scientific entities emanates. They worried that ontological

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[7] Elisabeth Nemeth, "Ernst Mach and the Early Logical Empricism",in *The Routledge Handbook of Logical Empricism,* ed.Thomas Uebel and Christoph Limbeck-Lilienau (New York: Routledge, 2022), 62

[8] Richard Rorty, *The Linguistic Turn: Essays in the Philosophical Method*, (Chicago: the University of Chicago Press,1967)

[9] Thomas Uebel, "Logical Empiricism", in *The Routledge Companion to Philosophy of Science 2nd ed. ,* ed. Stathis Psillos and Martin Curd(New York: Routledge,2014),90

commitments to non- observational entities of science will betray their verification criterion of synthetic statements.

In order to solve such problem, they classified scientific statements into observational and theoretical ones.[10] Observational statements of scientific theories are those that can be verified and theoretical ones are those that cannot be directly verified. Theoretical statements containing atoms or genes have no observational phenomena by themselves. However, they proposed that if theoretical entities can be reduced to observational phenomena, they are indirectly truth conditional. As a result a statement about particular theoretical entity is operationalized into a set of observational phenomena and assed if it obtains or not. This project of reducing of theoretical entities into observational phenomena aimed to preserve the ontology of scientific theories within empirical framework. Therefore it avoided scientifically realist attitude about theoretical entities.

The bifurcation of terms of scientific theories into observational and theoretical soon faced insurmountable difficulties.[11] The operationalization of theoretical entities into a set of observational phenomena was not adequate for the task capturing what a theoretical entity is. It is impossible to fix the nature and properties of a theoretical entity by several observational events. That is, what a theoretical entity is always open and includes what has been known about it and what has yet to be known about it. Theoretical entities have excess content that cannot be reduced into fixed set of observational phenomena. Thus it natures, properties and powers cannot be limited be few equivalent observational phenomena.

To me there was another searing criticism against logical empiricism bifurcation of terms of scientific theories into observational and theoretical (non-observational) that lead to the collapse of logical empiricism.[12] Maxwell argued that there is no consistent principle that demarcates theoretical terms from observational terms. Is it by unaided eye, or light microscope, or electron microscope or telescope where the line between observational and theoretical terms is drawn? On the contrary rather than a clear cut demarcation between theoretical and observation

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[10] Uebel, "Logical Empiricism", 92

[11] Stathis Psillos, *Scientific Realism: How Science Tracks the Truth*, (New York: Routledge, 1999),3

[12] Grover Maxwell, "The Ontological Status of Theoretical Entities", *In Scientific Explanation, Space, and Time: Minnesota Studies in the Philosophy of Science*, eds. Herbert Feigl & Grover Maxwell (Minneapolis: University of Minnesota Press,1962),181

term, there is only continuous and gradual relation between entities of varying size. He pointed out that there is no definable point beyond which unobservable entities reside. In addition this line is always changing. What was unobservable yesterday through naked eye is observable today with aid of light microscope and what is unobservable through light microscope yesterday is observable through electron microscope today. The advent of new technologies is always pushing entities that were inaccessible to observation towards realm of the observation. As a result there is no non-empirical conceptual analysis or logical analysis that tells us where the line of demarcation between the two kinds of entities lies. Furthermore sometimes what are unobservable (theoretical terms) are macroscopic objects like stars and moons that are too far away from earth. Most importantly the ontological status of things cannot be reduced to contingent procedural set up of science. That is, size and distance of entities has no bearing whether they are real or not.

The untenability of categorising scientific entities into observational and theoretical ones led members of logical empiricists into different directions.[13] Some like Ernest Nagel returned to their Machian roots of instrumentalism about non-observational entities. That is, unobservable entities are fictive tools that help us to organize, explain and predict the empirical phenomena. Other than this, they have no their own independent existence in the world. They became clear cut anti realist about entities that are inaccessible to empirical observation.

Others like Rudolf Carnap sought for neutral camp between realism and anti-realism.[14] Carnap argued that questions about the existence are two kinds. They are internal or external questions. Internal questions refer what an entity is and what its function are with certain linguistic framework. The linguistic frame-work can be within common sense language or within the framework of quantum theory or general relativity. Definitive answers can be given what electron is or what space-time curvature is within these respective linguistic frame-works. The external questions refer to what an entity is outside any linguistic framework or irrespective of any linguistic framework and if it exists really in the world. There are no answers to such questions since they are pseudo-philosophical questions. As a result for Carnap propounding scientific realism outside of a particular linguistic is not genuine philosophical endeavour.

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[13], Psillos, *Scientific Realism: How Science Tracks the Truth* ,10
[14] Uebel, "Logical Empiricism", 96

Still a third group led by Herbert Feigel moved towards pragmatic semantic realism.[15] Accordingly all terms of scientific theories have the same referential status. That is, there is no difference in their referential relation between terms of observational entities and terms of non-observational entities. As a result theoretical terms of scientific theories do refer to entities in the world like their observational counter parts. And terms of both kinds of entities will hold only if there are entities in the world that stand in referential relation with them. There is no difference in semantic status of theoretical and observational terms. Terms referring to the two kinds of scientific entities are equally truth conditioned and will be evaluated as true or false depending on the asserted factual conditions obtainment or lack thereof. The differences between the two kinds of entities are their epistemic conditions. That is, the evidence we use to verify and confirm as to their structure and properties might be different. But two questions should be separated; the truth conditional and referential status of scientific entity and the epistemic and verification conditions. However, this half way move towards scientific realism had a big caveat. The main motivating reason to adopt realism about observational and non-observational entities and mechanisms of scientific theories was pragmatic. Scientific realism was thought to be more fruitful compared to antirealist alternatives. Scientific realism is a conceptual framework the adoption of which lead in strengthening the explanatory and predictive power of science. In articulating science as a conceptual framework and in portraying pragmatic reasons as the decisive ones in adoption of scientific realism Feigel basically agreed with Carnap's views.

After Maxwell's criticism on logical empiricism's sceptical attitude to theoretical entities and their assignment of differential statues to theoretical and observational, it opened the door for scientific realism in a significant way. Hilary Putnam and Richard Boyd started to articulate and to defend scientific realism as tenable philosophical project in 1960's and 1970's.[16] I will explore and defend in the coming chapters scientific realism against the two prominent challenges that is developed since then.

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[15] Psillos, *Scientific Realism: How Science Tracks the Truth* ,10

[16] Stathis Psillos, "The Realist Turn in the Philosophy of Science" in *The Routledge Handbook of Scientific Realism*, ed. Joshua Saatsi, (New York: Routledge, 2017), 20

Chapter Two

Mapping Scientific Realism

2.1 Defining Scientific Realism

According to Richard Boyd scientific realism has four central claims.[17] First, it says that the things that are found in scientific theories do refer to objects in the world. That is, terms that are found in scientific theories and their ascribed attributes are the constituting entities and features of reality. A scientific term is causally linked with properties of the entity picked by the term. Second, such scientific theories are true or approximately true in their description of the world. Accordingly scientific theories and their terms are substantially accurate in their description of existent entities compared to their error. Third, the world depicted by scientific theories is the reality that exists separately from human conception or thought. Independence from human conception and perception has been the traditional mark of real existence (realism) of an entity and scientific realism has such commitments. Finally, scientific realism asserts that the progress of advanced sciences is a result of convergence and getting close to the true objects of the world; and reflects the continuity of latter-day more true scientific theories with earlier less true scientific theories. The last claim is also called convergence thesis of scientific realism and says that there is uninterrupted linkage between successive scientific theories. In addition, there is an accruement of scientific knowledge across time. Furthermore, later day theories succeed in getting closer to the real attributes and nature of entities found in reality compared to the partial account of these entities found in earlier scientific theories. In physics for example, subatomic particles like electrons, protons, neutrons; atomic particles like hydrogen or oxygen; and molecules like H_2O or CO_2 are things that are found in the world with their attributed features independent of human conceptual schemes. In biology the four nucleotides; DNA and RNA; gene and chromosomes, and cellular substructures like nucleus and mitochondria are things with their described features that exist in biological beings. In addition, these entities and their properties don't need translation into any other conceptions and are genuinely true features of the biological world. I will refer in this thesis the above kind of scientific realism as standard scientific realism.

[17] Richard N. Boyd, "On The Current Status of The Issue of Scientific Realism", *Erkenntnis* 19 (1983):45

In my view, the above first three claims of scientific realism are metaphysical, semantic, and epistemological theses.[18]

The metaphysical thesis is that the world has ontological entities and structures as described in scientific theories.[19] That is, scientific theories do not bring into existence structures and entities that are not found in the world in their attempt to characterize it. Rather, they capture the ontological structure of the world that existed before scientific theories started to give an account of it. As such the metaphysics of scientific realism is that there are macro and micro scientific entities which exist independently in the world. This realist commitment is in contrast to idealism or constructivism. Idealism asserts that there are no mind independent world and mind independent entities including scientific ones. And it is only mental content like thoughts, perceptions and sense data that are fundamentally real. Constructivism on other hand argues that scientific entities are a result of conceptual constructs and the kinds of entities that are accepted are dependent on such schemes. As result it is wrongheaded to claim there are mind independent or conceptual apparatus/paradigm/ neutral entities that exist in the world. In contrast to the sceptical position of idealism or constructivism, scientific realism argues that it is highly probable for there to be an objective external world as described by our best scientific theories.

The semantic thesis says that both the observable and the unobservable terms of scientific theories literally refer to the kinds of things that are found in the world.[20] Accordingly, the truth conditions of scientific theories' macro and micro entities have the same standard. That is, they are true if only if there is a referential relation to entities in the world and their attributes. In particular, the semantic claim of scientific realism is that entities that are found in scientific theories whether they are perceptible or not, they point/refer/ in an identical way to the objects in the world. As a result, a scientific theory is true if and only if there are things in the world that mirror the entities and their attributes of the theory. This semantic realism is contrasted broadly with two kinds of anti-realisms regarding the unobservable terms of scientific theories. Instrumentalism asserts that scientific theories, in general, and their unobservable constituents in particular are tools to systematise and predict observable phenomena. But these latter terms don't

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[18] Stathis Psillos, *Scientific Realism: How Science Tracks Truth*, (New York: Routldge, 1999)

[19] Anjan Chakravartty, "Scientific Realism", *The Stanford Encyclopedia of Philosophy* (Summer 2017 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/sum2017/entries/scientific-realism/Accessed March 01 2024/

[20] Chakravartty, "Scientific Realism"

refer to anything in the world and are as such meaningless. It is also different from logical empiricism view that statements and terms of unobservable scientific events and entities are reducible to their observable counterpart. Accordingly, terms of unobservable entities are strictly not referential but they are reducible to referring observational terms. As a result they are capable of being assessed as true or false. As a result, the unobservable terms which don't satisfy the logical empiricism verification criteria of meaning are only meaningful indirectly through their translated observational terms.

The epistemological thesis of scientific realism adds that the best scientific theories with established predictive success give us knowledge that is true and is justified account of the world.[21] Accordingly, the methodological sophistication of science gives us a warrant that its fruits are true or approximately true. To Andre Kukla, the epistemic thesis of scientific realism has certain varying gradients.[22] Each has weaker claim than the other. The first one argues that science gives us knowledge and scientific theories are true. It has strong and definitive answers as to the epistemological statues of scientific theories. Less definitive to it is the moderate view that scientific theories are only rationally justified and approximately true. The third and still the weaker view is that scientific theories give us rational warrant to hold onto their claims. That is, while scientific theories might turn out to be wide of the margin of truth, at the time of their assertion, it was rational to hold them. The last kind and weakest epistemological scientific realism is that it logically possible to be in a position sometime in the future or in state of science to hold scientific theories as rational system of beliefs. In this thesis, I am defending the moderate and approximately true notion of scientific theories.

There is another dimension to what scientific realism is.[23] That is, we can contrast scientific realism to the phenomenalist theory of knowledge in which the perceptual contents are the primary ontological entities and to Platonism in which abstract entities are the ultimate ontological entities. Scientific realism is a continuous extension of common sense realism which says that everyday objects like tables, chairs, and houses exist. In particular, it is a claim that in addition to everyday objects of the world, entities of scientific theories that are inaccessible to

[21] Chakravartty, "Scientific Realism"

[22] André Kukla, *Studies in Scientific Realism*, (Oxford: Oxford University Press, 1998), 10

[23] Kukla, *Studies in Scientific Realism,4*

the unaided eye (and all other perceptual organs) exist in our world. It claims atoms, electrons, protons, quarks, genes, DNA, galaxies, viruses, and other innumerable unobservable scientific entities exist in the world. Due to this, I believe that that since scientific antirealists mostly agree about the existence of everyday objects, the contention is mainly about the status of unobservable scientific entities. Thus, in my view scientific realism affirms that the unobservable scientific entities posited by the best scientific theories exist in the world with equal ontological status with everyday objects. And scientific antirealism denies such claims on various grounds.

2.2 Arguments for Scientific Realism

Hilary Putnam argued that anti-realism about science makes the incredible success of science miraculous in contrast to scientific realism which gives the best explanation for the achievement of science.[24] Accordingly, the best account for the success of science is that scientific theories are approximately true; and successive theories are rounding on the truth in a better way than the previous successful theories while preserving things/entities/ they got right. That is, scientific theories progressively converge toward the truth by reflecting the world that exists independently. Thus, it would be incredibly mysterious how the undeniably impressive predictive and explanatory success of scientific theories were achieved, if not for their approximately truth and referentiality.

Richard Boyd expanded Putnam's explanatory scientific realism, by arguing that realism about scientific theories is the best explanation for the consistent instrumental credibility of scientific methodology.[25] The successful work of sophisticated technological machinery or the predictive success of sciences is a reflection of the strength and the truth of scientific method and scientific theories respectively. Boyd added that scientific method and theories have reciprocal relationships.[26] That is, scientific method is dependent on host of accepted background theories and it in turn leads to the discovery of novel unobservable scientific entities. On other hand, posting new theoretical entities will lead to adjustment of scientific method which enables it to detect the prediction of the enriched theory. Accordingly, the dialectical relationship works

[24] Hilary Putnam, *Philosophical Papers, Volume 1: Mathematics, Matter and Method*, (London: Cambridge University Press, 1975),73
[25] Boyd, "On The Current Status of The Issue of Scientific Realism", 64
[26] Boyd, "On The Current Status of The Issue of Scientific Realism", 65

because the accepted scientific theories are approximately true and as such they assure the reliability of scientific method to predict and detect new phenomena.

Putnam's and Boyd's argument for scientific realism has the structure of abductive or inference to best explanation kind of inference.[27] Accordingly, the claim that scientific theories including their unobservable posits exist independently in the world is an abductive inference to the miracles success of science. That is, the best explanation for the success of science among all the alternative explanations is scientific realism. In addition, in every day scientific practice particular scientific theories use abductive explanations to predict novel phenomena successfully. Every branch of science searches for the best explanation of a natural phenomenon and use that explanatory theory to predict other novel aspect of nature. That is, inference is to the best explanation or abduction is a pervasive method of reasoning that enable focal scientific theories to predict novel phenomena. Therefore, it is also a generalization of this practice, which is indispensable to the everyday work of scientists, to say that the best account for the instrumental reliability of the scientific method is that scientific realism is true. And its unobservable entities of scientific theories do exist in the world. As such, abductive inference is a valid form of argumentation that scientific antirealists cannot reject and even if they did, they cannot give a motivated principle that spares their accepted epistemology and metaphysics.

As I will show, in the next chapter it is precisely the abduction of scientific realism to all entities and mechanism of scientific theory from the miraculous success of science that will be the target of pessimistic meta-induction. I will show that abduction to truth and referentiality of scientific theory from is justifiable only to the essential entities of successful scientific theory.

The other kind of defence of scientific realism is that attestation of theoretical entities from disparate process and experimental procedures. Wesley Salmon presented the potency of this argument via the principle of common cause.[28] He illustrated his case by tracing down how atoms and molecules got accepted as existing entities by the scientific community in the twentieth century. The determination of the number of molecules per a mole which is called Avogadro's number was possible by advent of microscopes with better magnifying power. But it

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[27] Richard Boyd, "*What Realism Implies and What it Does Not"*, *Dialectica* 43 no 1&2(1989), 7

[28] Wesley Salmon, *Scientific Explanation and the Causal Structure of the World,* (Princeton: Princeton University Press,1984),158

was not just the precise estimation of the number of molecules through careful single experiment (enumeration of vertical Brownian movement) that was crucial in convincing the realism of the molecules. It was the determination of the precise number of molecules by more than ten independent methods with similar figure per mole that established molecules as independent entities rather than instrumental and fictitious models. If the precise agreement in the number of molecules per mole was not a result of the reality of molecules, it would have been an improbable coincidence that is hard to justify. He compared this phenomenon with several independent witnesses that report same crime details and same involved agents. The likelihood of independent witnesses reporting same events and same perpetrators would be unexplainable coincidence. On the other hand a common cause of the reported crime and people is the most probable persuasive reason. Likewise the common cause of independent reality of molecules is the reason that led to the remarkable agreement by the more than dozens of independent measurements. That is, the reality of atomic molecules and their attributes were the underlying factor or cause that brought out in several casually independent processes the same phenomena (the Avogadro number). More generally it is the existence underlying unobservable entities (the common factor) that leads to the detection of their causal properties and effects in widely varying scientific mechanisms and processes.

Ian Hacking argued about the reality of microscopic entities that are seen with microscope.[29] He reveals that acquaintance and practice with microscope lead us to see entities that exist independent of scientific theories. While several kinds of microscopes are built with a help of particular theory, they have no substantial bearing on what is seen with the microscope. For example red blood cells that are seen by electron microscope and fluorescent microscope. These two kinds of microscopes employ two completely different kinds of mechanism in their working. While fluorescent microscopes use the process fluorescence and light in order to observe microscopic entities, electron microscope use stream of electron to see the ultramicroscopic world. But the same cell structure of platelets show up when they are seen with the two microscopes. Contrary to being artifacts[30] of the laboratory process, it is because they are

[29] Ian Hacking, *Representing and Intervening: Introductory Topics in Philosophy of Natural Sciences.* London: (Cambridge University Press, 1985), 186

[30] Artifacts are artificial structures or change in composition to genuine parts of microscopic entities that are brought about by external process of the laboratory.

real entities that they appear consistently in a microscope regardless of the microscopic mechanisms. In contrast to the inference to the best explanation argument and common cause argument for the existence of unobservable entities given in the preceding pages, Hacking argument is that the same observed entities seen with disparate kinds of microscopes are real rather than the artifacts of the laboratory. Furthermore, the grids which structure the specimen are prepared from a large macroscopic grid that will get reduced to microscopic size. And the same structural features of the macroscopic grid are seen under microscopes with different working mechanisms. The macroscopic features that were seen with naked eye were repeated with the microscopes. It is impossible in faces of such observation to argue that the microscopic entities are unreal or mere artifacts. Rather, if similar architectural attributes of microscopic objects are observed in microscopes with more than one working mechanisms (electron, light, florescent) then they are real entities with same epistemic statues with ordinary perception. Like the latter we might sometimes be erroneous about what we see with microscopes. But, in general, things that have gone through above process of scrutiny are real perceived entities which exist independently of us. Viruses, bacteria and other microscopic organisms are things that are consistently seen with microscopes of different working mechanism. Thus they are real entities that exist in the world rather than artifacts of experimental setting.

In my view, the above presented and second foremost argument by Hacking and Salmon for scientific realism is related with is called robustness criterion for scientific realism. That is, the existence of scientific entity is established, if it has properties that are detectable in variously and independent ways. Markus I. Eronen articulated building on William Wimsatt's account to support the arguments for scientific realism.[31] He defined robustness:

> *(Robustness) X is robust in the relevant scientific community at a certain time insofar as X is detectable, measurable, derivable, producible, or explanatory in a variety of independent ways.*[32]

The independent methods of accessing of the posited entities are process with distinct theoretical premises, experimental tests and mechanical process of detection. As a result the probability of

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[31]Markus I. Eronen, "Robustness and Reality", *Synthese* 192, no.12 (2015), 3961.
[32] Eronen, "Robustness and Reality", 11

disparate and independent methods agreeing in different scientific entities that are not real becomes less probable. Further, robustness is the source epistemic justification to sort out our ontological commitment among the variety of posited scientific entities. When a scientific community has robust account of a scientific entity, then the community is justified in positing the independent existence of that entity. This justified ontological commitment of robust scientific entities is a progressive and a fallible process. That is, entities which initially are minimally robust and accorded not much of reality will progress with time and development of independent of ways measuring them to become robust and real. Scientific realism is the correct for most of micro entities posited by the current best science since they are robust. For example electrons, photo electric effect; and photo sensitive small portion of retinal cells all which of were minimally robust at the time of their initial posit and had single method detection. But now these entities and phenomena are robust and real since there are varieties of independent methods to detect them.

In my view, contrary to abduction, the robustness criterion for scientific realism is more reliable defense against pessimistic induction and underdetermination of theory by data. The main reason for this fact is that there are no entities that are robust but whose choice underdetermined. In addition pessimistic induction hasn't established the case of discontinuity of robust scientific entities. As such, I will show in my final analysis, justification of scientific realism through robustness is one of the main ways to avoid the threat of the two objections that will be presented in the next chapter.

2.3 Understanding the Two Central Concepts in Scientific Realism

2.3.1 Truth-likeness:

In scientific realism, the concept of approximate truth has a crucial role. Approximate truth, verisimilitude and truth-likeness are used for the role that characterizes the relationship between scientific theories and reality. That is, truth understood as exact matching between propositions and state of affairs is less suitable concept to the world of science. In my opinion to think there is a scientific theory that maps to events, entities and process of natural phenomena perfectly without any degree of error is to think we have a total certain science of everything. Because of such predicament, the standard account of truth in terms correspondence between worldly states and propositions is replaced with notion of truth-likeness in explicating scientific realism.

It was Karl Popper who introduced verisimilitude first.[33] As science progress it improves in its closeness to truth. Verisimilitude is the degree of measurement that indicates the greater truth-likeness of successive scientific theories compared to the preceding ones. While the latter day scientific theories are not exactly true, they are more close to the truth compared to the earlier ones. Popper did give a formal account of what verisimilitude is. A scientific theory P is more truth-like than a scientific theory Q when its theory content has certain features. Theory content of P and Q includes the entire true and the false logical consequent propositions of scientific theories of P and Q. Accordingly theory P has more verisimilitude compared to theory Q if and only if it has more number of true logical consequences and is not different in number false consequences than theory Q; or has less number of false logical consequences and is not different in number of true consequences than scientific theory Q. To put in another way the degree of verisimilitude of a scientific theory is measured by the proportion of its true content to its false content compared to any other theory. Unfortunately, his formal account of verisimilitude faced serious challenges. As it turned out it is impossible to add the true content of a theory without increasing its false content or subtract its false content without decreasing its true content.[34] In addition it renders all false scientific theories as equally valueless. The main underlying reason is Popper's conception of truth-likeness by categorical true and false content. It is doesn't discriminate between statements that say the age of universe is 13 billion years or it is 6 thousand years. While the two statements are false statements, they differ in their degree of closeness to the true age of the universe. But popper's conception of verisimilitude doesn't capture this intuitive fact. As a result Popper's account truth-likeness failed to give us how scientific theory improves in its verisimilitude and gets closer to the truth compared to rival theories.

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[33] Karl Popper, Conjectures and Refutations : the Growth of Scientific Knowledge, (New york: Routledge, 1963), 314

[34] Psillos, *Scientific Realism,* 253

In aftermaths of the failure of Popper's verisimilitude formal or syntactic account emerged semantic focused likeness or possible world approach towards truth-likeness.[35] In order to give an account of truth-likeness it needs few conceptual arcs. Propositions classify possible worlds in two subcategories. These are possible worlds in which propositions are true and possible worlds in which they are false. Propositions of scientific theories ascribe fundamental constituting features to a world. Possible worlds are a result of the imaginable structural variations of the fundamental constituting features of the theory. The actual world is a possible world on which all the propositions of scientific theories that refer to it hold or are true. A proposition is true just in case out of the all possible worlds it is case in the actual world. In short propositions that ascribe features to possible worlds are true to extent what they or parts of them say hold in the actual world. These possible worlds have differing degree of similarity with each other. It is the task of likeness approach to gauge the extent of similarity and as result the degree of closeness between propositions that are about the worlds.

Crucially, truth-likeness on this approach is a measure of how close or distant any possible world is to the actual world and the corresponding propositions about them.[36] If we take for example S (sunny), C (cold) and H (humid) as fundamental constituting features weather in any possible world, we will have 8 possible worlds and the actual world is where S, C and H are true. The relative likeness between the 8 possible worlds is something that can be measured and geometrical represented. The possible world not S, not C and not H is world that is furthest or the most unlike to the actual world or to the Truth.

As I see it, in the literature of truth-likeness there are different formal or functional accounts of the distance of each possible world to the actual world with differing degree merit in each program. While we can dispute over how to identify the right and the most object function of truth-likeness, to me, the more worrying problem has been the language dependence of the likeness functions set in possible worlds. That is, when a language of truth-likeness function changes the truth-likeness value/closeness of a possible world to the actual world and to the Truth changes. One strong solution to language dependence problem of truth-likeness of possible

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[35] Graham Oddie & Gustavo Cevolani, "Truthlikeness", *The Stanford Encyclopedia of Philosophy* (Winter 2022 Edition), Edward N. Zalta & Uri Nodelman (eds.), URL = <https://plato.stanford.edu/archives/win2022/entries/truthlikeness/Accesed April 28 2024/

[36] Oddie & Cevolani, "Truthlikeness"

world approach is that not all languages have equal standing in describing the fundamental features and casual relation of the actual world. As such it is only predicates and universals of a language that veritably maps and links the existing entities and their order that can be an adequate candidate for truth-likeness function.

In my view, the intuitive account of truth-likeness is another independent and adequate formulation for the concept of truth likeness.[37] That is, the concept of truth-likeness is a clear enough concept. Non formal and non-quantitative nature of truth-likeness isn't a barrier or a defect for it to be used in ranking the relative approximation of scientific theories to the facts of the world. The need to give a formal account of truth arose because of the liar paradox involved in the concept of truth. But we don't have parallel problems identified in the concept of truth-likeness. As result it is not necessary to have a formal account of truth-likeness and the lack of it doesn't have any implication on the clarity and role of truth-likeness in sifting the relative correspondence of different scientific theories to the world.

For me, science is not in the business of developing perfect theories that exactly match the world state of affairs; rather it works with idealized constructs and approximate descriptions that work within certain margin of error.[38] And usually the idealized accounts of the existing world do indicate the degree of simplification involved in their formulations. As such truth-likeness is "an intuitive concept" of working science that measures the fit between scientific theories and the state of affairs they describe. truth-likeness is "an approximate fittingness*:* a description, statement, law, theory are truth-like if and only if there are respects and degrees to which they fit with the facts."[39] Accordingly, a theory is truth like if it succeeds to significant extent to accurately describe the entities and the phenomena it takes as a target. Furthermore, false theories have differing degree of approximation to events and entities they purport. Of these, theories which better fit and approximate the target entities at least under certain limiting circumstances compared to other theories are more truth-like than others. As such explicating the relative accuracy or approximation of false theories to entities and to events of the world by

[37] Psillos, *Scientific Realism,* 268

[38] Psillos, *Scientific Realism,* 266
[39] Psillos, *Scientific Realism, 267*

unraveling the conditions under which they fit to the world is what amounts to capture their truth-likeness.

Thus, I have established that there are enough formal and intuitive accounts of truth-likeness for scientific realism to rely on it.

2.3.2 Reference

In scientific realism the other central concept is reference. That is, the terms in truth-like scientific theories do refer to things in the world. It is to say there are kinds of entities with their attributes and causal power in the world as described by a scientific theory. In philosophy of language there are different accounts of how terms or linguistic symbols succeed in referring to things in the world. Each theory of reference has different implication for scientific realism and most scientific realists have preference to a certain kind of theory of reference as the most suitable to the project of scientific realism. I will show that for scientific realism I will defend causal-descriptive theory of reference is the best candidate.

According to descriptive theory of reference terms are description of the things they stand for.[40] That is, referring terms are concepts that contain the central attributable features of their referent objects. Accordingly the concept of the reference terms that is given by the descriptive features of things can be a singular attribute or a cluster of attributes. In the latter case there are more than one descriptive feature contained by the reference and each has differential centrality to the reference fixing task of the terms. But that nature of ordinary language is such that it is difficult to demarcate which descriptive features of those are essential and which of those aren't. To take an example the term Plato can be thought to succeed in referring to the human being Plato by the definite description of "the student of Socrates and the writer of Socratic dialogues". As such the concept of the proper name Plato will be transparent to every competent member of the linguistic community and this will be the above conjunctive description. Powerful Objections arose that led to decline of descriptive theory of reference. Chief among them is that someone who has no knowledge that Plato is the student of Socrates and writer of Socratic dialogues can still succeed in referring to Plato using the proper name Plato. That is, it is not analytic relation that holds between the referring term and the definite descriptions. One can know what the

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[40] Rod Bertolet, "Philosophy of Language", in *Routledge Companion Philosophy of Science*, 2nd ed. eds. Stathis Psillos and Martin Curd, (New York: Routledge, 2013), 48

refereeing term referent object is without any corresponding knowledge of descriptive features that were claimed as the concept of the reference. The motivators of the above objection presented causal-historical theory of reference.

According to causal-historical theory of reference term refer to objects by mechanism of causal and historical nature.[41] It starts when an object is dubbed with a term by the linguistic community or subset of that community through ostension refer to the object. And through the historical chain of use and communication of the term latter day users succeed in referring to the object using that term. That is, there is traceable historical link to the originally established causal link between the reference term and referent object which was achieved by the act of dubbing or ostension. The term Plato came to refer to the Greek philosopher Plato when his parents or other caregivers named him Plato and use such term to refer to him and when others including present day speakers follow their suit. In addition in causal- historical theory of reference what the referring objects are not analytic or fixed definite description; rather what the referent objects are left to empirical inquiry. While reference terms fix their referents through the causal-historical link, their suitable descriptive content are satisfied by a posterior investigation into the essential properties of that entity.

However, it is my view that the descriptive theory of reference is not fitting to the thesis of scientific realism.[42] Its fixed singular or cluster of descriptions as concepts of a term that refer to objects make it difficult how changing and evolving account of entities posited by scientific theories achieve continuity in their reference. That is, different scientific theories ascribe different descriptive features to objects; and formulation of reference as definite description raises an insoluble problem to the claim of referential stability in face of changing scientific theories. As result it makes itself vulnerable to the thesis of incommensurability of reference terms across scientific theories. And this threatens scientific realism claim of continuity of scientific terms between past, present and future truth-like scientific theories.

To me, causal- historical theory of reference is more promising.[43] Accordingly, reference terms can sustainably fix their referents despite the evolving nature of the descriptive account of

[41] *Bertolet, "*Philosophy of Language", 50
[42] Psillos, *Scientific Realism,* 272
[43], Boyd, "On The Current Status of The Issue of Scientific Realism",68

their referents as scientific theories change. This is enabled because of the original ostensive dubbing and the subsequent unbroken historical links to it. A referent or an object is named with such and such reference term and this linguistic event is maintained through threads of use that preserve the reference term to the named object. However, the descriptive features or content of the referents changes, the referential relation between a scientific term and the referent object remain fixed. And to scientific realism casual-historical theory of reference delivers the formers promise that there is a substantial referential continuity among successful truth-like scientific theories.

However, I believe that the causal-historical theory of reference is adequate to observational entities and their reference terms but not to the microscopic entities and their corresponding reference terms.[44] That is, non-observational terms are inseparable from descriptive account that is given by the scientific theory. Furthermore there is no observable entity that is independently available to the initial referential dubbing event as claimed by causal-historical theory of reference. What is available is a theoretical entity that is defined with set of descriptions provided by a scientific theory and it is taken as responsible for certain kinds of observable phenomena and causal effects. He argued that unobservable entities which are at the heart of scientific realism debate are dependent on a scientific theory that gives them their descriptive content to establish referential relation with their refereeing terms. As result ostensive dubbing is not sufficient to fix reference in non-observational world. In what he called causal-descriptive theory of reference a reference term have certain kinds of descriptive features as given by a scientific theory. It has causal origin when a referent entity of the above kind or properties is taken to be the offending entity to the observed phenomena and effects. That is, the theoretical entity is the cause or origin of the phenomena under the study and it is so because it has kind of causal powers and properties attributed to it. As result referring terms of theoretical entities are both descriptive and causal in nature.

In my view, causal- historical accounts of reference needs to be modified into causal-descriptive theory of reference, since it clearly establishes the case of referential continuity from the case of failed referential continuity.[45] In causal-historical account reference terms seems to

[44] Psillos, *Scientific Realism,* 279
[45] Psillos, *Scientific Realism,* 280

always succeed in referring to entities. Regardless of how divergent successive scientific theories are the reference terms remain fixed in the latter account due to lack any descriptive content and historical network of causal linkage nature of reference. In particular in unobservable entities where ostensive dubbing is unavailable and their terms are intimately tangled with theory, it becomes mysteries how referential continuity is established. The only discernable continuity in such cases is the observed phenomena and causal effect that is need of an explanation. But this doesn't give us if there is continuity between referent entities of successive scientific theories that do the explaining. As result a common aim between different scientific theories to explain phenomena doesn't assure referential and ontological continuity among them. On causal-descriptive account two successive theories do have referential continuity if and only if there is a substantial shared similarity in the referents of the two theories constitutive descriptive features. And these attributed properties of the referents are primarily responsible for the observed phenomena and its effect. If there is not any overlap of the relevant core properties of the referents in the two successive scientific theories then there no continuity of reference between the two theories. On this ground causal-historical theories of reference is needed to be amended by descriptive theory of reference at least for non-observational terms in order to establish what they are and clearly ascertain if there is referential continuity across the terms of scientific theories. I will assume in this thesis the causal-descriptive account for reference of scientific terms.

Chapter Three

Threats to Scientific Realism

3.1 Underdetermination of Theory by Data and its Different Shades

Underdetermination of theory by data (the short form, underdetermination will be used interchangeably) is one of the main ideas that push against scientific realism.[46] Underdetermination says that there are more than one scientific theories that are inconsistent with each other but have the same observational consequences. That is, it is not just one scientific theory that fit or entails same empirical evidence; rather there is more than one, perhaps unlimited number of scientific theories, that confirm to the evidence. The presence of contradictory scientific theories that are consistent with given experimental or observational evidence leads to the conclusion of the impotence of evidence in scientific theory choice. And it entails that evidence by itself cannot constrain which scientific theory to choose. Consequently, it undermines the scientific realism idea that the scientific entities and their relation are true description of the world. Since the entities of contradictory scientific theories have the same observational evidence, then it begs the question as to why we privilege one theory's entities as mirroring the world ontological features while rejecting the other's entities as false. There are a variety of underdetermination theses. Holist underdetermination, transient underdetermination, and equivalent underdetermination are the most salient kinds of underdetermination.[47]

Pierre Duhem brought the underdetermination thesis in the context of physical theories in early 20th century.[48] He argued that physical theories have a particular problem compared to biological or chemical theories. That is, in physics contrary to the former subjects, it is difficult to separate physical theories and laboratory settings that test them. In use of thermometer or galvanometer to measure a physical hypothesis, it is taken for granted the background physical theories that are involved the construction and working of these instruments. When a physical theory is in doubt and a physicist wants to know if the theory is true, he proceeds to test it. He

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[46]Anjan Chakravartty "Scientific Realism", *The Stanford Encyclopedia of Philosophy* (Summer 2017 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/sum2017/entries/scientific-realism/Accessed March 25, 2024/

[47] Margaret Greta Turnbull, "Underdetermination in science: What it is and why we should care", *Philosophy Compass,* 2018, *3, 2(2018):e12475*

[48] Pierre Duhem, *The Aim and Structure of Scientific of Physical Theory,(*Princeton*:* Princeton University Press,1954), 180

does so by inferring the observational consequences of the theory and arranges the test conditions or procedures for it. These procedures will indicate whether the observational consequence of the theory is detected or not. The theorist then concludes his theory is true. But Duhem argued that things are far complicated than the above. A scientific theory is not tested and cannot be tested just in its own. That is, an experimental test cannot separate a single scientific theory from whole sets of scientific theories and test only that theory. When the predicted observational consequence of a theory is tested large collection background scientific theories are assumed. And they are accepted as true. But when the observational consequences turn out to be false the contradicting evidence points to the whole system of these accepted theories rather than just the single hypothesis under investigation. As such the negative experimental result doesn't tell us where the error lies from the whole chain of theories. It only points that there is one false theory or hypothesis among the many intertwined scientific theories and hypothesises.

The conclusion that it is just the hypothesis under test which is false isn't a result logical assessment of above holist predicament of scientific theories.[49] For example in newton corpuscular theory of light, light is made of tiny corpuscular particles. These particles have different velocity when they travel through different mediums. In this, Newton asserted that the refraction index of light from one medium to another is determined by the ratio of its velocity in the latter medium to its velocity the former medium. One observational consequence of such theory is that light travels faster in water compared to in air. But Foucault tested the last hypothesis and found that light travels faster in air compared to in water. Now what is contradicted isn't only the last prediction of the Newtonian emission theory of light. On the contrary it is the whole chain of propositions that are in the theory. As such one can modify the other background assumptions including the core corpuscular thesis of light in order to adjust to the contradictory experimental evidence presented by Foucault. But the evidence by itself is impotent to tell us where the mistaken belief lies in the emission web of propositions. And decidedly the experimental evidence doesn't inform us whether to reject or to amend the whole corpuscular theory of light. Thus he concludes:

> *The physicist can never subject an isolated hypothesis to experimental test, but only a whole group of hypotheses; when the experiment is in disagreement with his predictions,*

[49] Duhem, *The Aim and Structure of Scientific of Physical Theory,*186

what he learns is that at least one of the hypotheses constituting this group is unacceptable and ought to be modified; but the experiment does not designate which one should be changed.[50]

In physics experiment isn't fundamental event that can dictate to accept or reject a theory.[51] While experimental testing of a hypothesis is taken to resemble mathematical argument of reduction absurdum, in reality the two methods of reasoning in the two fields are quite different. In mathematics the demonstration of the absurdity of a certain claim makes inevitable its contradictory claim to be true. But in physics when experiment is set up to test between two theories the experimental result doesn't just bear on the single predicted hypothesises of the two theories. On the contrary, it bears on the two competing theories whole propositions. However, these webs of scientific propositions are not themselves tested in isolation. Furthermore the current presence of just two competing theories to get confirmation from an experiment don't the rule out the presence a third or a fourth group of theories that can be compatible with the experimental evidence. Unlike the mathematical reduction absurdum argument, the experiment doesn't force us or show us to accept only one of them. In order for experiment or observational evidence to have equal strength to the reduction absurdum argument, it is first needs to establish the uncountable number of system of theories that can fit the experimental result. Then show how the evidence bears on the whole web of each scientific theory. Thus experimental evidence is not just comparison of two hypotheses but the whole propositions of theories and not all the theories that can fit the experimental data are tested at the time of testing. All of the above points show us that how an experiment is unlike reduction absurdum argument where there are only two choices.

When a web of theory faces an experimental result then mostly the theory's particular proposition will be modified.[52] But the process of modification will leave core components of the theory intact. The reason for this fact is that in certain era there will always background theories or components of theories that are taken as facts. Without any logical necessity the burden modification falls only on the certain propositions that are peripheral to the accepted core theory propositions. In addition when a theoretical model that describes observational phenomena is

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[50] Duhem, The Aim & Structure , 187
[51] Duhem, The Aim & Structure , 188
[52] Duhem, The Aim & Structure , 211

found less than accurate pragmatic factors like the cost of rejecting a whole theory are given priority. As such the default responses will be modification of theory in order to better fit or predict the phenomena. Dramatic changes in history of science tend to occur when core assumption of scientific theories are modified or replaced which were taken for granted for centuries. Accordingly a contradicting experimental evidence on theory leaves it open which part or propositions of a theory to modify and to reject. And the consideration that goes into the process of modification or rejection of some components of a theory is not guided by logically necessary implication of the evidence.

Quine presented more forcefully the holist predicament of not just theories of physics but all scientific theories and propositions of day to day language.[53] He criticised the empiricist and logical empiricists' criteria of meaning. Their idea that meaning of scientific a term or a statement is equivalent to it's the empirically available perceptual events or qualities are erroneous. On the contrary, it is the case that only theories of science, as one intertwined arc, are the appropriate candidate for meaning that can pass the above empirical test. All sciences whether it is physics or biology or mathematics or chemistry depend on empirical experiences at their margin. That is, the emergence conflicting evidence on a scientific theory leads to modification of some components of that scientific theory or other branches of science which are intimately linked with the above theory. This process of modification usually spares the core or background theories including logical rules of statements that are taken for granted or assumed as true. But modifying the laws of logic and mathematics is one of the available linked candidates with the scientific theory under investigation that can make the conflicting evidence compatible with theory. Quine reminds us that the proposal to reject the millennial old the law of the excluded middle to solve the contradiction in quantum mechanics.

While such extreme modifications are usually are not brought to the table, the reasons for doing so are only pragmatic reasons like the ones presented by Duhem.[54] But logical rules and other background scientific theories that are the inner core part of the whole web of all of science escape the process of modification precisely for they are central assumption of our scientific knowledge and epistemology. And the typically rejected empirical consequences of scientific

[53] W. V. Quine, " Two Dogmas of Empiricism", *The Philosophical Review* 60, 1(1951), 35
[54] Quine, " Two Dogmas of Empiricism", 43

theories are the marginal sections, whose cost of rejection is minimal, to the whole web of science. What this shows is that what do in the event of contradictory empirical evidence is undetermined by it. As result there are no fast and hard rules that apply to all science as to which sections of scientific theories to revaluate in the face of conflicting consequences. Thus web of scientific theories confront evidence as one whole and they are underdetermined by it.

Andre Kukla presented another dimension of underdetermination argument that challenges scientific realism.[55] He argued that if the only factors that are considered to decide the acceptance or rejection of scientific theories are the level of their empirical support, the underdetermination argument threats loom large over scientific realism. That is, it is possible to construct algorithms that produce finite or infinite number of empirically equally supported scientific theories to any scientific theory. If this is a case, then theory choice between scientific theories is a vagarious process and antirealism wins.

One algorithmic example is that for every scientific theory S there is another scientific theory S' that has same observational prediction as S but contradicts S. [56] That is, S' says S observational statements or predictions are true but S itself is false. These two scientific theories are empirically equivalent yet they are inconsistent with each other. For example, taking intentional states of minds as fundamental entities in prediction of human behaviour has been hugely empirically fruitful. However, the competing physicalism thesis that argues biological states are the fundamental causal entities has same observational statements as the former. Yet physicalism argues that intentional psychology is false. Another algorithm is that for any scientific theory S there is an independent theory S'. And during empirical observation events proceed as predicted by theory by S but the world behaves as predicted by S' in the intervals where there is no observation taking place. Furthermore theory S' contradicts theory S. These two theories are empirically indistinguishable yet they are inconsistent with each other on events of the world that take place during non-observation. S' theory behaves in different way from S because according to S' theory the world is governed by creatures who use mechanical machines for its continual functioning. When these machines turn off for various reasons, the laws of S fail to hold but not S' laws. Quantum mechanics is one primary example where the event observation

[55] Andre Kukla, Does Every Theory Have Empirically Equivalent Rivals?, Erkenntnis (1975-), 44, 2 (1996), 139
[56] Kukla, Does Every Theory Have Empirically Equivalent Rivals, 140

or its lack seems to play a central as to what happens in the world. Once again another kind of empirical indistinguishable scientific theory S'_1 to S is that in S'_1 the empirically observed events are results of alteration and modification on the events and perceptual faculties of the observers. While theory S'_1has different causal process and ontological commitment empirically it is equivalent to the traditional empirical scientific theory S.

According to the proponents of equivalent underdetermination, the foregoing arguments show that there are empirically equivalent alternatives to established scientific theories.[57] And they add that from this, it is possible to construct without limit a conjunction of the alternative scientific theory and some other non- observational statement that have identical empirical consequence. That is, the conjunct hypothetical statement can be filled with entities that have no casual connection and no empirical consequence. So the conjunctive between the alternative scientific theory and the latter will have same observational prediction to the previous scientific theory. Hence every scientific theory has unlimited number of empirically equivalent alternatives and as result it is empirically undetermined.

The third kind of underdetermination that is presented against scientific realism is recurrent transient underdetermination.[58] Recurrent transient underdetermination is tied with what is called "unconceived alternatives". Unconceived alternatives are scientific theories that are well supported or confirmed by evidence but they are yet to be formulated as a candidate scientific theory. Accordingly, there are alternative scientific theories that have not been thought up by the scientific community up to now but are well confirmed by the body of evidence that is given to support priorly accepted scientific theory. And he argued that the history of science is permeated with scenarios that exemplify recurrent transient underdetermination. That is, there is a repeated experience across the whole science in all of which there were scientific theories that had robust confirmation but were no presented or thought as alternative until latter time. Despite such shortcoming in the imagination of scientists, there were other alternative scientific theories which were well confirmed to then available body evidence. Furthermore, the evidence from history of science show us that in past although it seemed the available evidence support only couple or so scientific theories, latter it is discovered that the previous evidence also confirms

[57] Kukla, Does Every Theory Have Empirically Equivalent Rivals,162
[58] Kyle Stanford, Exceeding Our Grasp: Science, History, and the Problem of Unconceived Alternatives, (Oxford: Oxford University Press, 2006), 17

other scientific theories that were not formulated at the prior time. And these latter alternative theories remain obscure to us until they are discovered as result of varied pushing factors. For example unconceived later day theories of heredity like Mendelian genetics and contemporary molecular genetics are well confirmed by the same evidence with which the germ-plasma theory of inheritance was confirmed at the earlier times. Stanford gave many similar examples from different branches of science like the above where subsequently formulated scientific theories gained robust confirmation by the same evidence that was used to support earlier scientific theories.

Therefore, there is a recurrence of underdetermination to a body of evidence across time as the number of well confirmed scientific theory increases across time.[59] It is because such occurrences it is called recurrent transient underdetermination. The underdetermination of this kind is not dependent on which type of confirmation theory that is taken to be the appropriate to gauge the relation between evidence and theory. However, Stanford concedes that recurrent transient underdetermination from unconceived alternative theories is modest, empirical and inductive claim that argues from the factual history of science rather than deductive formal proof as it was argued from equivalent underdetermination. But recurrent transient underdetermination is more serious challenge since it shows us how there will be unimagined yet well confirmed future alternatives to our current best scientific theories. That is, since there have been many and varied later time discovered and well confirmed scientific theories which were earlier not thought up by the scientific community, there will be currently unconceived comparably confirmed scientific theories to our presently accepted best scientific theories.

3.2 Pessimistic Meta-induction

Pessimistic meta-induction (pessimistic induction will be used interchangeably) is an inductive argument against scientific realism developed by inquiring into the history of science.[60] Accordingly, the history of science shows us that there were a plethora of past scientific theories that were successful in explaining and in predicting phenomena. But these theories currently are rejected as false theories. They argue that recurrent change of the dominant and the accepted scientific in every major branch of sciences is a remarkable

[59] Stanford, *EOG*, 22
[60] K. Brad Wray, " Pessimistic Inductions: Four Varieties", *International Studies in the Philosophy of Science*, 29,1(2015), 61

feature for a discipline that purports to hold truth at any period of time. And the ground for such frequent overhaul is that previously successful theories that were accepted as true are deemed false after sometime. Springing from this fact, they conclude that most of the current best scientific theories for which we inferred truth from their empirical success will likely face the same fate of those past theories sometime in the future. As a result, it is argued that there is a strong probability that our current best scientific theories will be rejected as false theories. Thus, it is wrong to conclude from the success of current scientific theories their truth and the record of science itself is a giant inductive witness.

Larry Laudan challenged scientific realism by looking into the relationship between referentiality and truth of scientific theories on one hand and the success of scientific theories on other hand.[61] In addition, he inquired whether successive scientific theories do in fact to preserve earlier successful theories ontology. He did these by looking into the history of science itself.

The first line of argument from scientific realism was that the success of science points us towards referring scientific theories.[62] That is, if scientific theories are successful in explanation and prediction then that will give us reasonable credence to take them as referring theories. Laudan pushed against such claim by providing a series of examples from history of science. Accordingly, there were a myriad of scientific theories in the past that were hugely successful in their explanatory power and prediction but are thought now as completely non-referring scientific theories. Despite their current status as exemplars of non-reference, in the past they were taken to be successful in every measure of a scientific theory's success.

He lists several past scientific theories that were seen as prime example of scientific theory success but are now discredited as non-referring theories.[63] These were:

- *the crystalline spheres of ancient and medieval astronomy*
- *the humoral theory of medicine*
- *the effluvial theory of static electricity*
- *'catastrophist' geology,(Noachian) deluge*

[61] Larry Laudan," A Confutation of Convergent Realism", *Philosophy of Science* 48, 1 (1981),21
[62] Laudan, ACCR, 22
[63] Laudan, ACCR,33

- *the phlogiston theory of chemistry*
- *the caloric theory of heat*
- *the vibratory theory of heat*
- *the vital force theories of physiology*
- *the electromagnetic aether*
- *the optical aether*
- *the theory of circular inertia*
- *theories of spontaneous generation*[64]

To him what these examples elucidate is that the success of scientific theories is not an adequate ground for the taking the entities of scientific theory to be referential.[65] Furthermore he argued that having a successful of scientific theory might be thought to give us a reason to some but not to all entities of the scientific theories to be referential. But this face saving argument by a scientific realist is not sustainable because of the holistic nature of scientific theories and its incompatiablity with convergence thesis of scientific realism. That is, separating a successful scientific theory's entities into referring and non-referring ignores the fact that theory get confirmation and support from evidence as a whole not in isolation for each entities. As a result, it is impossible to separate the composite of scientific theory into referring and non-referring parts. Secondly, if the normative and descriptive assertion that successive scientific theories should preserve and do reserve the entities of successful past scientific theories, then it becomes difficult to ascertain whether later theories do in fact reserve the entities of past theories. That is, if it is only some entities of a scientific theory that are referential then it becomes ambiguous to sort whether they are preserved in latter scientific theories or not.

In addition for him, the history of science is also full of scientific theories that are currently seen as referential but were unsuccessful for centuries.[66] That is, atomic theory, kinetic theory and Wegenerian theory of geology are scientific theories that are currently seen as referential but they were taken be unsuccessful in their explanation and prediction in

[64] Laudan, ACCR,33
[65] Laudan, ACCR, 34
[66] Laudan, ACCR, 25

the past. These pieces of evidence from history of science demonstrate that reference is not sufficient for the success of scientific theory. As such the referential success of a scientific theory doesn't guarantee its empirical success. The consequence of such predicament for scientific realism is that it renders the referential status of a scientific theory's entities as superfluous for its empirical success. Thus, the history of science is full of scientific theories that were successful but are non-referring and were unsuccessful but are referring. Furthermore, history of science demonstrates that there is no necessary or sufficient logical relation between reference and success of a scientific theory.

The second line of Laudan's attack was that unravelling the presumed link between successful scientific theories and their truth-likeness.[67] To take a scientific theory as true/ truth-like, there must be entities in the world as described by the scientific theory. That is. The scientific theory terms must refer to the things. As such reference is a necessary perquisite for the notion of truth/truth-likeness to be exhibited by scientific theories. But as we have shown in preceding pages, the success of a scientific theory gives us no reasonable ground to take that theory as referring theory. Consequently appealing to the notion of approximate truth is non-starter without overcoming the fact of a plethora of non-referring but successful past scientific theories. Furthermore the truth-likeness has no direct bearing whether that theory can achieve adequate level of empirical success. That is, as referential success didn't guarantee empirical success, the truth of a scientific theory doesn't entail its explanatory and predictive success as well.

The other core dimension of scientific realism isn't backed by the record of science as well. [68] The convergence thesis is that successive scientific theories on the whole do preserve the entities and the working mechanisms of preceding successful theories and scientists do and should engage in such endeavours. That is, since previously successful scientific theories are approximately true and referential then the normative claim of scientific realism is that scientific theories should strive to keep the entities and law of the earlier theories in their new supplanting theory. And the descriptive claim is that as fact of the matter scientists do develop new theories that keep the most of the entities and posited process of the preceding

[67] Laudan, ACCR, 32
[68] Laudan, ACCR, 36

successful theories. In addition it is argued the history of science proves both claims right. Contrary to such claim the record of science is full scientific theories that do not preserve the ontologies of successful earlier counterparts and scientists do not strive to keep the past successful theories. Statistical mechanics did not preserve thermodynamics; Newtonian mechanics did not preserve Cartesian mechanics; modern genetics did not preserve Darwinian pangenesis and the list goes on.

More technically conception of preservation or retention is the notion of limiting case.[69] An earlier scientific theory is a limiting case of a successor theory only when the entities and laws of the former are found in the later scientific theory. On such account the retention of few entities and some laws of an earlier theory doesn't qualify to say that it is a limiting case of the later scientific theory. That is, when the later theory fails to preserve some entities of the earlier theory then it also fails to retain the causal process and natural laws that involve the discarded entities. For example aether theory of classical mechanics which are sometimes presented as limiting case of relativistic quantum mechanics, has ontology (aether) and laws governing the interaction of aether and objects that is not recognized by the supplanting relativistic mechanics. Such consequences are typically a result of the supplanting novel scientific theories ontology tends to be radically different than their preceding counter parts. If as scientific realists argue that limiting case should be followed and is followed development of novel theories with novel ontology would have been impossible. As shown with above counter examples science is permeated by scientific theories that don't observe the convergence dictum or contradict its' purported description. Furthermore unless an explicit and large scale evidence of preservation of earlier theories by the later ones is presented then prima facie the convergence thesis of scientific realist is, thus, defeated.

Lyons construed the above Laudan argument as deductive modus tollens rather than an inductive argument.[70] As such he argued that what Laudan did is to undermine the justificatory link between the success of scientific theory and the explanation that it's truth

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[69] Laudan, ACCR, 39

[70] Timothy D. Lyons, "Scientific Realism and the Pessimistic Meta Modus-Tollens", in *Recent Themes in Philosophy of Science: Scientific Realism and Common Sense*, Eds. Steve Clark & Timothy D. Lyons,(Springer, 2002), 63

being the only reason. As result the historical examples given by Laudan were counter examples in which the theories were successful but not true. This predicament undermines Putnam's and Boyd's idea that it would be utterly mysterious if a theory was successful but not true and truth is the only adequate explanation for their success. The historical counter examples showed that there were scientific theories for which truth isn't the reason that can be given for their explanatory and predictive success. Accordingly, the formulated modus tollens is that:

> If scientific realism is true, successful scientific theories will be true
> There are successful scientific theories that were false, as given by Laudan
> Therefore scientist realism is false.

Lyons held that the above deductive argument is true even when we narrow the notion of success to novel success.[71] That is, it holds even when we limit that a scientific theory is successful only when it predicts an empirical phenomenon that is not known at the time the scientific theory is formulated. Again the history of science gives us counter examples of scientific theories that predicted novel phenomena but are themselves false. And this furthermore undermines the place of the truth of a scientific theory in its novel predictive success. As a result, modifying the parameter of scientific theory success to novel success to make inevitable the truth of scientific theory fails. To illustrate his point, he gave new lists of scientific theories each of which predicted a novel scientific phenomenon though they were false.

- *The Original (pre-inflationary) Big Bang Theory*
- *Dirac's Relativistic Wave Equation*
- *Bohr's 1913 Theory of the Atom*
- *Mendeleev's Periodic Law*
- *Phlogiston Theory*
- *Kekule's Theory of the Benzene Molecule*
- *Caloric Theory*

[71] Lyons, Scientific Realism and the Pessimistic Meta Modus-Tollens", 69

- *Dalton's Atomic Theory*
- *Maxwell's Ether Theory*[72]

In addition to above list Peter Vickers added other new false scientific theories that also gave startling novel prediction which is thought to bury the idea that the success of a scientific theory has any significant relationship with the truth of scientific theory.[73] An aether theory of electron that predicted fluctuating mass before advent of general relativity; Velikovsky eccentric theory of solar system accurately predicted the surface temperature of Venus; early 20th century Bohr's atomic structure model successfully predicted the spectral lines of ionized helium; and Kirchhoff's diffraction formula predicted the propagation of light through small apertures successfully. These are only partial list of what is presented by Vickers.

Therefore, it is argued that the deductively constructed historical evidences against scientific realism have the advantage over the inductive historical pessimistic arguments. The main reason is that the modus tollens is not vulnerable to objections of inductive strength and relevance that tend to be raised against the latter.[74]

Contrary to the above kind of inductive pessimism which Samuel Ruhmkorff called "global pessimistic meta-induction"; there is what he calls "local pessimistic meta-induction" that has more merit.[75] It refers to kind of pessimistic induction that is grounded in particularly scientific field track record and it is more potent form of inductive rebuttal against scientific realism. Local pessimism makes inductive generalization about the prospect of the currently accepted theories rejection in the future within that particular field from the history of previous theories in its area.

He took the finding by medical researcher that reported the most cited papers published in the most reputable journals of the field reported findings that were subsequently either rejected or the purported result were found to be much smaller.[76] The published papers were pioneering researches that were done with contemporary standard statistical methodologies within the

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[72] Lyons, Scientific Realism and the Pessimistic Meta Modus-Tollens",70
[73] Peter Vickers, A Confrontation of Convergent Realism, *Philosophy of Science*, 80, 2 (2013),191
[74] Lyons, Scientific Realism and the Pessimistic Meta Modus-Tollens", 65
[75] Samuel Ruhmkorff, "Global and Local Pessimistic Metainductions", *International Studies in the Philosophy of Science,* 27, 4(2013),409
[76] Ruhmkorff, "Global and Local Pessimistic Metainductions",418

period of 1990- 2003. Such process of identification of scientific finding and papers on clear parameter of citation, publication in most reputable journals and being pioneering research on the subject makes it is clear on what ground the scientific papers were selected. And this has significant advantage over global pessimism fueling historical evidences, since proponents of the latter are accused of cherry pecking past scientific theories for their convince. As shown, 41% percent these medical research findings were refuted by later researches or found the previous to be much inflated. Thus, the inductive generalization is that similar proportion of currently accepted medical scientific findings will be rejected in the future for exact same reasons. That is, they will be found either false or exaggerated by future medical researches. Due to this predicament scientific realism wouldn't be the fitting attitude towards medical researches of the above kind.

In my direct answer to pessimistic meta-induction which will be presented in the next chapter will focus primarily on the inductive and global form of the pessimistic induction. The main reason is that the deductively formulated historical counter examples against the necessary and sufficient relationship between successful of scientific theories and scientific realism can be easily undermined. That is, in my view the relationship between successful scientific theories and their approximate truth is better explicated through inductive and abductive means. As a result the presence cases of historical counter examples don't tell us much about the degree of credence we should have about the truth of a successful scientific theory. On other hand the local form of pessimistic induction while it is more potent form attack about realism in particular area of science it bears little on the general philosophical position of scientific realism. That is, it doesn't tell me if I am justified in my scientific realism towards all scientific subjects' successful scientific theories. Therefore, my focus will be on adequately responding to the inductive pessimistic generalization about successful scientific theories and their truth.

Chapter Four

Solution one: Scientific Realism Response to Underdetermination and Pessimistic induction

4.1 Scientific Realism Answer to Underdetermination

In my view, there are least two kinds of underdetermination each of which has fundamentally different implication for scientific realism.[77] The first kind of underdetermination is more or less an established fact about the relationship between evidence and theories. That is, it is true that for any given set of empirical data there is more than one numbers of inconsistent theories that can entail that set of data. Deductive relation between a body of evidence and a theory are not competent enough to choose a single scientific theory that has the most fitting relation with the evidence. Furthermore, the apparatus of deductive logic is impotent to filter out the myriad scientific theories that entail the evidence. As a result, there are always more than one contradictory scientific theories that are deductively compatible with a body of evidence. This much is undeniable.

However, this kind of underdetermination doesn't tell us the place of non-deductive methods in regulating and sorting out the rival scientific theories to given set of data.[78] As such, if there are non-deductive methods of regulating theory and evidence relation in way that avoids the aforementioned pitfalls of deductive methods, then it is the shortcoming of deductive method that is the culprit for the underdetermination of the above kind. And there are non-deductive methods that differentiate different scientific theories that entail a given set of evidence. Using the non-deductive methods, I will show that inconsistent scientific theories garner a differential level of support from the same evidence. Thus, although they all are deductively compatible with the evidence, the theories have unequal level support from the evidence.

In my view, the second kind and the more extreme form of underdetermination is holist underdetermination that implies all theories can equally stand tall regardless of the evidence.[79] Holist proponent of underdetermination argued that theories faces experiment in group. And

[77] Larry Laudan, "Demystifying underdetermination", In *Scientific Theories*, Ed. C. Wade Savage, (Minnesota: University of Minnesota Press, 1990), 267-97.
[78] Laudan, "Demystifying underdetermination", 267-97
[79] Laudan, "Demystifying underdetermination", 267-97

when there is contradicting evidence to such theories it doesn't tell us where the error lies in the web of the theories. Furthermore by changing certain auxiliary portions of the system of theories, it can be made to fit the evidence. Because of such fact, theory choice is underdetermined. But to say that a system of theory can be held and made to fit the previously contradicting evidence means either it can be made compatible with the evidence or it can be made to entail the evidence. In addition it implies that it is rational to persevere to maintain a web of theory whatever the scale of the recalcitrant evidence and the severity of artificial modification within it in order to make the theory compatible or entail the evidence.

However, I argue that in addition to the compatibility and entailment relation between evidence and theory there are relation of explanation and support or confirmation.[80] Both of the latter are distinct from the former two that are contained in holist account of underdetermination. To make a theory compatible with or entail the evidence doesn't tell us anything about its explanatory power to the evidence or the strength of confirmation of the scientific theory by the evidence. Thus the indefinite modification of a system of scientific theory in the face of conflicting evidence might succeed in making the theory compatible or entail the evidence. However, it doesn't preserve or improve the explanatory scope and the empirical support the previously unmodified theory enjoyed. And the holist didn't argue if it is rational to continue to hold a scientific theory at the price of explanatory scope or strength of empirical confirmation. To me, the implication of such claim would be every system of theory will have a comparable degree of confirmation from a given body of evidence. That is, every system of theory has an equal epistemic footing as any other system. Yet other than the claim that any system of theory can be made compatible or entail a given evidence, there is no any other sustained argument in favour of any system of theory can have and continue to have equal confirmation by a body evidence compared to other systems of theories.

Despite such formulation of extreme underdetermination, in my view, proponents of holist underdetermination did not interrogate if methods beyond deductive compatibility can constrain theory choice.[81] That is, they failed to give us an account, if the same kind of extreme underdetermination that imply epistemic relativism can be sustained in the face of inductive

[80] Laudan, "Demystifying underdetermination", 267-97
[81] Laudan, "Demystifying underdetermination", 267-97

methods of theory choice. I argue that the use of inductive methods of confirmation will reveal that competing contrary theories that entail or compatible with the body of evidence have different degree of support from that evidence. As such it is not just enough to claim underdetermination based on compatibility or entailment of theory and evidence, rather it needs to be shown that the inductive methods fail to discriminate theory choice as well. Even if there is more one system of theories that can get comparable degree of confirmation using the latter methods, it doesn't entail that every compatible theory or system of theory can get the same luck. As such there is no ground to pronounce the extreme form of underdetermination that doesn't privilege one system of theory from any other.

On other hand, in my appraisal, the inference of underdetermination from empirical equivalence of theories is untenable.[82] The main reason for it is that the notion of empirical equivalence between theories is not something that can be given an adequate account. Two theories were taken to be empirically equivalent if they have the same observational consequences. That is, regardless of their non-observational content and consequences, the two theories are empirically equivalent. This conception of empirical consequence is anchored by the notion observational and non-observational consequences. In addition it also needs the notion of auxiliary premises that are needed for the derivation of empirical consequences in conjunction with the core theory.

Accordingly, if the concept of empirical equivalence is going to be explicably in any way, it has to pass problems related with demarcation of terms into observational and non-observational terms (consequences).[83] It has to pass challenges related to the stability of auxiliary premises needed for derivation of empirical consequences as well. As shown in chapter one of this thesis, one of the main contributing factor for the rise of contemporary scientific realism was the collapse of the supposed differentiation of components of scientific theory into non-observational entities and observational phenomena or consequences. As shown by Maxwell, the progress of scientific instruments and new technologies are constantly increasing the content of the observable phenomena by making accessible events and entities that were previously deemed non-observational. Due to such fact there is no stable line that can be used to

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[82] Larry Laudan & Jarrett Leplin, "Empirical equivalence and underdetermination", *Journal of Philosophy,* 88, no. 9(1991):449

[83] Laudan &Leplin, "Empirical equivalence and Underdetermination",452

compare the empirical consequences of two theories and declare unequivocally their equivalent status.

On other hand in order to derive the observational consequences of a theory and do comparison for empirical equivalence, auxiliary premises (background assumptions) are needed as mediating link and as background knowledge. But background auxiliary assumptions are not again stable set of facts; rather they are in constant state of flux as the state of science changes. As result auxiliaries that were used to derive observational consequences of a theory might get rejected subsequently and derivation the observational consequences of the theory will get blocked. Or new auxiliary premise that is brought from development in other part of science might enable derivation of new observational consequences that were deemed non-observational parts of the theory. Because of these predicaments, the observational content of theories is unstable as it enlarges or shrinks depending on the new technological innovations that enable new observational entities or the changing status of the accepted auxiliary premises.

Although proponents of equivalent underdetermnation might respond with claim that empirically adequate instrumental theories versions of the ontologically committed scientific theories might overcome the above two objections, in my view, it is not a robust response.[84] That is, the empirically adequate theories might be empirically equivalent to their theoretical entities propounding counterparts. However, I argue that these kind of scientific theories are not genuinely competing and independent to the original scientific theories. On the contrary, they are dependent or parasite on the latter kind of theories to derive their empirical adequate consequences. Hence, they cannot be used establish the claim of underdetermination from the presence of empirically equivalent theories.

Even if empirical equivalence between two theories is achieved, it doesn't make difference on the epistemic status of the two theories.[85] The reason is that, as I pointed out earlier, empirically entailed consequences of a theory are not a necessary or sufficient condition for the strength of confirmation of a theory by empirical phenomena. As such two theories that are taken to be empirically equivalent might garner asymmetrical level of support from the observed consequences. On other hand, empirical phenomena that are not entailed consequence

[84] Laudan &Leplin, "Empirical equivalence and Underdetermination", 456
[85] Laudan &Leplin, "Empirical equivalence and Underdetermination",461

of a theory do support and accrue confirmation to a theory. At times, even empirical evidences that are analogical in nature do increase the epistemic warrant of a scientific theory. The lesson of the above arguments is that empirical evidences that are not consequences of a theory can increase the confirmation of theory and the empirical consequences of a theory might not increase the epistemic status of a scientific theory. As a result, it is a grave error to infer underdetermination among scientific theories based the purported claim of empirical equivalence which has no bearing on epistemic statues of the competing theories.

In my view, it is the residual legacy of logical empiricism that tied the content of scientific theories with their observational consequences. That is, the conflation of the epistemic status of rivalry scientific theories with their entailed empirical consequences and the inference of underdetermination based on the equivalent of the later status of theories is result of basing semantics as the Holy Grail of knowledge.[86] This trend emerged with rise of logical positivism who attempted to settle epistemic issues in various areas of human endeavours by semantic criteria of verifiability. And the subsequent philosophers of sciences followed the same strategies of solving epistemic problem by semantic procedures. Yet scientific theories increase their epistemic stature through various non-deductive methods that explicate the theories relation with evidence within which semantics plays little role if any. As such it is fallacious to base the equivalence two scientific theories only on the entailed empirical consequences and it is unwarranted inference to declare underdetermination of scientific theories based on such unsound premise.

In my view, Contrary to Duhem and Quine holist contention that it is impossible to isolate a hypothesis of a theory, it is possible to isolate a single hypothesis using Bootstrapping hypothesis testing.[87] If we are using Bootstrapping it is not true that test evidence accrues confirmation or rejection only to the whole theory as a unit. Rather, it is possible to test how evidence bears on single hypothesis of a theory. As a result the inference of underdetermination from purported holist theory of testing is defeasible. In Bootstrapping method of confirmation a particular body of evidence in combination with other hypothesises of a theory test only a particular hypothesis that is under scrutiny. That is, the evidence, which usually need to be from

[86] Laudan &Leplin, "Empirical equivalence and Underdetermination",468
[87] Clark Glymour, "Relevant Evidence", *Journal of Philosophy* 72, no. 14(1975): 408.

different sets of observations if it is going to be robust test, bears at that time of testing only on the single hypothesis of the theory while leaving other part of the theory intact. The observational evidence bears on the particular component of a theory while leaving the status of other components or hypothesises of the theory un-decidable based on it. When the observational evidence and the other hypothesises of the theory affirm the hypothesis under the inquiry, then the hypothesis is declared true given the theory. The other hypothesises of the theory in turn are tested in isolation by the combination of different set of observations and the theory's other hypothesises. Using such process, the status different propositions or hypothesises of the theory's with regard to evidence is tested. Because of this predicament some parts of the theory might get strong affirmation while other hypothesises of a theory might get rejection from varieties of observational evidences. The status and the strength of the whole theory confirmation is a result of the theory's hypothesises accruement based on separate empirical evidences that are in their favour. In doing so, a theory is able to test its own hypothesises in non-circular fashion on how it fairs with distinct set of evidences and to what degree it gets confirmed by those evidences.

To me, what is true about the holist program of theory and evidence relation is that hypothesis testing involves a whole lot more background/ parts/ of a theory rather than just a single hypothesis and an evidence.[88] But this doesn't mean theory faces acceptance or rejection from evidence only as whole. Furthermore, while in principle there might be two theories that are non-translatable with one another but are empirically indistinguishable, in the actual world of science, there are no two such cases. In addition developing genuinely distinct theories that have comparable degree of confirmation from the same set of evidence is not easily achievable task as theorists of underdetermination make out to be. It is because of this fact when they set out to formulate a rival theory , they will soon discover that their new theories either tend to parasitic on the old genuine theory or garners less empirical support compared to the old one.

In my view, the second main method that helps us to know which scientific hypothesis to reject in the face of disconfirming evidence is subjective Bayesian probabilistic inferences[89].[90]

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[88] Glymour,"Relevant Evidence", 424

[89] It is one of the main approaches to probability in which probabilities are degree of confidence or credence of a rational agent who obeys axioms of probability.

[90] Jon Dorling, "Bayesian Personalism, the Methodology of Scientific Research Programmes, and Duhem's Problem", *Studies in History and Philosophy of Science*, 10 no.3(1979):177

Such method will pre-emptively block will the prospect of holist underdetermination. With such method I can explicate the tendency of scientists not to be concerned about the central tents of an established scientific theory by occasional disconfirming instances on one hand and to see the confirmation instances or evidence in high regard is again explicable with Bayesian probabilistic framework.

So let's say S_1 and S_2 are two propositions of a scientific theory the conjunction of which entails experimental evidence, $E_{p.}$[91] And let E_{P1} be the actually observed evidence that contradicted $E_{p.}$ Now subjective Bayesian inference can help us discern which hypothesis to reject in light the disconfirming evidence E_{p1}. When formulated using the basic laws of probability calculus the above statements will be translated as:

$P(S_1 . S_2/ Ep) = 1$ and $P(S_1 . S_2/ E_{p1}) = 0$.

The next task is then to use the subjective Bayesian framework so that we can evaluate rival hypothesises that have better chance than the later conjunction. Let say that $\neg S_1$ be the set of the most reasonable alternative hypothesises to S_1 and contain S_1', S_1'', S_1''' and so forth. Then $P(S_2. \neg S1/E_{P1})$ can be evaluated since;

$P(\neg S_1) = P(S_1') + P(S_1'') + P(S_1''')$.

The determination of the relative likelihood of the alternative hypothesises in the face of disconfirming evidence like E_{p1} will enable us which hypothesis to reject and which to affirm.

To illustrate let me take a concrete example from history of science during 19th century.[92] And take the core of the Newtonian theory N and add to it a needed auxiliary proposition that claimed the tidal friction has minimal impact on the moon lunar acceleration, S_1. In addition let Ep be the predicted (entailed) moon lunar acceleration from the conjunction of N and $S_{1,}$ and Ep_1 be the actually observed acceleration that contradicted E_p. The prior probability of the then established Newtonian theory over which the 19th century scientific community has firm confidence is taken by subjective Bayesian to be (0.9) and the prior probability of the then more

[91] Dorling, "Bayesian Personalism, the Methodology of Scientific Research Programmes, and Duhem's Problem", 178
[92] Dorling, "Bayesian Personalism, the Methodology of Scientific Research Programmes, and Duhem's Problem",179

doubtful S_1 is taken to be (0.6) . What is revealed using Baye's formula[93] and the conditional form of law of total probability[94] is the differential impact of E_{p1} on the posterior probability of N and S_1. In doing these calculations, He assumed that at the time given the established statues of Newtonian theory, N, the disconfirming evidence, $E_{P1,}$ was unexpected; hence he gave it a low prior probability. The reason being the Newtonian theory predicted only E_p and there was no other competing scientific theory that anticipated E_{p1} at the time. What Bayesian determination of the respective posterior probability of N and S_1 is that the probability of N in in light of Ep_1 didn't change much (it became 0.8976 from 0.9) while the probability of the auxiliary hypothesis, $S_{1,}$ became very improbable (it became 0.003 from 0.6). The posterior probability of two propositions in light of the disconfirming evidence clearly indicates that it is the later hypothesis (S_1) that should be discarded. Hence the problem of underdetermination is defeated.

Let me illustrate further the potency of subjective Bayesian inference using the examples from Howson and Urbach.[95] William Prout argued that the mass of particles is whole number multiplication of the hydrogen atom. In deed the observational results showed that most atoms mass was whole number and it was multiplication of the atomic weight of hydrogen. But not all measurement of the atomic weight fitted this theory. In particular, Prout measured the mass of chlorine to be 35.83(not whole number multiplication of hydrogen mass). In the face of such recalcitrant measurement he opted to blame the auxiliary hypothesises rather than his core theory that said the mass of every atom is whole number and multiplication of hydrogen. The auxiliary hypothesises were the assumption about the credibility of the measuring instruments, the methods used for measurement and the chemical used for measurement. As result, rejecting the measured result 35.83, he rounded the mass of chlorine to the whole number 36. In order to make sense of Prout's choice using Bayesian inference let see the status (prior probability) of Prout's main theory and the auxiliary hypothesises in at that historical time. At the time Prout's theory had widespread agreement from the scientific community and was thought as more or less true. On other hand the auxiliary hypothesises used for measuring the mass of atoms were accepted as

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93 Bayes formula which regulates how belief or hypothesis(H) should be modified in light of evidence(E): $P(H/E)= (P(H) \times P(E/H)) \div P(E)$

94 Total probability of let say A in sample space S that is partitioned into mutually exclusive partitions of which B is a member is $P(A)= P(B) P(A/B)+ P(\neg B) P(A/\neg B)$

95 Colin Howson & Peter Urbach, *Scientific Reasoning: the Bayesian Approach,* 3rd ed.(Illinois: Open Court, 2006),103

reasonably good methods but with caveat of now and then erroneous reports. Then we can reasonably assign the prior probability of Prout's theory, P, to be approximately 0.9 and auxiliary hypothesises, A, prior probability to be about 0.6. The posterior probability of P and A are related with the probability of the observational evidence, E, as it is measured in laboratory. In addition, as Dorling assumed, for mathematical simplicity theory P and auxiliary hypothesis are independent which means;

$Pr(P/A) = Pr(P)$ and $Pr(\neg A/P)= Pr(\neg A)$ and vice versa.

Then using law of total probability Pr(E) and Pr(E/P) will be :

$Pr(E)= Pr(E/P)\ Pr(P)+ Pr(E/\neg P)\ Pr(\neg P)$

$Pr(E/P)= Pr(E/P.\neg A)\ Pr(\neg A/P)+ Pr(E/P.A)\ Pr(A/P)$

But since the measured observational result of chlorine which was 35.83 contradicts the conjunction of P and A, then Pr(E/P.A) is zero. Combing such fact with the independence of A and P will give us;

$Pr(E/P)= Pr(E/P.\neg A)\ Pr(\neg A)$,

And if we extend it to the remaining variables we will get:

$Pr(E/\neg P)= Pr(E/\neg P.A)\ Pr(A)+ Pr(E/\neg P.\neg A)\ Pr(\neg A)$

$Pr(E/A)= Pr(E/A.\neg P)\ Pr(\neg P)$

$Pr(E/\neg A)= Pr(E/P.\neg A)\ Pr(P)+ Pr(E/\neg P.\neg A)\ Pr(\neg P)$.

If we make further assignment about the prior probability of the conditional, the following might be reasonably numbers. That is, given Prout's theory, P is has a higher prior probability, so the conjunction of P and not A is expected to be more plausible in light of E. as result the following are reasonably assignments.

$Pr(E/P.\neg A) = 0.02$

$Pr(E/A.\neg P) = 0.01$

$Pr(E/ ⌐A.⌐P)= 0.01$

Using these, we can calculate the results of the previous equations;

$Pr(E/P)= 0.02×0.4= 0.008$

$Pr(E/⌐P)= (0.01×0.6)+ (0.01×0.4)= 0.01$

$Pr(E/A)= 0.01×0.1= 0.001$

$Pr(E/⌐A)= (0.02×0.9)+ (0.01×0.1)=0.019$

$Pr(E)= 0.008×0.9+ 0.01×0.1= 0.0082$

To calculate the posterior probability of Pr(P/E) and Pr(A/E), then we will use Bayes's theorm as did Dorling in the preceding illustration;

$Pr(P/E) = (Pr(E/P) ×Pr(P))÷Pr(E)= 0.878$

$Pr(A/E)= (Pr(E/A)×Pr(A)) ÷Pr(E)= 0.073$

What these two results show us is that the marked differential impact of the measured result of chlorine (35. 83) on the two propositions. That is, the posterior probability of P which asserted that the mass of atoms is a whole number multiplication of hydrogen remained closer to its prior probability of 0.9. On other hand the posterior probability of the auxiliary hypothesis, A, became extremely low (0.073) from its prior probability of 0.6. As result it conclusively indicates it the later proposition that should be discarded in light of the conflicting evidence. Thus, in my view, Quine and Duhem thesis that it is impossible to isolate which hypothesis to reject in light of recalcitrant measurement is defeated through the use subjective Bayesian inference.

On other hand, contrary to their prior assumptions, it is my view that that underdetermination does conflict with confirmation holism.[96] That is, holist proponents of confirmation argued that theories do not face experimental evidence in isolation but as whole. As result it is only a network of scientific propositions that can be blamed or get affirmation from a particular body of empirical evidence. The underdetermination that is in conflict with

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[96] Samir Okasha, "Underdetermination, Holism and the Theory/Data Distinction", *The Philosophical Quarterly*, 52, No. 208 (2002),303

confirmation holism is a variant of empirical equivalence underdetermination. It says that there are more than one scientific theories which are empirically equivalent on the available empirical evidence. And there will not be any empirical evidence that can differentiate these two or more scientific theories. The latter claim in particular is serious threat to scientific realism if it is tenable.

However, confirmation holism does also operate at level of theories (inter-theoretical) and two theories with identical evidence might become differentiable when the two are conjoined with a new scientific theory.[97] That is, in conjunction with the new scientific theory one of the two theories might have new empirical consequences, while the other might fail to have that consequence. It might also be that one of the two theories can cohere with a more general scientific theory and the other might not. On both counts two scientific theories that were empirically equivalent, are not any longer underdetermined because the credibility of one the two theories have changed. The change is result of one of the theories conjunction with the emerging scientific theory with which it has additional empirical consequences or it is able to be in encompassed within a larger theory that has far larger empirical and explanatory reach. As a result the two previously empirically equivalent theories became differentiable. That is, the scientific theory that failed to cohere with the new theory or be embedded with larger theory is rejected. And this is a result of the holist nature of confirmation at level of theories not just within theories. However, their status was overturned because the credibility of one the two theories have changed.

The scientific anti-realist might respond with global underdetermination thesis that says that there might be more than one total science scientific theories between which there will be no evidence to distinguish them.[98] Total science comprise all scientific theories of all branches of science into one composite whole that explains all the empirical evidence of the world. As I see it, running to extreme kind of global underdetermination thesis does come in conflict with another central concept in philosophy of science. Theory/data distinction or theory ladeness of observation according to which gathering empirical evidence is heavily guided by scientific theory one chooses and it is impossible to demarcate strictly between a theory and its evidence.

[97] Okasha, "Underdetermination, Holism and the Theory/Data Distinction", 307
[98] Okasha, "Underdetermination, Holism and the Theory/Data Distinction",312

The implication such fact for global underdetermination is severe. That is, global under determination needs a clear differentiation between theory and evidence so that one clearly marks one total scientific theory from other. As such global underdetermination is contradicted by the maxim of vague distinction between theory and data. Thus global underdetermination is rendered improbable because of the lack of demarcation between theory and data.

Therefore, I argue that confirmation holism, which proponents of underdetermination presented to strengthen their argument, contrary to their wish, does weaken the claim of the underdetermination and support scientific realism.

As I see it there is a significant fact underdetermination argument from unconceived alternatives ignores.[99] That is, it is true that there will be more than one scientific theory that can be compatible with any given body of data. But it is also true that for any two empirical equivalent scientific theories there will be novel evidence in the future which can differentiate them. That is, proponents of underdetermination like Stanford have forgotten the other side of empirical equivalence and underdetermination. As a result, the reasonable possibility of a novel evidence that can change the balance of weight between two theories that had comparable degree of empirical support will also change their underdetermined status. Combing these two predicaments with comparative notion of truth-likeness will give us convergent scientific realism.

However, it might be objected that while the prospect of two empirically equivalent scientific theories might be diffusible by future discriminating evidence, it can cannot claimed anything about the truth status of the current theories.[100] In order to alleviate such problem comparative notion of truth-likeness which I presented in chapter two is essential. Comparative truth-likeness is concept that enables us to compare the degree of truth or closeness to the truth one scientific theory compared to other theory. As a result past theory that is superseded by previously unconceived alternative scientific theory can be compared for its relative truth-likeness with later theory. Therefore the emergence of novel scientific theory in the future that is compatible with evidence of current scientific theory isn't something that threatens scientific

[99] Peter Godfrey Smith, "Recurrent Transient Underdetermination and the Glass Half full", *Philosophical Studies*, 137 no.1 (2008):141.
[100] Smith, "Recurrent Transient Underdetermination and the Glass Half full",145

realism. On the contrary the two theories can be measured on how close they are to the truth and it can be rationally decided which theory to succeed the other without raising the possibility underdetermination from unconceived alternatives. Thus, in my view, the myopic gaze of proponents of empirical equivalence underdetermination has forgotten that for any couple of empirically equivalent scientific theories it is highly likely there will be evidence which discern between the two theories. Furthermore, we can explicate underdetermination from unimagined future alternatives is explicable with comparative notion of truth-likeness without drawing from it any anti realism conclusion.

4.2 Solution and Response to the Problem Pessimistic Meta-Induction

In my view, one way to counter the threat of pessimistic induction is to follow Psillos "divide impera et move".[101] According to pessimistic meta-induction, past successful theories have turned out to be false, for we have taken currently successful scientific theories to true or truth-like. And the past theories contain entities and process that are rejected or are not recognized by our present scientific theories. But if the success of past scientific theories was carried not on the kind of entities and process that are rejected in current theories rather on the kind of entities and process that are preserved in current scientific theories, it is clear to me that there is a way out of pessimistic induction. So when a past successful theory is rejected as whole but its success producing parts (entities and mechanisms) are retained in a new superseding theory, there will be continuity between the two theories. However, pessimistic induction argument is based on the discontinuity of entities and process of past and present empirically successful scientific theories. The partial continuity between the superseding scientific theory and the ceded scientific theory over their posited entities that are responsible for their empirical success takes the wind out of the pessimistic induction.

In my view, it is true that genuine empirical success of a theory is a result of its truth-likeness although not all entities of the theory are responsible for it.[102] That is, it is not all of the entities and process of a theory that contribute to its success and even when they do they don't take equal share for the theory empirical success. As a result some parts of the theory are necessarily needed for its empirical success while other parts are not essential for its success. An

[101] Stathis Psillos, *Scientific Realism: How Science Tracks the Truth*,(New York: Routledge, 1999), 96
[102] Psillos, *Scientific Realism*, 103

entity, E, is essential for empirical success of a theory, T, if an empirical prediction, P, of T is not producible by other entities of T without the presence of E. naturally then it is only the essential entities of a scientific theory that are taken be the true aspect of the theory and it is only those parts that will be preserved in succeeding scientific theory. Accordingly, scientific realists need to commit only to the retention of the essential part of a scientific theory but not to the retention of non-essential entities of the theory or the whole theory.

However, in order to show the truth of divide et impera argument we need to look into the history of science.[103] That is, does history of science hold to our bifurcation of entities of successful scientific theories into essential ("working posits") and non-essential ("idle")? And does it vindicate our claim that the essential entities have been preserved in subsequent scientific theories? As it happens, the practice of working scientists reflects the asymmetric status of the constituting entities of scientific theory. Thus, scientists tend to give substantial credence into the existence of entities which they believe are necessary for the generation of empirical consequences a theory and they are lot less of confident towards entities of a theory that aren't instrumental for the derivation of empirical prediction. That is, scientists themselves depending of the strength of empirical support of entities and their role in predicting empirical phenomena have differential ontological commitment to the different entities contained in a theory. Those entities that are needed for generation of empirical phenomena of a scientific theory are thought to truly exist and other parts of a theory that have marginal role to the empirical consequence of the theory are deemed suspicious or superfluous.

For instance, caloric theory of heat which Laudan presented as exemplar of successful past scientific theories that are now seen as false was in fact heterogonous in regards to the acceptability and truth-likeness of the different entities posited within it.[104] Specifically the caloric fluid account of heat in the theory wasn't essential for the empirical prediction of the theory and wasn't seen as truly extant by much of the then scientific community. And it is precisely this aspect of the caloric theory of heat that got discarded subsequently, while parts (entities and mechanism) of caloric theory of heat which were instrumental in its empirical success got retained in the supplanting theory of heat. The latent energy of heat which is the

[103] Psillos, *Scientific Realism*, 105
[104] Psillos, *Scientific Realism*,108

amount of heat energy that got added or lost while the temperature of a system or a body remain fixed is one aspect of the caloric theory of heat that was retained in the subsequent theories of heat. The postulation adiabatic process for sound propagation in the air was aspect of caloric theory of heat that was preserved in later theories of heat as well.

Thus, I argue that, wholesale rejection of past genuinely successful scientific theories that got superseded by new theories and the dubbing all of its constituent entities and mechanisms as false is not tenable.[105] On the contrary, there is a need to sift through the essential and non-essential components of the theory and check whether the essential components got retained in a succeeding theory. If so that theory is truth-like as whole and the essential entities are the true features of the world. The continuity of these entities does vindicate the claim of scientific realism.

I can even respond to the challenges of pessimistic induction with much less resource than the above.[106] It is just enough to show that the entities which the proponents of pessimistic induction presented as necessary for a scientific theory success and hence need realist commitment are not in fact essential for the theory success. As a result, the supposed entities don't demand realist commitment from the scientific realist. And such answer need to be given only when scientific realists are provided with entities that are deemed to be essential to a theory's success yet are false or non-existent. The only burden on the scientific realist is to show that those not approximately true entities are not needed to derive the predictive and explanatory success of a given scientific theory.

Therefore, I contend that in order to solve the challenge of pessimistic induction, it is not always necessary to say which entities are essential and specify them as the fuel behind the success of a theory.[107] Rather, it suffices to point out the entities claimed to be essential by anti-realist are not needed to deliver the success of the theory. One way of doing this is to look for statements that are entailed by statements which were challenged by antirealist as not approximately true yet are essential for a theory success. And to show that these entailed statements are not committed to those entities which were thought to be necessary to the theory

[105] Psillos, *Scientific Realism*, 107
[106] Peter Vickers, "Understanding the selective realist defense against the PMI", *Synthese* 194, no.9 (2017):3221
[107] Vickers, "Understanding the selective realist defense against the PMI",3223

success. At the same time the entailed statements of the theory even without those entities do preserve the empirical success of the theory. For example for a scientific theory, T with proposition, P, P seems necessary for the empirical prediction of theory, T. And P contains some entities and mechanisms that are not approximately true. In such cases we can avoid the looming threat of pessimistic induction if there is an alternative proposition P_1 that is entailed by P. Furthermore, P_1, preserves the empirical success of theory, T and it is devoid of those entities and mechanisms that are not approximately true. As result pessimistic induction can be defeated with minimal work which shows entities that doesn't need realistic commitment. And with a work that demonstrates the elimination such entities is not consequential to deliver the theory success.

In the next few pages of this chapter, I will defend scientific realism by looking into the strength and content of the pessimistic induction argument. For one, pessimistic induction does commit base rate fallacy.[108] That is, pessimistic induction is fallacious in its supposition that success of a scientific theory is not reliably indicator of the truth/ approximate truth/ of the theory. The central concept here is reliability. In medical literature, it is defined in terms of the rate of false positives and the rate of false negatives. An instrument or a test is reliable measure of a disease, if it has low false positives and low false negatives. False positive is the rate or the probability the test is positive when there is an underlying disease is absent and false negative is the rate/ the probability/ test is negative while the underlying disease is there.

Applying the above conception of reliability to the preceding discussion of success and truth of scientific theory, success is reliable indicator of the truth of a theory, if it has low false positive rate and low false negative rate.[109] That is, the probability of theories which are successful though false is low and the probability of theories which are unsuccessful though true is low. On the contrary, the contention of proponents of pessimistic induction is that success of a theory isn't a reliable indicator of its truth, since success has high level false positive and high level of false negative. The evidence they gave was from history of science which show us there were far larger scientific theories that were successful in the past but are now seen as false compared to those scientific theories that were successful and still seen as true. But such argument ignores the base rate of true scientific theories in the past. Base rate in this context is

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[108] Peter J. Lewis, "Why the Pessimistic Induction Is a Fallacy", *Synthese* 129, no. 3 (2001), 371
[109] Lewis, "Why the PM Is a Fallacy",375

the background probability that indicates the rate of true scientific theories out of random set of past scientific theories. Accordingly if the base rate/probability/ of true past scientific theories is low, it will have consequential result for the pessimistic induction argument. That is, even if success is reliable indicator of truth of a scientific theory, there will be far many false but successful scientific theories compared to successful and true past theories. As such, while the proportion successful and true theories is significantly higher to the proportion of successful and false theories , the absolute number of successful and false theories is higher to the number the successful and true scientific theories. But the numerical abundance of false and successful theories over true and successful theories doesn't undermine the argument that success is reliable indicator of truth. That is, if true theories were rare in the past, we have the full explanation as to why there were more successful but false theories than successful and true theories.

The only argument from the track record of science that would undermine the thesis that success is reliable indicator of truth is high false positive rate.[110] And we can investigate such fact by taking a random sample of past false scientific theories and by seeing the proportion of successful theories among them. If the proportion of false but successful theories of the total set of false theories is high, it defeats the idea that success is reliable indicator of truth. But the evidence provided by Laudan for his pessimistic induction argument was a convenient list of successful past scientific theories many of which that are seen as false. This evidence does nothing to undermine the contention of scientific realist that success is reliable measure of truth in science.

In addition, pessimistic induction argument commits what is called "turn over fallacy".[111] That is, proponents pessimistic induction argued that most scientific theories accepted in the past are false and hence it is highly probable our current scientific theories will turn out to be false. In propounding such argument, the antirealist considers all of the past scientific theories as a whole. But such conclusion ignores the fact that it is relying on the cumulative nature of past false theories. As matter of fact as science progress the past will contain more and more theories that are false and only few among the past theories will remain true. For example let's consider at historical time T the number of accepted scientific theories is A. At latter time, $T_{1,}$ of those

[110] Lewis, "Why the PM Is a Fallacy",378
[111] Marc Lange, "Baseball, Pessimistic Inductions and the Turnover Fallacy", *Analysis* 62 no.4(2002):282

theories that were accepted majority will be rejected and only few will be preserved. Hence the cup false past theories is getting fuller by simple fact of time passing because there is higher rate of turnover or change of scientific theories relative to those that remain true.

However, in my appraisal, to use all of these false theories of the past science in order to make an inductive pessimistic argument is to be oblivious to fact of accumulation past theories.[112] The pessimistic induction argument of this kind pulls it strength not from the induction argument itself but from the additive nature of false past theories. The pessimistic induction, which argues most of our present time scientific theories will turn out to be false, would pass if it is shown that at any historical moment in the past the false theories outnumber the true ones. While it might be the case that depending on the selected historical time false and true theories might out number one another, it is only through a single historical period seen separately that we can see the strength of the inductive pessimistic argument.

Contrary to the standard pessimistic induction argument that lumps all of past theories together and compares them to the current theories, it is necessary to look each historical moment scientific theories separately.[113] And after such separation the scientific theories of each time frame is compared to our current theories. Pessimistic inductive argument of such structure is precisely is inductive and avoids the turn over fallacy. For instance, of scientific theories in 1913, knowing the proportion of scientific theories that turned out to be false relative to those that are still seen as true will avoid the turn over fallacy and can lend support to the inductive pessimistic argument. But the fact that the summative total of theories accepted in past is asymmetrically false, doesn't imply at any selected historical moment the proportion of false theories will be higher than the true ones (as evaluated by standard of current science). Thus pessimistic induction of Laudan's kind that relays on summative feature of false past theories commits the turn over fallacy. Furthermore, the proponents of such argument have failed to come by a pessimistic inductive argument that is not vulnerable to such error. And they have failed to show that most of selected historical moments contain more false theories compared to the true ones. As a result, the pessimistic induction conclusion that most of our current theories will turn to be false and success doesn't point to truth is unwarranted.

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[112] Lange, "Baseball, PMI and the Turnover Fallacy", 283
[113] Lange, "Baseball, PMI and the Turnover Fallacy", 284

Even if it is granted that pessimistic meta-induction is not fallacious argument, in my view, it is an extremely weak inductive argument.[114] Inductive arguments or generalization about the unobserved present or future phenomena from observed events is substantiated through two ways. The first is through random sampling and the second is through selection of cases or events that are genuine representative of the unobserved cases. Random sampling of known or observed cases has shown itself to be reliable statistical model of representing the unobserved cases or events of the world, if it is followed through. The latter mechanism of induction is reliable since the observed cases are of the same natural kind, share same casual structure and are governed by same natural laws or mechanism to the unobserved ones. Pessimistic induction generalization is unlike the two standard forms of strong inductive arguments.

If I take pessimistic induction to be an inductive argument that relays on the shared properties, causal structure and mechanism of past scientific theories to current scientific theories, we can see that past scientific theories diverge from the current theories in significant ways.[115] Past scientific theories posit different entities and causal mechanisms to the current ones which impede one from assuming there is uniformity between the two. As such pessimistic induction cannot be an induction based on shared property and working mechanism. If it was the case, it would have gave us a warrant to assume the current or future scientific theories are like the past ones and the past scientific theories are a good representative of the entities and mechanism of the current ones. For instance inductive generalization about the unobserved the properties and causal nature of Gold is based on the observed cased of Gold properties and causal interaction. The reason being the observed Gold are representative of the natural kind and casual powers of the rest. Unlike such cases, pessimistic induction fails to be strong inductive generalization from the shared nature and causal mechanism of the observed case to the unobserved ones.

If I take the pessimistic induction to be an inductive generalization from random sampling, then it doesn't fare better as well.[116] The reason for such predicament is that in random sampling there is comparable chance for every past successful scientific theory to be in the

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[114] Moti Mizrahi, "The Pessimistic Induction: A Bad Argument Gone Too Far", Synthese 190, no.15(2013):3209

[115] Mizrahi, "The Pessimistic Induction", 3217

[116] Mizrahi, "The Pessimistic Induction", 3219

sample. But in the pessimistic induction past successful scientific theories that were used to bolster the argument were not selected through random sampling. On the contrary, there were handpicked in cherry picking manner and were used to confirm the prior assumption of the pessimistic induction proponents. The scientific theories in the list that were used for their inductive argument were elected purposively because they were assumed to be successful, past and false theories. In particular, the scientific theories from Laudan's list were theories were earlier than 20th century and there was no single successful scientific theories from the last century. That is, theories from 20th century had no equal probability to those scientific theories that are before 20th century to be in the sample for pessimistic inductive generalization. This is a simple encapsulation of the fact that the sample that was used for such extreme generalization was biased and non-random. So since the selected cases or the sample is not reflective of the varied and the many kinds of past successful scientific theories, it has consequential implication on the inductive strength pessimistic induction. That is, pessimistic induction is weak inductive argument with no adequate ground (sample base) for its ambitious generalization about the fate of presently successful scientific theories.

In my view, the preceding pages have established two things. First when I take pessimistic induction argument seriously, it shows only discontinuity and rejection of the non-essential entities of scientific theories that are not responsible for success of scientific theories. But it is only the essential entities or parts of scientific theories that are truth-like and are retained in supplanting scientific theories. Other hand, pessimistic induction does commit the turn over fallacy, base rate fallacy; and even when I pass over it fallacious content it is an extremely weak inductive argument that is not a serious threat for scientific realism. In my view, on both counts pessimistic induction is not a significant threat for scientific realism.

Chapter Five

Solution Two: Modified Scientific Realism or Selective Realism

The kind of scientific realism that was articulated by Putnam and Boyd has given birth to other kinds of scientific realism. In my view, entity realism and structural realism are the prime examples of the modified form of scientific realism that have potent defence against pessimistic induction and underdetermination. Entity realism is a selective realism only to some parts or entities of scientific theory with experimental demonstrated properties. In entity realism causal warrant but not inference to the best explanation grounds scientific realism. For structural realism the fundamental ontological category a successful scientific theory captures is the relation between entities. As such, in structure realism scientific theories give us approximate truth about the fundamental structural relations that exist in the world. Accordingly, we look in scientific theories for structure world they capture not for their contents. In the coming pages I will outline what entity realism and structural realism are and I will show how each of them are competent solutions against pessimistic induction and underdetermination.

5.1 Entity Realism

Ian Hacking argued that the best evidence for scientific realism is found in experiments.[117] As such, he advocated for a kind of scientific realism that privileges entities with demonstrated causal properties in the lab rather than theoretical entities that are inferred from their explanatory and predictive success. Theoretical or unobservable entities pass the bar of existence, only when using their supposed properties one is able to construct experimental devices that are used in turn to detect other novel aspect of the world. This can be shown using electron as case study.

Electrons didn't become real entities in the world when they were first used in explaining an empirical phenomena or when their mass and charge was measured.[118] Although these might be the initial cursory steps most entities pass, which eventually become experimentally real, they don't commend ontological commitment from us at this stage. Electrons became real entities when they (their causal properties) are used in experimental apparatus to uncover other

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[117] Ian Hacking, *Representing and Intervening: Introductory Topics in Philosophy of Natural Science*, (New York: Cambridge University Press,1984),262

[118] Hacking, *Representing and Intervening, 263*

phenomena of scientific concern. Indeed, the causal properties of electrons have been used by various experimental instruments to detect and measure other kinds of scientific phenomena. As a result, when there is an established process of manipulating and isolating the causal properties of electron in order to see other aspect of nature, then electron or other particles like it will become genuine ontological entities that exist in the world.

For instance electrons were used to detect parity violation in neutral weak force[119] or current.[120] Parity violation is asymmetrical distribution of particles, in these case electrons, between right and left side of the weak force current. The causal properties of electrons were employed in the working of experimental apparatus called PEGGY II in order to uncover the unexpected parity violation in neutral weak current. Until then parity conservation or symmetry over distribution of particles in weak force was the standard scientific view since right and left were thought not to matter to natural phenomena. In such process, PEGGY II works by emitting linearly polarized electrons from surface of oxygen and cesium painted crystalline Gallium Arsenide in vacuum using circularly polarised laser light. Repeated experiments using such procedures that accounted for possible statistical errors, ascertained asymmetrical polarization or parity violation of the linearly polarized electrons towards the left side compared to the right ones. The proportion of polarized electrons scattered on the left side exceed the right side. Thus, electrons were manipulated to detect previously unknown phenomena of parity violation in weak neutral currents. As result it firmly marks electron to be really an extant ontological entity.

Rather than seeking scientific realism from theory oriented reasoning such as the role of a theoretical entity in explanation and prediction of empirical phenomena, we need to look in to practice oriented ontological commitment.[121] That is, when an entity, as shown above with electron, is used to successfully investigate and uncover some other aspect of natural phenomena that entity is an independently existing entity. In Hacking's word when thinking about realism; "think about practice, not theory".[122]

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[119] It is one of the four fundamental forces of nature: gravitational, electromagnetic, strong and weak nuclear forces. The weak force is weaker than the electromagnetic force and governs the interaction between subatomic particles.
[120] Hacking, *Representing and Intervening,*265
[121] Hacking, *Representing and Intervening,273*
[122] Hacking , *Representing and Intervening,274*

Nancy Cartwright version of entity scientific realism has different argument for the reality of unobservable entities.[123] According to her, the standard scientific realism reliance on inference to best explanation to argue for existence of natural laws and scientific entities is flawed. The main objection against inference to the best explanations is that an explanation's truth for particular phenomena is not constitutive of the strength of that explanation for the phenomena. The property of being true is external to the qualities of being an excellent explanation. As a result, being the best explanation has no necessary relation with being a true explanation.

On other hand, theoretical entities are parts and parcel of causal explanations.[124] The existence of theoretical entities is vindicated because their role in causal explanations. That is, the structure of causal explanations inherently validates the inference of cause from an effect. When one presents causal explanations for phenomena, he necessarily needs a cause. And that cause needs to be extant as well. Unlike best explanation of the above kind, in order for causal explanation to work or succeed there must be an existing cause for the phenomena or the effect in need of causal explanations. What this leads to is that there are entities and micro-world objects which are responsible for the phenomena. That is, there are entities with specific set of causal properties that brought out the observed phenomena in a particular consideration. However, casual explanation has no implication about the status and the existence of theoretical physical laws. And what is significant about Cartwright's entity realism emanates from the asymmetrical status of scientific natural laws and theoretical entities. Causal explanations affirm the existence of theoretical entities in the natural world but not natural laws.

For example, just like from the vapor trail in the sky of a flying jet, we infer that it is probably caused by the plane flying a few minutes ago, we infer from similar tracks in the particle detector cloud chamber the existence of a particle.[125] That is, from a resultant physical phenomena it is inferred an equally physical casual entity. As a result, the existence of the particle just like the jet is a constitutive ingredient such kind of causal explanations. If causal

[123] Nancy Cartwright, *How the Law of Physics Lie*, (New York: Oxford University Press, 1983), 87
[124] Cartwright, *How the Law of Physics Lie,91*
[125] Cartwright, *How the Law of Physics Lie,92*

explanations necessarily commit us into the existence of causal entities of a phenomenon, when do causal explanations are taken to succeed? In this, Cartwright concurs with Hacking that entities with demonstrated casual properties in experimental setting are taken to be real entities. The use of Millian notion of cause as entity that is a sufficient or a necessary condition of an experimental event will provide conceptual map in the investigation of entities that are responsible for successful causal explanations in such contexts. The vindication entities like electron and proton as extant objects in the world is a result of such process.

To me, selective entity realism advocated by Hacking and Cartwright based on casual explanation and manipulation causal properties of entities is best taken as epistemic thesis.[126] That is, the best evidence we have for existence of an entity is demonstration of its causal properties. As result entity realism is not best taken as metaphysical thesis. Since on metaphysical reading, it would be saying that things that exist in the world are only things whose causal properties are manipulated. There might be entities which are inaccessible to our intervention and manipulation. In addition, the inference of entities using experimental intervention on their causal properties is not infallible process. Hence it cannot be sufficient condition for metaphysical thesis to have demonstrated experimental causal property in the lab following a causal explanation. As a result, intervention and manipulation are the best possible epistemic warrant for our ontological commitment. It is the best possible epistemic warrant because it is better than inference to best explanation and deductive- nomological model[127] of explanation related inference to the truth of a theory and the existence of its entities. That is, the strength of scientific theory to group, summarise and predict; or entail and subsume diverse phenomena doesn't tell us anything about the truth status of the scientific theory. Furthermore, there might an alternative scientific theory that can do the same job of adequately explaining that diverse phenomena. On the contrary, in causal explanation existential commitment to the causal entities of phenomena is integral part of the causal explanation. In addition in causal explanation experimental manipulation and intervention process will rule out alternative entities that might be responsible for phenomena. Lastly, the strength of any theoretical explanation is impotent to defeat the existence of an entity inferred from a causal explanation which is affirmed by

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[126] Mauricio Suarez, "Experimental Realism Reconsidered", in *Nancy Cartwright's Philosophy of Science*, Stephan Hartmann, Carl Hoefer and Luc Bovens ed. (New York: Routledge, 2008), 141

[127] It was the dominant model of scientific explanation proposed by Carl Hempel in mid-20th century analytic philosophy

experimental intervention and manipulation. That is, no matter how good a theory is in terms of explaining phenomena, it doesn't parallel causal warrant strength in commending an ontological commitment. As a result, inference of truth and existence entities based on a theory's explanatory strength fades as an epistemic warrant when it is compared to causal explanation's warrant.

Thus, entity realism is a selective epistemic realism anchored in causal warrant that is provided by causal explanation and manipulation of causal properties in a laboratory.

In my view, basing scientific realism on causal warrant of entity realism does make the threat of pessimistic induction insignificant. That is, pessimistic induction attacks standard scientific realism for its inference of truth and reference from success of scientific theory using historical cases doesn't work on entity realism. However, Entity realism is sceptical of inference to best explanation as guide to scientific ontology as well. Accordingly, it sees the strength of a scientific theory in explaining and predicting phenomena as immaterial to the theory's truth and to the existence of its entities. Truth is external to the strength and adequacy of theoretical explanation. Instead we have best warrant to infer existence only those entities whose causal properties are manipulated to detect other natural phenomena and are involved in causal explanation. Thus, scientific realism, particularly the epistemic kind, about the past and present scientific entities that are part of causal explanation and have demonstrable causal powers is defensible and is invulnerable to pessimistic meta-induction.

In addition, as I see it, entity realism has adequate resource strength in answering the challenge of underdetermination. Entity realism doesn't take all entities of successful scientific theory as independently extant entities. Rather, it takes to be real only those entities of a scientific theory involved in causal explanation and have demonstrated causal properties. Entities whose properties are manipulated and intervened in order to detect other aspect of nature have given us the best possible evidence for our epistemic scientific realism about them. This stringent epistemic standard for reality of theoretical entities in entity realism will enable to filter out myriad possible alternative scientific theories. That is, there are no alternative scientific entities with established causal properties that are presented as alternatives by the proponents of under determination to a scientific entity that have causal warrant. As a result, entity realism is able to block the possibility of underdetermination of theory by data.

5.2 Structural Realism

I agree that, at times it true that there it is difficult to reconcile standard scientific realism and radical changes in theoretical content of successive scientific theories.[128] Scientific realism concept of approximate truth of genuinely successful scientific theory might not enough to explicate when the changes between entities of successive theories is dramatic. That is, how do we understand the truth-likeness of two successive and successful scientific theories whose theories entities is diametrical different from one another. While progressive convergence to reality and approximate truth can be claimed in faces of scientific theories which show partial continuity of theoretical content to one another, such predicament seems improbable when there is a radical or a revolutionary change in the entities and mechanisms of successive scientific theories. In my view, in such predicaments structural realism is potent means to defend against the threat of pessimistic induction.

In structural realism, the main continuity between genuinely successful and successive scientific theories isn't content but structure.[129] That is, successive scientific theories mainly succeed in accurately describing the relations that exist between entities in the world and it is this aspect of scientific theories that get retained in all supplanting scientific theories. Accordingly, successive scientific theories tend to ascribe divergent entities and mechanisms to the world. The lesson from such radical changes in theoretical entities of successive scientific theories, as pessimistic induction shown, is that there might not be such kinds of entities at all. Even if there is a failure in representing and getting right the properties of entities by scientific theories, there is still a virtue in successful scientific theories. That is, scientific theories do succeed in representing the various kinds of relation that exist between entities of nature. The improvements in superseding scientific theories mainly are about discerning the previously unknown networks between entities of nature.

The continuity between successive scientific theories is reflected, in particular, in the continuity of mathematical structure of those theories.[130] The mathematical equation reflects the structure or the kind of relationships between entities that are found the world. Even when there is no strict preservation of the mathematical equations of a previous scientific theory in the latter

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[128] John Worrall, Structural Realism: the Best of Both Worlds?, *Dialectica* 43, No.1-2(1989),99
[129] Worrall, "Structural Realism",117
[130] Worrall, "Structural Realism",120

ones, the mathematical equation of superseding scientific theory does hold the earlier scientific theories' mathematical structure as special case or limiting case. That is, contrary to Boyd's claim that the content or entities of the superseded scientific theories being the limiting case of the superseding theories, it is mainly the arc of interaction between entities in earlier theory that is retained as special or limiting case in the latter scientific theories. Thus, genuinely successful scientific theories capture the fundamental relations between entities and it is precisely such relations that will be retained in subsequent scientific theories not content of these theories or their claim about the internal properties of those entities.

In the above kind of structural realism the knowledge we gain from science is the structural relation between entities for two reasons.[131] First the structures of phenomena or observable events as experienced by agents mirror the structure of the underlying objects or causes that are found in the world. Second the difference observed in two phenomena (effects) is the result of a difference in their causes. What scientific endeavour uncovers using these principles is the structure of the underlying entities and their distinct casual relations. But it does not incur into the identity of the internal constitution or properties those objects which fail to show in causal consequences and in structure of perceived phenomena. Rather, what it accomplished and will continue to achieve is capturing the isomorphic relation between the structure of the fundamental entities in the world and the human being's perception of observable phenomena.

Structural realism isn't homogenous formulation of scientific realism. According to James Ladyman there are at least two kinds.[132] These are epistemic structural realism and ontic structural realism. Epistemic structural realism is motivated to limit scientific realism in way that makes it invulnerable to pessimistic induction. It asserts that the only knowledge we gather in doing science is the structural relation between entities or relata. At the same time science doesn't give us any firm knowledge regarding the properties and internal constitution of these entities or relata. As a result, the claims of scientific realism should be limited only to the structural relations that exist between things. The views of John Worrall presented above are precisely in the epistemic structural realism camp.

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[131] Ioannis Votsis , "The Upward Path to Structural Realism", Philosophy of Science 72, No.5(2005):1362.
[132] James Ladyman, "What is Structural Realism", *Stud. Hist. Phil. Sci.*29, No. 3(1998), 410

In order to avoid commitment to entities of scientific theories, it is advocated by epistemic structural realists the theories should be translated to their Ramsey sentence equivalent.[133] The Ramsey sentence translation of scientific theory does away with direct reference of its theoretical entities while preserving the empirical consequence of the theory. The structural relations are shown through the logical connectives, existential quantifiers, variables and predicates. The Ramsey sentences translation of scientific theory, Θ, will looks like the following.

> $\Theta(O_{1,} O_{2,} O_{3} \ldots O_{n}{:}T_{1,}T_{2,}\ T_{3} \ldots T_{n})$, O are the observational content of the theory and the Ts are the theoretical / non-observational content of the theory. The Ramsey sentence of the theory, Θ, will be: $\exists t_{1} \ldots t_{n}\Theta(O_{1,} O_{2,} O_{3,} \ldots O_{n}{:}\ T_{1,}T_{2},T_{3} \ldots T_{n})$.

The existential quantifier in Ramsey sentence indicates only the presence of some structural relation and properties without specifying or committing us to specific ontology.

However, I argue that Ramsey sentence formulation of epistemic structural realism faces uphill challenge because of objections on Ramsey sentence translated scientific theories.[134] That is, Ramsey sentence translation of scientific theory doesn't tell us anything substantial about the structural relation of its entities apart from what can be inferred a priori. Contrary to epistemic structuralist wish, the only thing the Ramsey sentence of scientific theories can tell us are relations that emanates from the set theoretic relation of the entities of scientific theory. That is, since Ramsey sentence formulation of scientific theory focus on formal relations expressed using first order logic, it doesn't specify which kind relations or structure exist between which kinds of entities. Despite our stated goal of warranted knowledge of structure between things in the world, Ramsey sentence structural realism has failed to characterize the relation that hold between specific entities. It just vaguely asserts that certain relations hold between the members of scientific theory without specifying the intended relations. As result Ramsey sentence of scientific theories cannot tell us anything about the fundamental relation that exist between things in the world. Even if we pass over epistemic realism's above difficultly, it doesn't engage in a principled way with change of the ontology of from supplanted theory to the superseding theories. That is, it doesn't address on how tackle and understand the discontinuity of posited things (ontology) as it proceeds from one theory to the next. I believe that while the above short

[133] Ladyman,"WSR", 411
[134] Ladyman,"WSR", 412

coming of epistemic structural realism is unrelated to issue of dealing with pessimistic induction and underdetermination, it is one of the independent epistemic consideration the can be used to in the final process selecting the most favorable kind of scientific realism.

On the contrary, in my view, ontic structural realism is in a better position than epistemic structural realism on the above issues.[135] It uses semantic approach towards scientific theories. That is, for ontic structuralism scientific theories are models with varying degree of similarity to the world. They in particular model the structural relations that exist between entities in the world. The predictive success of scientific theories is a result of these model close resemblance to the structure that is found in reality. Unlike epistemic realism, it doesn't see scientific theories as propositions or sentences that can be translated in to first order language for Ramsey sentence transformation. In addition these models or scientific theories are in business of explicating the possible, the necessary and the contingent modal relations of entities in the world. Accordingly, there is commitment to modality by ontic structural realism. The continuity between successive scientific theories is the result of modal structure of the world which these scientific theories model through the language of mathematics.

Ontic structural realism (OSR, henceforth) has different ontology compared to standard scientific realism I outlined in chapter one.[136] In contrast to standard scientific realism which takes individual entities and their internal properties as basic ontological category, ontic structural realism takes the relations between the relata or entities as the most fundamental ontological category. As i will show in next section various OSR proponents differ their stance over what individual entities are and what is their ontological hierarchy is in comparison to structure between them, but OSR as whole take structural relation to be the foundational ontological frame work of reality. I argue this radical shift in basic ontology from standard scientific realism will also help deal with the problem of underdetermination of theory by data. The problem of different scientific theories with different basic individual entities over which evidence cannot enable us to choose one from other is dissolved, if structure or relations are the most important ontological features of reality. As such, the relevant question is shifted to which

[135] Ladyman, "WSR", 415
[136] Ladyman, "WSR", 418

among scientific theories is best model of the basic relation found in nature not whose scientific theory entities is the real one.

In my view, the strength OSR capacity to deal with under determination is related with the lesson it took the results of quantum physics (QM).[137] The lesson is that in the theory (QM) can take the fundamental particles like electrons as individual entities with stable identity or as fields with certain properties on space-time positions. This implies that the formulation quantum particles as individual objects or as non-individual objects are two varying way of formulating the underlying basic ontology which is the structure. Such consequence from one of most successful scientific theories motivates OSR to claim that structure or relation is most primitive and fundamental ontology. The shift is reflected in the priority of laws and mechanisms expressed in mathematical equations that reflect the structure of nature over the individual entities which were the starting point of standard scientific realism.

To me, it is clear that different formulation OSR has different emphasis and prioritization about structures, objects, individuals and their properties. The first of these is eliminative OSR.[138] Eliminative OSR argues that there is mind independent modally structured world which successful scientific theories capture or model. However, there are no non-eliminable objects or entities with internal properties, identity and individuality. That is, there are no objective entities as they are called objects in themselves in Kantian metaphysics beyond the objective structural relations. The dictum is that "There are no things, structure is all there is".[139] Objects are heuristic devices that are used by epistemic agents in order to guide themselves in the world by constructing a rough model of the world. As such the metaphysical claims about individual objects and there identity is reducible to the more fundamental and primitive ontological category of modal structural relations. And there are no inherently irreducible individual objects with their internal properties that are ontologically fundamental or primitive. Furthermore, it denies that the structural relation dependence on presumed internal features of entities. That is, the fundamental modal structures of world don't supervene on independently existing individual entities in space-time and their internal properties. Rather, these individual entities acquire their

[137] Ladyman, "WSR",419
[138] James Ladyman and Danny Ross, *Everything Must Go: Metaphysics Naturalized*, (Oxford: Oxford University Press,2007), 130
[139] Ladyman & Ross, *Everything Must Go*, 130

properties from the structural relation they are part of or are constituted by the modal structure they are featured in. According to eliminative OSR, we should by part with idea that the building blocks of reality are entities that have separate existence in particular space-time points.

The motivation for such kind of metaphysics of science is that a search for an ontology that is in agreement with fundamental theories of physics namely quantum mechanics and general relativity.[140] Eliminative OSR is apt to overcome the challenge of these hugely successful scientific theories present in contrast to standard scientific realism.

The challenge from QM is related to how the permutations[141] of same kind of quantum particles problematize the identity of individuals in quantum mechanics.[142] That is, how to tackle individuality of two particles which have identical internal properties and have no determinate space-time location. For example two electrons in entangled quantum state share all kinds of parameters that might be used to discern them. They have the same mass, charge and other state independent property; and the also have the same state dependent properties like their space-time trajectories and spin state in relation with each other. The state dependent properties of one electron are predictable and depend on other electron state dependent properties since they are in entangled quantum state. Regardless of these problems, if we are to maintain quantum particles are individuals we will violate Leibniz's law of principle of identity of indiscernible (PII). PII states that there are no two things that share all of their properties or only have indistinguishable properties. In light of the above predicament there are few options available. The first might be to reject the PII and maintain that quantum particles are individuals. The second option is to claim that individuality transcends the internal properties and the relational properties of things and hence two particles can have separate individuality despite having identical state dependent and state independent properties. While this conception of individuality saves it from being untenable, it is metaphysical opaque notion of individual identity of which there is no possibly of accessing it. The third option is to concede that quantum particles are not individuals. It is this predicament of quantum particles as individual identities (of the transcendent kind) or as non-individuals that led them OSR proponents to say that there is a metaphysical underdetermination.

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[140] Ladyman & Ross, *Everything Must Go*,131

[141] It is refers to the process and exchange of position by same kind of particles within quantum mechanics.

[142] Ladyman & Ross, *Everything Must Go,*132

That is, there are three metaphysical options available for scientific realist over which empirical factors have no determinate power. And the eliminative OSR solution out of this conundrum is to reconceive quantum individuals (individuality in general) in structural terms. Since on eliminative OSR conception the structure is the fundament ontological grid which constitutes the reducible features of individual objects, all quantum particles are particular state of the structure at that space-time point. In OSR, it is the quantum state structures or relations that take metaphysical precedence over the search for discernable individual quantum entities. As such if there are individual particles with internal and relational properties it is wholly what they accrue from the quantum structure; and they are reducible to it.

The motivation from general relativity is related to the nature of space-time.[143] The metaphysical view regarding space-time has been between those who endorse absolute space-time (substantivalism) and those who endorse space-time exist only to extent there are entities or substance that are related (relationalism). Theory of general relativity (GR) doesn't tell us which of the two views the right one. On one hand general relativity implies that space-time has independent existence regardless of its content and can exist even if there no single entity within it. Furthermore the space-time has energy of its own and can interact as agent and as receiver with its contents suggests space-time is an absolute substance over and above the relation of objects. On other hand space-time in general relativity isn't fixed entity but it is dynamical structure. In particular the general covariance of feature of general relativity is antema to substantivalism conception of space-time. According to the general covariance, law of general relativity will continue to hold even if there is an arbitrary change of the space-time coordinates. That is, to the equation of general relativity the change of specific geometrical points or locations has no any substantial bearing. As such, it indicates that space-time points are devoid of any individuating properties which can make a difference to the result of GR under differentiable coordinate transformation. The result is that it pushes against substantivalism about space-time that is based on individuality of each space-time points. Here again the solution to above predicament according eliminative OSR is taking the space-time as structure devoid fundamental individual points. The general covariance becomes a problem for substantivalism because it propounds there is an absolute space-time with discernable individual coordinates. Hence if

[143] Ladyman & Ross, *Everything Must Go*,141

space-time is a structure ontologically prior to the particular space time points and entities contained in it, then above problem is diffused. Thus, eliminative OSR finds apt solution to the problem about the nature of space-time in general relativity by eliminating individual space-time points and replacing them more fundamental ontology which is the space-time structure.

How do I identify the ontological structure that is prior to individual objects? While there might different approaches in various areas of science, mathematical group theory is the key to grasp the structure of nature in physics.[144] Group theory was developed in relation with symmetry. Symmetry refers to mathematical transformation of mathematical objects that leave them intact. Applied to physical world, a set of mathematical transformations which remained tied to same physical phenomena, despite being distinct mathematical equations is what is to mean to have symmetrical transformation. As result what exists objectively is in the world is what stays the same or invariant under such transformations. Under such conception invariance is the sine qua non of objectivity. Whether it is in quantum mechanics or in general relativity different mathematical structures that are symmetrical indicate the presence of same underlying physical structure. For various theories of physics in order to be considered equivalent with one another in their theoretical content, it is not needed for them to have identical individual theoretical entities. Rather, it is asked if there is underlying physical invariant structure that is captured by all those mathematical models or equations of the physical theories. If there is one invariant physical structure or state, those mathematical equations of theories will be transformable with respect to one another. Thus, that invariant physical structure or state reflects the objectively existing structure in the world. Furthermore, individual entities are eliminated in favor of structural ontology in such group theoretic model of physical world.

The second type OSR is moderate structural realism that preserves the individual objects.[145] In contrast to eliminative OSR, objects have the same ontological standing as structures or relations. Moderate OSR took a lesson from a basic objection directed towards eliminative OSR. That is, structures or relations require or presuppose relata or objects and it seems impossible both ontologically and conceptually to see structures and relations without

[144] Ladyman & Ross, *Everything Must Go*,145
[145] Michael Esfeld & Vincent Lam, "Moderate Structural Realism about Space-Time", *Synthese* 160, No.1(2008)

objects that relate to one another. Concurring with such criticism, in moderate OSR there are structures as well as objects in relations. And there is no ontological hierarchy between the two.

However, it denies that objects have intrinsic properties that are out of reach forever as claimed in epistemic structural realism.[146] Intrinsic properties are attributes of an object that are there regardless of the object being existentially alone or being in relation with other objects. Rather, all the properties objects have, according to moderate OSR, are relational. As such, objects have no any extra relational or extra-structural properties that are foreclosed from scientific inquiry and knowledge. In addition there are no any intrinsic properties of objects over which structural relations between objects supervene. Thus, there are objects but all they are or have is relational or structural properties. These structures are a reflection of the concrete physical interaction between entities in the world and are able to confer an individuating identity to the entities. Without a need of intrinsic properties, relational properties are enough to demarcate one object's identity from the others. That is, just like a belief or a term in a web of belief which get its meaning from its inferential and contextual relation with other believes, objects get their relational property or identity from their relation with other objects.

Proponents of moderate OSR went further in their later articulation on the relation between objects and properties.[147] They argued that the traditional metaphysics distinction between object and properties is a conceptual but not an ontological one. Properties for them like Spinoza's views are the way of or the mode of objects existence in a concrete world. It follows from it there is no question of ontological separation between objects and properties and there is no question of ontological priority. This attack on the traditional metaphysics on separation of objects and their properties does apply to the relational properties as well. Therefore, on the modified view of moderate OSR there are objects and the only properties of significance of them are relational properties but there is no way of making an ontological distinction between objects and their relational properties. Still unlike eliminative OSR, there are objects and relational properties in moderate OSR.

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[146] Esfeld & Lam, "Moderate Structural Realism about Space-Time"
[147] Michael Esfeld & Vincent Lam, "Ontic Structural Realism as a Metaphysics of Objects", in *Scientific Structuralism*, Alisa Bokulich & Peter Bokulich ed., (New York: Springer Science+Business Media, 2011), 150

Therefore, in my view, in above the framework of structural realism it is evident that pessimistic induction and underdetermnination are not significant threats. That is, scientific realism in the vein of structural realism is not vulnerable to underdetermination and pessimistic induction. Since what pessimistic induction has shown using historical case examples was discontinuity of content of scientific theories and rejection of past successful scientific theories' entities. Rather, on both main kinds of structural realism what is preserved between successive and successful scientific theories is only structure of the world these theories describe. Individual scientific entities are either out of the reach of scientific knowledge or are secondary to the structure. Furthermore, I believe that OSR semantic view of scientific theories and group theory informed notion of symmetry between theories deflates the potency of pessimistic induction. That is, even if two or more successful scientific theories have different individual entities as long as they are symmetrical transformable they are about one objective structure of the world. Thus, Pessimistic induction which based on discontinuities of individual entities of successive scientific theories becomes irrelevant for structural realism.

In addition, to me, the problem of underdetermination is dissolved in structural realism as well. Since what proponents underdetermination argued was that the underdetermination of theory choice over scientific theories whose individual entities are their fundamental ontological category. Underdetermination was about the impossibility of rational choice between scientific theories with different individual scientific entities. However, both on epistemic and ontic kind of structural realism individual scientific entities are not the primary thing successful scientific theories capture but it is the structural relation between entities of the world. Furthermore, in structural realism two or more scientific theories are not compared for the relative accuracy in terms of individual entities. Rather they are compared which among those theories models best the fundament structure found in real world. Second, if two scientific theories are comparable or symmetrical using group theory for each other, then these scientific theories do represent one and same underlying structure of the world. Therefore, my view, the threat of underdetermination is dissolved since if two theories are symmetrical, the two theories are not rival over which the evidence impotence to choose. Rather, they are different way of formulating one and the same world.

As I have established above there no much difference between epistemic structural and ontic structural realism in answering the objection of pessimistic induction and underdetermination. In my view ontic structural realism the semantic view of scientific theories and the apparatus of group theory have more resource to deal with if it is argued that there is structural form of underdetermination. However, in my view, which form of structural realism will be chosen as the most fitting account of the world described by science is independent of the pessimistic induction and underdetermination. All forms of structural realism are competent to defend against pessimistic induction and underdetermination.

Chapter Six

Conclusion: Appraising the Prospect of Scientific Realism

I will conclude this thesis by appraising the strength of scientific realism defences that I argued for in the preceding chapters against pessimistic induction and underdetermination.

6.1 Scientific Realism and Pessimistic Meta-induction

First, let me see, how scientific realism fares, if I take the pessimistic induction as valid or cogent attack on scientific realism.

In my view, on that point, standard scientific realism that was presented by Hilary Putnam and Richard Boyd has defective defences. As articulated by both, scientific realism has four claims about scientific theories. The metaphysical thesis claims that entities of science exist in the world; the semantic thesis claims that the terms of a scientific theory literally refer to things in the world; the epistemic thesis claims that science give us a knowledge about the world; and the convergence thesis claims that there is a convergence between successive scientific theories towards the truth. The main argument presented in its favour was the miraculous success of scientific theories in the past few centuries. That is, the best explanation for such scale of success of scientific theories is their approximate truth or truth-likeness. Approximate truth of scientific theories explains best the success of scientific theories.

However, as Larry Laudan and others showed the history of science tells a different story. In the past, there were many scientific theories that were remarkably successful in their explanatory and predictive power but were discarded after sometime. The reason for the rejection of such theories was, later, they were deemed as false and non-refereeing scientific theories. In addition, history of science shows us that it is not the case that all new scientific theories retain the entities and mechanisms (the ontology of past theories) in their own postulation. Rather, history of science shows us that there are cases of significant changes in the scientific entities of successive scientific theories. There are two main implications for the standard scientific realism. First, inference of approximate truth and reference to all parts of scientific theories from their explanatory and predictive success is not defensible. Inference to best explanation is a defective guide to the metaphysical, semantic, and epistemic thesis of scientific realism. Second, the many counter examples of discontinuity between successive scientific theories make it difficult to maintain convergence thesis of scientific realism. Has scientific realism given an adequate answer to the blistering attack of pessimistic induction?

It is possible to defend scientific realism but not the scientific realism that was presented and argued for by Putnam and Boyd. As I see it, it needs a significant qualification both on the content of the four theses and most importantly on the use of inference to best explanation to advance such theses. As such the first way out is to follow that of Psillos's proposal. That is, not all of entities and mechanisms in a scientific theory commend a realist commitment. In a scientific theory only those entities and mechanism that are essential (working posits) for the theory success demand realistic commitment. It is only those entities that actively contributed for the theory predictive and explanatory success of a scientific theory that are found in the objective world. And it is precisely only those entities of past scientific theories that will be retained in subsequent supplanting scientific theories. This argument for scientific realism is not vulnerable to the pessimistic induction. Since what is shown by historical cases of currently rejected scientific theories that were successful is that not all of their entities and mechanism are true and referential. However, Psillos solution is not just a priori defence of scientific realism, but it is also an empirical claim. As a result, it is not wholesale affirmation of all successful scientific theories. Rather, it needs a case by case inquiry into the history of each subject scientific theories. Such inquiry is done to ascertain, if in fact the essential entities of the past successful theories are retained in the current ones. Psillos did provide some examples of preservation of essential or active entities of successful past theories in current ones. In opinion, while it is not general defence to all successful scientific theories, Psillos's modest selective scientific realism provides a way out of pessimistic induction by presenting coherent conceptual defence that is backed up by historical cases.

For me, entity realism is not easily vulnerable to pessimistic induction as well. In entity realism what is independently real in the world is an entity that is part of causal explanation and has a demonstrated causal property that is manipulated and intervened in order to investigate other features of nature. Causal warrant but not explanatory and predictive success of scientific theories is our best evidence for the objective existence of scientific entity. As such the pessimistic induction that attacked standard scientific realism for its inference of truth and reference from success of scientific theory using historical cases doesn't work on entity realism.

Entity realism is sceptical of inference to best explanation as guide to scientific ontology as well. Accordingly, it sees the strength of a scientific theory in explaining and predicting phenomena as immaterial to the theory's truth and to the existence of its entities. Truth is external to the strength and adequacy of theoretical explanation. Instead we have best warrant to infer existence only those entities whose causal properties are manipulated to detect other natural phenomena and are involved in causal explanation. Existence of causal entities is an internal constituent of causal explanation. Thus, in my view, scientific realism, particularly the epistemic kind, about the past and present scientific entities that are part of causal explanation and have demonstrable causal powers is defensible and is invulnerable to pessimistic meta-induction.

Furthermore, in my opinion, structural realism does evade pessimistic induction without much difficulty. To structural realism the fundamental constitutive features of objective world are not individual entities but it is the relation or it is the structure between entities. On the epistemic structural realism, we can only have knowledge of the structure of the world but not the internal properties of each object in the world. On ontic structural realism these individual entities are either reducible to structure or only have relational properties. Hence, on the latter view there is no attribute of individual properties that is foreclosed from scientific investigation. On both variety of structural realism the ultimate focus of their realism is the structural relation between entities. As a result the pessimistic induction which showed cases of marked discontinuity and divergence in successive and successful scientific theories constituting individual entities bears little on structural realism. Pessimistic induction didn't show historical cases of discontinuity between successive and successful scientific theories' structure. On structural realism, it is precisely the structure or the relations of successful scientific theories that get retained in subsequent scientific theories.

In my view, however, the cogency pessimistic induction is doubtable. That is, pessimistic induction is fallacious in at least two respects and even when taken as non-fallacious inductive argument it is a weak induction that overshoots its claims. It commits base rate fallacy and turn over fallacy. Pessimistic induction in attacking the reliability of success of scientific theories about the truth of the theory, it ignores the rate of true theories in the past. Accordingly, if true scientific theories were rare in the past, there will be very few true theories out of the total set of past scientific theories. Due to this, even if success is a reliable guide to truth in scientific theories, there will be far more number of false but successful scientific theories compared to true and successful scientific theories. That is, while the proportion of true and successful scientific theories outweigh the false but successful scientific theories, the absolute number of false but successful is larger than true and successful scientific theories. Thus, pessimistic induction without considering the base rate of true theories in the past concludes that success of scientific theory isn't reliable guide to its truth.

Pessimistic induction commits turnover rate fallacy as well. The simple fact of time passing increases the accumulated number of false scientific theories. Pessimistic induction ignores this fact and tries to pull its inductive strength from it. It treats the past scientific theories as one whole bundle to make its erroneous conclusion. However, if it is going to be an induction generalization about the fate of current theories, it needs to show that past scientific theories each seen separately in their time period support its claim. That is, it needs to be shown that within a specified historical period the number of false scientific theories outweighs the true ones as evaluated by the standard current science. If the specific period from the past contains more false theories than true ones as seen from perspective the present science, then there is precisely inductive support for pessimistic induction. Unfortunately, proponents of pessimistic induction failed to show that there are such cases of historical periods and they only argued by lumping the past scientific theories as one unit.

Even when I pass my tussle over the fallaciousness of pessimistic induction, it is a weak inductive argument. Inductive arguments draw their strength from two resources. One is from random sampling of the evidence or phenomena which will be used to test ones hypothesis. Two is from shared casual and natural properties of the sampled phenomena to the rest of the phenomena. The sampled phenomenon is a suitable representation of the rest of its kind. Pessimistic induction has neither of them. The historical examples that were used to construct pessimistic induction were non-randomly and purposively selected because they were suitable for its conclusion. Laudan and others didn't randomly sample from the total of past theories to test the hypothesis that success of scientific theory points to the truth of the theory. On the second point, past successful scientific theories are diverse from each other and from the current scientific theories. As such, there is no shared causal and other attributes that can be used for inductive generalization of the second kind. As a result, pessimistic induction is not sufficiently strong to warrant its bold conclusion.

6.2 Scientific Realism and Underdetermination of Theory by Data

Holist underdetermination argued that scientific theory choice is not constrained by empirical evidence. As a result, there is no reason to privilege one scientific theory as true and referential while leaving others out. Using deductive methods, if a scientific theory entails evidence, it is confirmed by it. That is, in the face of recalcitrant evidence it remains open which part of scientific theory is false. Furthermore, the theory can made to be compatible or entail that evidence with slight or radical modification of one of its hypothesis and background assumptions. Such framework of sorting theory and evidence relation is not up to the task of locating the specific false hypothesis or comparing the degree of confirmation of one theory over the other by a given body of evidence.

As I argued in the chapter three, what is needed in order to defend scientific realism from holist underdetermination is a shift in confirmation methods of scientific theories to Bayesian confirmation methods or to hypothesis testing by Bootstrapping method. Subjective Bayesian confirmation method is able to tell us which statement to reject in the face of contradicting evidence. Furthermore, with Bayesian confirmation we are able to explicate when conjunction of a hypothesis of an established theory and an auxiliary assumption are rejected by evidence, why practising scientists usually blame the auxiliary assumption. Contrary to Duhem-Quine thesis, Bayesian confirmation provides us with clear solution which hypothesis to reject and which hypothesis to accept. Hypothesis testing by Bootstrapping will single out as to how evidence bears on a specific hypothesis of a theory as well. A variety of evidences using Bootstrapping method test the various hypothesises of a theory, one hypothesis at a time while holding others as given. Bootstrapping method of hypothesis testing of theory is able to make sense of why certain portions of theories are taken to be true while other portions are taken as doubtful. Thus, both subjective Bayesian confirmation method and Bootstrapping method are able to test in isolation each hypothesises of a theory. And they are able to assign blame or confirmation for each hypothesis depending on how it fares relative to the evidence.

Empirical equivalence underdetermination claims that there is more than one scientific theory that gets equal confirmation from single set of evidence. There are alternative scientific theories that have no ontological commitment to unobservable entities but are empirical equally adequate to the scientific theories that postulate the existence of unobservable. Furthermore, it is able to provide algorithmic variety of scientific theories that are empirically equivalent to a realist scientific theory. Thus, it argues that we have no ground to privilege realist scientific theories

It my view that empirical equivalence underdetermination is weak and unsustainable. On one hand empirical equivalence is based on rejected clear cut distinction between observational and theoretical (non-observational) phenomena and on other hand it assumes a stable set of auxiliary hypothesis which are needed to derive observational consequence of a theory. However, as I have shown in chapter one and three, there is no clear boundary between observational and non-observational phenomena and the set of background auxiliary hypothesis is changing depending on the state of science. Furthermore, algorithmic constructions of empirical equivalent alternative scientific theories to a scientific theory are not genuinely independent rivals. Rather, to me, they are parasite or dependent on the original scientific theory to have their theoretical content. This is reflected in the dearth of independent and alternative scientific theories to originally formulated scientific theories in actual scientific practice. Even if, two genuinely independent scientific theories are empirically equivalent at certain point in time, it doesn't mean that they will remain so at later time. That is, it highly likely that there will be a new evidence which confirms one theory but not the other. It is highly likely that one theory can cohere with another new theory and will have new observational evidence while the other fails to do so. As a result empirical equivalence underdetermination ignores the fact that it is highly probable that there will be discerning evidence in future for currently empirical equivalent theories.

Underdetermination from unconceived alternatives argues it is highly likely that there will be alternative scientific theories that are not presently conceived which are confirmed by the same evidence of the currently accepted scientific theory. Accordingly, history of science is evident to this fact. At later time, novel scientific theories emerged that were confirmed by identical set of evidences which confirmed earlier accepted scientific theories.

In my view, underdetermination from unconceived alternatives is reconcilable with scientific realism. The presence of currently unconceived and future scientific theory that is confirmed by the same evidence of the currently accepted scientific theory is explicable through truth-likeness. As such, those future scientific theories and the current scientific theory can be evaluated for the degree of approximation to the truth. The future alternative scientific theory that is more truth-like than the presently accepted scientific theory and is confirmed by similar evidence as current one isn't a threat to scientific realism. Rather, the emergence of more truth-like scientific theory in the future that is not presently conceived is a reflection of the progress of science across time. Therefore, Contrary to the wish of anti-realists, presently unconceived future alternatives support the convergence thesis of scientific realism.

Entity realism and structural realism have additional strength in answering the challenge of underdetermination. Entity realism doesn't take all entities of successful scientific theory as independently extant entities. Rather, it takes to be real only those entities of a scientific theory involved in causal explanation and have demonstrated causal properties. Entities whose properties are manipulated and intervened in order to detect other aspect of nature have given us the best possible evidence for our epistemic scientific realism about them. In my view, the stringent standard for reality of theoretical entities in entity realism will filter out myriad possible alternative scientific theories. As a result, entity realism is able to block the possibility of underdetermination of theory by data.

I argue that for structural realism the question of underdetermination does not arise, since in it the fundamental constitutive future of reality is structural relations not the relata. As such, the relevant question for structural realism is which among scientific theories model best the structure of the reality than others. Scientific theories that have similar structure or are symmetrical reflect the same objective structure of the world. Two scientific theories with distinct scientific entities but are symmetrically transformable with respect to each other using group theory or some other method represent one and the same objective world. Individual entities and their internal properties are forever foreclosed from scientific knowledge on epistemic structural realism. And in ontic structural realism individual entities are either eliminable to the structure or have only relational properties. On all faces of structural realism, there is no problem of underdetermination over whose scientific theory unobservable entities to choose relative to a given body of evidence.

Thus, to me, while scientific realism has bright prospect, it needs to concede and modify two things. First, it needs to leave behind the full-fledged standard explanatory scientific realism that is articulated by Putnam and Boyd. That is, inference of objective existence to all entities of a scientific theory from its predictive and explanatory success is not tenable. In addition, I argue that it needs to adopt Bayesian or Bootstrapping method of confirmation method. In my view, it is these two methods that have a greater accuracy in discerning the degree and the kind of relation between theory and evidence.

As an end note, I hold that the metaphysical, epistemic and semantic thesis of competent scientific realism is defensible in two ways. In the First way, the content of scientific theories that are taken to be real is limited to the essential or working posits of successful scientific theory; to entities of scientific theories that have causal warrant; and to entities of scientific theories that are Robust. In the second way, it is by radically shifting what is metaphysically fundamental and what is epistemically accessible in scientific theories. As I have shown in the preceding pages, in structural realism successful scientific theories model the fundamental structural relations that are found in the world. Individual entities of scientific theories are ontological secondary and are reducible to the structure or only have relational identity. While structural realism is a radical change in the ontology of scientific theories, it makes scientific realism in its selective form indomitable to pessimistic induction and underdetermination. That is, structural realism has deflated pessimistic induction and underdetermination by making both objections irrelevant to it. In my view from the above three kinds of selective scientific realisms, one might be chosen by separate semantic, epistemic and metaphysical considerations that are unrelated to pessimistic induction and underdetermination.

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