CHAPTER 5: IS GENUINE THEORY CHOICE POSSIBLE?

5.1 Introduction

Relativism is a long-lasting thesis ever since the time of Ancient Greek Philosophy. During the course of debate, relativism has evolved into various versions. As elaborated in Chapter 4, it is seen that epistemic relativists hold that scientific theories emerge dependently on cultural or psycho-sociological context. From the perspective of relativist, the contextual scientific theory is legitimated not solely by reason, but largely by the irrational factors such as psychological, sociological, cultural and subjective aspects. As claimed by relativists, these irrational factors could not be (universally) rationalized and thus provide no common evaluative standards for theory choice. As a consequence, theory choice between two rival theories which emerge in different contexts will be inevitably arbitrary.

The challenge faced by relativist is thus unfolded in this way: is genuine theory choice possible? Notably, it is a question which is distinct from the question of "is theory choice possible?" For relativist, theory choice is possible in the sense that a scientist could make a choice under any circumstances—although it is inevitably an arbitrary choice. With this response from relativists, one may reasonably ask: does an arbitrary choice count as a genuine choice? Presenting a child with two rival theories, he may perform a random choice despite the fact that he is not equipped with the required knowledge. Isn't relativist's stance on arbitrary theory choice analogous to the random choice made by a child? If it is so, we may conclude that genuine theory choice is impossible.

Relativists may reply that the arbitrary choice, which is context-dependent, made by a scientist is different from the random choice made by a child. He may argue that a genuine theory choice is the one which requires relevant knowledge as the prerequisite. Scientists who choose arbitrarily between two rival theories need to have the specific knowledge to identify that those rival theories are context relevant (e.g. able to identify which paradigm a theory is subsumed under), so that they would not beg the question. Further, relativists may still argue, a scientist's theory choice is not only possible but genuine, and thus different from the random choice of a child, in the sense that he can tell why and how two rival theories are distinct. A well-trained scientist is able to specify the different contexts under which a theory is acceptable.

However, knowledge itself does not suffice to show that whoever possesses it can possibly make a genuine theory choice. One may know a discipline inside out, yet he may not have a rational ground to make a theory choice if the rival theories emerge from different contexts (e.g. different paradigms). As widely recognized, the lack of a common rational ground for theory choice renders relativist choice arbitrary and irrational. Speaking of genuineness of theory choice, it is expected that there exist certain rational grounds for arbitrating between rival theories. Although relativist's appeal to non-rational factors in accounting science has rejected foundationalism and rationalism, a genuine theory choice is still possible if there is genuine disagreement among scientists. Genuine disagreement refers to rational epistemic disagreement on the theoretical content of theories among scientists who are working within the same context when they are presented with rival theories. Scientists can justify their disagreement in theory evaluation despite the fact that their ways of doing science may be influenced by cultural and psychological factors. The emergence of genuine disagreement among scientists can be seen as an indicator of rationality in theory choice.

An important factor that deters genuine theory choice is originated neither from the knowledge of scientist nor from the irrational criteria; indeed, it is a factor that originates from the rival theories. A scientist with good knowledge who applies rational criteria for theory choice may not make a genuine theory choice should the rival theories are indistinguishable epistemically from the original theory. That implies that a rational criterion for theory choice does not warrant a rational outcome, i.e. the chosen theory may not be always superior to its rivals. Section 5.2 is devoted to the discussion of this issue. I discuss, in Section 5.3, whether a rival-generating algorithm has any teeth in defending a relativist notion of theory choice. A concluding remark for this chapter is given in Section 5.4.

5.2 Indistinguishable Rival Theories

Relativists always claim that there is no rational way to arbitrate between rival theories. As shown by Duhem-Quine thesis of underdetermination, relativists argue, scientific theory is inevitably underdetermined by evidence. The appeal to methodology and logic offers no solution to a rational theory choice. Scientists have no rational grounds to make a choice by weeding out the false theories, because the holistic nature of theory prevents one to deduce the falsity of a theory from the failure of that theory in making a correct prediction. There is no way to know which auxiliary assumption is responsible for the failure of a correct prediction. Hence, relativists claim that evidence is never sufficient to force the rejection of any theory, therefore no rational theory choice is possible.

By invoking the thesis of underdetermination against rational theory choice, relativists presuppose that all scientific theories are a priori equally good. This presupposition confers all rival theories the same epistemic value, for otherwise one would be able to make a rational theory choice if one theory is superior to the others. Despite the a priori equal status of all scientific theories in terms of epistemic value, they may have unequal non-epistemic evaluative value, such as simplicity, aesthetics, and coherence, which cannot be judged in a rational way.

Does this presupposition that all scientific theories are a priori equally good valid? If it does, we have to admit the fact that rational theory choice is impossible a priori, as all rival theories are a priori equally good and indistinguishable in terms of their epistemic merits; further, we have to also admit that rational choice is impossible a posteriori, as demonstrated by the underdetermination thesis that no evidence can determine a choice. As a consequence, it would seem that relativism about theory choice is persuasive.

Laudan has posed a challenge to this presupposition of the equal epistemic value of theories. He calls it the egalitarian thesis (Laudan 1998). He defines it such that "every theory is as well supported by the evidence as any of its rivals." (Laudan 1998, 324), and attributes it to Quine's formulation of underdetermination. Laudan claims that it is this egalitarian thesis which is championed by relativists that makes them find support in the underdetermination thesis against rational theory choice.

Egalitarian thesis which is held by relativists, according to Laudan, is a strong argument asserting that all theory, without exception, is equally good in terms of their evidential support. It is coupled with the thesis of empirical equivalence, which states that every theory has equivalent rivals, to arrive at the underdetermination thesis. Laudan holds that both egalitarian and empirical equivalence thesis are too strong as they are applied to all theory. Both theses hold that, given an evidence *E*, one cannot arbitrate between candidate theories because any theory and any of its rivals are equally supported by *E*. From the standpoints of relativist, it is not enough that at least some rivals are supported by *E*, because it would make a rational theory choice possible since there are some theories which are superior to others. To consistently maintain that rational theory choice is impossible, relativists must hold that all rival theories are equally supported by empirical evidence. Relativist account of the egalitarian thesis, and the claim of the impossibility of rational theory choice, would become untenable if one is able to show that at least one theory could demonstrate a greater evidential support than other rivals.

The mistake of the relativist egalitarian thesis, contends Laudan, is that its arguments for the case of empirical equivalence and underdetermination of theory by evidence are based "a priori and wholesale by philosophical legislation or fiat." (Laudan 1988, 137) Laudan maintains that there is no reason for one to presuppose a priori that all theories are equally good in terms of evidential support. Instead, this issue "must always be settled in terms of a detailed knowledge of the case in hand, and each case must be separately argued for.” (Laudan 1988, 137). Laudan, together with Leplin, has given a detailed elaboration on this claim (Laudan and Leplin 2002) based on three theses: the variability of the range of the observable (VRO), the need for auxiliaries in prediction (NAP), and the instability of auxiliary assumptions (IAA). Laudan and Leplin demonstrate that the proper understanding of these three theses will dispel the thesis of empirical equivalence and the relativist egalitarian thesis.

Laudan and Leplin formulate the thesis of the VRO as such:

> Any circumscription of the range of observable phenomena is relative to the state of scientific knowledge and the technological resources available for observation and detection.
>
> (Laudan and Leplin 2002, 364)

The thesis of VRO is a thesis that concerns the boundary between observables and unobservables. Laudan and Leplin agree with the traditional view that the boundary between observables and unobservables is dynamic, as the improvement of experimental methods and instruments will make the previously unobserved entities observable. Hence, there is no fixed range of the observable. The class of observable phenomena undergoes changes in the course of scientific development. Laudan and Leplin argue further that this variability of the range of the observable implies the implausibility of the empirical equivalence between rival theories; for the dynamic boundary of observable/unobservable will introduce new evidence into any theory as science progresses, which results in the empirical inequivalence between a theory and its rival.

The admission of the thesis of VRO is necessary but insufficient to refute the empirical equivalence thesis, because relativists may trivially construct auxiliary assumptions to resume the empirical equivalence of any two rival theories. Having recognized this, Laudan and Leplin formulate the thesis of the need for auxiliaries in prediction (NAP), as such:

> Theoretical hypotheses typically require supplementation by auxiliary or collateral information for the derivation of observable consequences.
>
> (Laudan and Leplin 2002, 364)

Laudan and Leplin agree with the relativists that auxiliary assumptions are required to derive the observable consequences, while they disagree that any auxiliary assumption could be counted as epistemically significant. Opposing the construction of auxiliary assumption in an ad hoc way, Laudan and Leplin assert that the empirical equivalence of any two rival theories is not always warranted.

> The empirical commitments of theories depend……on what auxiliaries are epistemically available to the scientific community. One is not free to pick and choose one's auxiliaries depending on what theory one wants to credit, in utter disregard of what collateral beliefs enjoy independent support. For then there could be no fact of the matter as to whether any two theories are observationally equivalent…..
>
> (Leplin and Laudan 1993, 14)

In addition to the theses of VRO and NAP, Laudan and Leplin formulate the thesis of the instability of auxiliary assumptions (IAA) in their attempt to refute the empirical equivalence thesis[1]:

> Auxiliary information providing premises for the derivation of observational consequences from theory is unstable in two respects: it is defeasible and it is augmentable.

(Laudan and Leplin 2002, 365)

Similar to the range of the observable, the range of the auxiliary content is variable. Laudan and Leplin recognize that new auxiliary assumptions could be added to, and the existing auxiliaries could be removed from, the theoretical systems over time. This fact suggests that the empirical equivalence of any two rival theories is not warranted as claimed by relativists. It is so because when new auxiliary assumptions are added to, or removed from, a theoretical system, the observational consequences deriving from the auxiliaries also change accordingly. Thus, there is no warranty that two once empirically equivalent rival theories could share the same empirical content when the class of auxiliary has changed over time.

By appealing to these three theses (VRO, NAP, and IAA) in attacking the thesis of empirical equivalence, Laudan and Leplin do not make explicit the point whether they have interpreted the empirical equivalence as a temporal or an atemporal thesis. However, it appears that the VRO and IAA are taken to be the temporal thesis, for Laudan and Leplin assume that the range of observables and auxiliary assumptions changes over time[2]. It is so interpreted by Kukla in his articles (Kukla 1993; 1996) which aim to defend the empirical equivalence thesis by refuting Laudan and Leplin's argument.

> Laudan and Leplin's argument differs from its ancestor by introducing a temporal dimension: even if T_1 and T_2 have the same empirical consequences under the *current* auxiliaries, this fact would not establish their timeless empirical equivalence, since there are possible states of future science in which the new auxiliaries permit an empirical discrimination between them to be made.
>
> (Kukla 1996, 143)

Kukla adopts two strategies in his defense of the empirical equivalence thesis. First, he demonstrates that Laudan and Leplin's repudiation of the empirical equivalence thesis fails to achieve the intended aim. He contends that there is no sensible reason for rejecting the empirical equivalence thesis even Laudan and Leplin's argument is plausible. Second, Kukla provides a reason for accepting the empirical equivalence thesis by demonstrating that there are indefinitely many empirically equivalent rivals, which could be constructed in an algorithmic way, to any theory.

Kukla's defense of empirical equivalence is based upon the assumption that Laudan and Leplin's arguments contain a temporal dimension; that is, the theses of VRO and IAA have implicitly granted that there is a possibility for any theory to be observationally discriminated from its rival over time[3]. This temporal dimension of the range of observables and auxiliaries, according to Kukla, implies a relation between time-indexed theories; that is to say that the epistemic status of a theory is time-dependent. It is so because the range of observables and auxiliaries varies in the course of scientific development. To refer to the epistemic status of a theory, according to Kukla's construal of time-indexed theories, one need to locate the status of that theory's observables and auxiliaries in time. Kukla's indexical construal of Laudan and Leplin's argument is well-established because it is consistent with their arguments that the range of observables and auxiliaries changes over time.

> Alternatively, however, one could say that Laudan and Leplin's point about non-fixity demonstrates that the notion of empirical equivalence needs to be construed as a relation between indexed theories –i.e. triplets consisting of a theory, a partitioning of phenomena into observables and non-observables, and a specification of the permissible auxiliaries.

(Kukla 1993, 2)

Kukla's indexical construal of Laudan and Leplin's argument is further supported by their claim that the notion of empirical equivalence must be relativized to a particular state of science. Such state of science, apparently, has a temporal dimension, and thus theory is inevitably time-indexed. Laudan and Leplin state that:

> … any determination of the empirical consequence class of a theory must be relativized to a particular state of science. We infer that empirical equivalence itself must be so relativized, and, accordingly, that any finding of empirical equivalence is both contextual and defeasible. This contextuality shows that determinations of empirical equivalence are not a purely formal, a priori matter, but must defer, in part, to scientific practice.
>
> (Laudan and Leplin 2002, 366)

Kukla argues that Laudan and Leplin's theses of VRO and IAA, as they are time-indexed, are not convincing to compel the proponents of the empirical equivalence thesis to change their mind; for at best it just forces the proponents of empirical equivalence to "substitute a relativized notion [i.e. time-indexical notion] of empirical equivalence for their absolute notion, but that it leaves everything else in the received view the same." (Kukla 1993, 2) What Kukla implies is that Laudan and Leplin's argument about the variability of the range of observables and auxiliaries does not make empirical inequivalence prevalent in science as time goes by. It is because as theory is to be interpreted as time-indexical, its epistemic status is corresponding to the observables and auxiliaries, which are also time-indexical. In any particular point in time, any theory always has its empirically equivalent rivals. Although empirically equivalent theory T_1 and T_2 may be distinct as new evidences accrued and new auxiliaries added, they are still doomed to be empirically equivalent with some other rivals at any temporal point. To illustrate, assume that theory T_1 and T_2 are empirically equivalent at time t_1. Although both theories may be empirically distinct at t_2, it is plausible that T_1 and T_2 are now empirically equivalent to some other theory, say T_3 and T_4, respectively. Consequently, the range of the candidates for theory choice is also varying across different temporal points. Despite the candidate of theory choice is different at different point of time (T_1-T_2 pair at t_1; T_1-T_3 pair and T_2-T_4 pair at t_2), the thesis of empirical equivalence is still undefeated.

> Suppose that I believe that for every theory T_1, there is an empirically equivalent theory T_2, and that I am confronted with their [Laudan and Leplin's] argument. The fact that the auxiliaries can change might impel me to reconstrue the notion of empirical equivalence as a relation between *indexed* theories—i.e., couples consisting of a theory and a specification of the permissible auxiliaries. But there is nothing in the argument that would force me to give up the view that every *indexed* theory has empirically equivalent rivals with the same index.
>
> (Kukla 1996, 142)

According to Kukla, admitting the variability of observables and auxiliaries does not force the proponents of empirical equivalence to give up their view. For the phenomenon of empirical equivalence is still valid between time-indexed theories.

> … if you believed that every theory has empirical equivalents before encountering Laudan and Leplin's objections, then you should now believe that every indexed theory has empirically equivalent theories with the same index.
>
> (Kukla 1993, 2)

> Belief in EE [empirical equivalence] is the belief that, whatever the new theories may be, it will always be possible to find (eternal) empirical equivalents to them.
>
> (Kukla 1996, 144)

Kukla's indexical interpretation of Laudan and Leplin's argument not only demonstrates that the admission of the variability of observables and auxiliary assumptions fails to refute the thesis of empirical equivalence; it also persuasively confers an a priori status to empirically equivalent theory—which is a relativist tenet opposed explicitly by Laudan and Leplin. As widely agreed by philosophers, indexicality always "generate certain kinds of a priori truths" (Cappelen and Lepore 2002, 276), because "indexicals are linguistic expressions whose meaning remains stable while their reference shifts from utterance to utterance." (Cappelen and Lepore 2002, 271) Kukla's use of temporal indexicality sets the empirical equivalence of two rival theories on a fixed temporal point (e.g., time t_1). He argues that by referring to a particular temporal index (e.g., time t_1), there always exist some theory T_1 which is empirically equivalent to some rival T_2. By admitting Laudan and Leplin's argument of the variability of observables and auxiliaries, the fact that T_1 is empirically distinguishable from T_2 does not break the state of empirical equivalence at another temporal index (e.g., time t_2); for T_1 is inevitably empirically equivalent to some other rival, say T_3, at the new temporal index t_2. Hence, we may safely conclude that at any temporal index t_n, there always exist some empirically equivalent theories in science. As such, we may safely conclude that, although it was not spelled out by Kukla, empirical equivalence of theory is an a priori phenomenon. Notably, we arrive at this a priori conclusion by admitting Laudan and Leplin's claim that observables and auxiliaries are changeable over time, yet defeat their claim that the empirical equivalence thesis is untenable on an a priori ground. Laudan and Leplin's argument is too feeble to rebut Kukla's defense of the empirical equivalence thesis, for their claim on the variability of observables and auxiliaries is characterized by temporal indexicality.

Laudan and Leplin have recognized the robustness of Kukla's argument. They objected Kukla's temporal indexical reading in their subsequent reply (Leplin and Laudan 1993), claiming that empirical equivalence should always be interpreted as an atemporal thesis.

> EE [Empirical Equivalence] is clearly intended, by proponents and detractors alike, as an atemporal thesis, and we have so interpreted it. It denies for any theory the possibility of (ever) observationally discriminating it from some rival theory.
>
> (Leplin and Laudan 1993, 8)

According to Leplin and Laudan, empirical equivalence is an atemporal thesis because it is a claim that denies the empirical divergence of observational consequence class, whereby this denial is independent of temporality. That is, regardless of being at any temporal point *t*, the meaning of empirical equivalence is invariable. They argue further:

> Thus suppose that two rival theories have hitherto appeared to have all the same empirical consequences. If we now discover a test, performable or not, for which those theories predict different outcomes, the conclusion is that they are not (atemporally) empirically equivalent after all, not that they are no longer equivalent or would no longer be were the test performed.
>
> (Leplin and Laudan 1993, 8)

Leplin and Laudan attempt to defend in a way that empirical equivalence, as a concept, does not have temporal attribute in its meaning. That is to say, the meaning of empirical equivalence is not changeable with time. However, they sometimes confused between the invariable meaning of empirical equivalence and the empirical state of theories. They seem to imply that we should judge the empirical state of two rival theories at some temporal point *t*, regardless of whether these rivals are empirically equivalent in the earlier temporal point. From the quoted paragraph above, it appears to them that although two once empirically equivalent rival theories could evolve to become empirically inequivalent as time goes by, such transition does not endure in time. The transition is discrete. Suppose that theory T_1 is empirically equivalent with T_2 at time t_1, they may be empirically inequivalent at t_2. For Leplin and Laudan, T_1 is not "becoming" empirically divergent from T_2. It is because, according to Leplin and Laudan, a temporal transition requires differential change of T_1 and T_2. However, both rivals must change identically. Thus, the non-differential change of two theories leads Leplin and Laudan to claim that the empirical equivalence is atemporal.

> If two theories are empirically equivalent, then their observational consequence classes can never diverge; the content of their (common) observational consequence class can change, but it must change *identically* for both theories.
> (Leplin and Laudan 1993, 8)

Leplin and Laudan imply that a previously proclaimed empirically equivalent pair of theories, which later turns empirically inequivalent, should not be interpreted as "becoming empirically inequivalent". Instead, they implicitly maintain that one should judge the empirical status of rival theories at a later temporal point; for they hold that the empirically-equivalent-turned-empirically-inequivalent theories "are not (atemporally) empirical equivalent after all" (Leplin and Laudan 1993, 8) at a later temporal point. They intend to demonstrate, though they fail to make clear, that the meaning of a concept (i.e. empirical equivalence) is not changeable with time. They further take it for granted that the empirical status of two rival theories is not evolving with time. What makes a pair of empirically equivalent rival theories *turn* empirically inequivalent is not an epistemic transition. Though Leplin and Laudan do not claim that it is a cognitive transition, their argument seems to favor this assertion. For they imply that a final judgment on the empirical status of rival theories should be made at some later temporal point.

However, Leplin and Laudan's defense is unpersuasive because of two reasons. First, they ignore the fact that the empirically-equivalent-turned-empirically-inequivalent theories have endured in time, from t_1 to t_2. Though they are right in saying that empirical equivalence, as a concept, is invariable in its meaning in time, they are wrong to conclude that the rivals are not undergoing transition in the observational consequence class in time. Second, Leplin and Laudan's defense is feeble in the sense that there is no way to identify the best judgment time t when confronted with two empirically equivalent rival theories. As required by their argument, two empirically equivalent rivals should be judged at some later time so that one may conclude if they are eventually empirically inequivalent. But when is this judgment time? It is impossible to set this later temporal point because two rivals may be empirically equivalent forever. Furthermore, it is also possible to have a case where two empirically-equivalent-turned-empirically-inequivalent rivals turn empirically equivalent again as science progresses. Leplin and Laudan's hope to have a final judgment on the empirical status of rival theories is indeed hopeless.

Leplin and Laudan's reply to Kukla fails to justify the claim that empirical inequivalence of rival theories is prevalent in science. Their defense is centered on the analysis between two *particular* rival theories T_1 and T_2 along the scientific development, which leads them to conclude that these two theories may be empirically inequivalent as new empirical evidences are added and the range of auxiliary assumptions is augmented.

However, Kukla argues in another way that although these two theories, T_1 and T_2, may be empirically inequivalent as time goes by, the phenomenon of empirical equivalence is still prevalent as these theories may be empirically equivalent with some other theories, say T_3 and T_4, respectively. For Kukla, Leplin and Laudan's argument of the variability of observables and auxiliaries does not expel the phenomenon of empirical equivalence from science, although he may agree with Leplin and Laudan that a *particular* pair of empirically equivalent rivals may be turned empirically inequivalent. If Kukla is right, underdetermination of theory by data would be prevalent, and the rational theory choice would be impossible for at least some theories.

However, Leplin and Laudan have their point in their defense against the relativism and the impossibility of rational theory choice. Laudan claims that a sensible and consistent relativist must hold an extreme claim that "there are *never* objective grounds for choosing between *any* two theories" (Laudan 1988, 118). This extreme claim warrants the impossibility of objective theory evaluation, thereby supports relativist tenet in the problem of theory choice.

> If relativism is to have any teeth in it, it must assert that *all* genuine theories are on a par epistemically. More importantly, if the relativist commits himself to anything less than such a thesis, then he is, in effect, acknowledging that *some* theories are objectively superior to certain others. Such an admission would undermine the force of the relativist's challenge to the objectivist element of traditional epistemology.
>
> (Laudan 1988, 119)

In Leplin and Laudan's reply to Kukla's attack, they somehow successfully show that rational theory choice is possible for at least some rival theories. As time goes by, the empirically equivalent rivals T_1 and T_2 may turn empirically inequivalent, where the rational choice is possible between T_1 and T_2. Although Kukla holds that the empirically-equivalent-turned-empirically-inequivalent T_1 and T_2 are always in a state of empirical equivalence with other theories (e.g. T_3 and T_4, respectively), he does not demonstrate that it is a fact in science. Kukla's point is somehow ad hoc, and it was recognized by Hoefer and Rosenberg as "bizarre construction" and should not be counted as genuine rivals (Hoefer and Rosenberg 1994). Furthermore, Kukla's argument does not fully support a consistent relativist account even if we admit his claim that empirical equivalence is always prevalence in science. For, as demonstrated by Leplin and Laudan, Kukla's argument does not prevent the empirical inequivalence between any two rival theories. Consequently, rational theory choice is at least possible for *some* rival theories. It is sufficient to defeat the relativist claim that there are no objective grounds to arbitrate between *any* two theories. Moreover, even if empirical equivalence is the case in science, the problems of underdetermination and theory choice do not necessarily follow (Stanford 2001; Laudan and Leplin 2002) because empirical evidence is not the only factor in arbitrating between two rival theories.

Whether Kukla's argument of the prevalence of empirical equivalence is a fact in science can indeed be disputable. One may reasonably raise the doubt whether there are genuine cases of empirically equivalent theories in science. Hoefer and Rosenberg concur with Leplin and Laudan that one should not consider conceptually equivalent rival theories as genuine rivals, because these theories do not exist despite it makes sense to believe their existence given the fact that they entail the same evidence (Hoefer and Rosenberg 1994).

Such theories are spurious rivals because one may trivially conceive of infinitely many conceptually equivalent rivals to any particular theory. This issue will be discussed in the next section.

5.3 Algorithmically Generated Rival Theories

Contra to Leplin and Laudan, and Hoefer and Rosenberg, Kukla is well-known for his firm stance in maintaining that empirically equivalent rivals can be generated algorithmically to any theory in science, each of which is not epistemically trivial, and hence should not be dismissed in the debate of the underdetermination thesis. His arguments were elaborated at length in his papers (1993, 1996, and 2001). Strikingly, Kukla endorses a strong version of algorithm theory of empirically equivalent rivals, claiming that an algorithm can be constructed to generate "indefinitely many empirical equivalents to any theory" (Kukla 1993, 1). Kukla attempts to demonstrate that such an algorithm is universal, which is not invented by him but "it seems to belong to the philosophical public domain." (Kukla 1993, 4). Admitting the prevalence of the rival-generating algorithm, Kukla intends to show that the phenomenon of underdetermination is prevalent in science. Notably, Kukla's attribution of the algorithm as prevalent in "philosophical public domain" seems less convincing to show that this algorithm is real and has scientific significance. In fact, Kukla's argument would be more robust if he claims that the rival-generating algorithm belongs not only to "the philosophical public domain" but also to the scientific public domain.

In his 1993 paper written in response to Laudan and Leplin's famous *Empirical Equivalence and Underdetermination*, Kukla's proposal of a rival-generating algorithm is a gambit that provides a reason for accepting the empirical equivalence thesis which is rejected by Laudan and Leplin. Algorithmically generated empirically equivalent rival theories may motivate relativism, which is a scenario that concerns Laudan and Leplin. For Laudan and Leplin, the proposal of a rival-generating algorithm is an instrumentalist move that does not yield genuine rivals to any existing theory. Despite the possibility of such algorithms producing empirically equivalent rivals, Laudan and Leplin are skeptical about their empirical success, given the effects of the variability of the range of observables and the instability of auxiliary assumptions in the course of scientific development (Laudan and Leplin 2002).

> Another approach is to construct an algorithm for generating empirical equivalents to a given physical theory… For example, there exist instrumentalist algorithms for excising the theoretical terms of a theory without empirical loss. Whether such algorithms are in fact successful is rendered highly dubious by the premises of our argument. It is by no means clear that a theory's instrumentalized version can match its capacity for empirical commitment, once the role of auxiliaries in fixing such commitment and the variability of the range of the observable are acknowledged.
>
> (Laudan and Leplin 2002, 368)

According to Laudan and Leplin, algorithmically generated empirically equivalent rivals fail to attain the same empirical success of the genuine scientific theories. It is because the algorithmic rivals cannot account for the new discoveries, as new observables and auxiliaries are added to the knowledge base in the course of scientific development. As Laudan and Leplin put it, they are "univalued", because they operate on the original theory (Leplin and Laudan 1993). This limitation is further evidenced by their incapability to produce new applications as time goes by.

> At most a theory's instrumentalized version can be held empirically equivalent to it relative to a circumscription of the observable and a presumed or intended domain of application. But while theories fix their own intended interpretations, they do not fix their own domains of application, nor the resources for detection of entities they posit. Algorithmically excised references may pick out entities that become detectable. New applications may arise with changes in collateral knowledge. Indeed, it is a measure of a theory's success when posited entities acquire a technological role, and applications for which the theory was not designed become possible.
>
> (Laudan and Leplin 2002, 368)

Notably, the example of algorithm given by Laudan and Leplin is a type of algorithm that generates empirically equivalent rivals which have a lesser theoretical content than their original theory. These rivals are generated via a mechanism of excision of the theoretical references. Hence, this reflects the lines of thought of Laudan and Leplin that the algorithmically generated rivals cannot produce new applications, and thus apparently inferior to the original theory. It follows that these inferior rivals are not a real rival to a given theory because they are not on the same par epistemically. Despite these algorithmic rivals are empirically equivalent to a given theory, theory choice is not an issue here because these rivals are not genuine rival to the original theory. As argued by Laudan and Leplin, one does not need to worry about the indefinitely many empirically equivalent rivals to any theory, for they are not genuine rival theories. If anti-realists are to rely on algorithm thesis in their argument for the universality of underdetermination of theory by data, they will soon find that the underdetermination thesis is untenable given that any algorithmically generated rivals are not genuine scientific theory.

Hoefer and Rosenberg against Laudan and Leplin's view that there exist no empirical equivalence of any theories (Hoefer and Rosenberg 1994). This view is too strong to the extent that Laudan and Leplin have ruled out "as genuine rivals theories that are conceptually or logically equivalent… and instrumentalized theories that strip away some or all of the unobservable structure from an existing theory." (Hoefer and Rosenberg 1994, 596). Apparently, Hoefer and Rosenberg share the commitment of Kukla that conceptually or logically equivalent instrumentalized alternatives are the genuine rivals, but they diverge on two points. First, Hoefer and Rosenberg do not take Kukla's view of algorithmically generated rivals seriously. They claim that empirically equivalent rivals to a given theory can emerge naturally. Second, Hoefer and Rosenberg do not share with Kukla (and Laudan and Leplin) the meaning of genuineness for empirically equivalent theories. For Kukla, algorithmically generated empirically equivalent theories are always genuine; while it is not the case for Hoefer and Rosenberg. To count a theory as genuine, according to Hoefer and Rosenberg, one has to consider the ontology of the corresponding world. Two kinds of theory have been proposed by Hoefer and Rosenberg that correspond to the ontology of the actual world: local and global theories.

According to Hoefer and Rosenberg, the distinction of local and global theories needs to be made in order to better articulate the thesis of empirical equivalence and underdetermination. Local theories are partial and incomplete from the perspective of a unified theoretical system. Global theories, on the other hand, are "systems of the world" (Hoefer and Rosenberg 1994). These global theories are unified theoretical system which is sufficient to account for all phenomena in the actual world. Newtonian mechanics, quantum mechanics, and general relativity theory are among the examples of the global theories (Hoefer and Rosenberg 1994).

Hoefer and Rosenberg argue that the thesis of underdetermination of theory by data does not hold in the case of local theories. It is simply because these local theories are partial and evolving. Given two empirically equivalent rival local theories at a point of time, the state of empirical equivalence will be dismissed in the future as science progresses. This can be accounted by the fact that local theories do not correspond to the systems of world, for the former is partial while the latter is complete. Hence, Hoefer and Rosenberg conclude that the theses of underdetermination and empirical equivalence are not an issue in local theory. From the perspective of local theory, Hoefer and Rosenberg concur with Laudan and Leplin that empirical equivalence is not a real threat in science.

However, Hoefer and Rosenberg claim that underdetermination of theory by data is unavoidable in global theories. They criticize Laudan and Leplin for not seeing this threat in science. Underdetermination of global theories is characterized by the fact that all possible evidences that constitute the so-called "systems of the world" are equally supporting the logically distinct global theories. The global theories are complete and "comprehensively account for all observations—past, present and future" (Hoefer and Rosenberg 1994, 594). Notably, Hoefer and Rosenberg confer the global theories a status of final truth. It is not sufficient for a global theory to entail all possible and actual phenomena, indeed, it must be empirically confirmed as a true theory that corresponds to the systems of the world.

> By contrast, the thesis of underdetermination of theory by evidence is about empirically adequate total science; it is a thesis about what Quine calls "systems of the world"—theories that comprehensively account for all observations—past, present and future. It is a thesis about theories that entail all and only the true observational conditionals, all the empirical regularities already confirmed by observation and experiment.
>
> (Hoefer and Rosenberg 1994, 594)

Hoefer and Rosenberg's characterizing global theory as true theory makes their account of empirical equivalence differs from that of Laudan, Leplin and Kukla. Because all global theories are true, the emergence of genuine empirically equivalent global theories would render science in a serious threat. Laudan, Leplin and Kukla do not stipulate that empirically equivalent theories must be true. For them, the issue is whether empirical equivalence holds between any given theories, and whether any two empirically equivalent rivals (if any) are non-trivial epistemically. This difference between Laudan-Leplin-Kukla and Hoefer-Rosenberg lies in the fact that the former authors do not consider the theory completeness that the latter authors do. In their discussion of the thesis of empirical equivalence, the former authors regard theory as an evolving epistemic entity, while the latter authors view global theory as a completed edifice. According to Hoefer and Rosenberg, global theories as complete theories are empirically adequate, which entails all the past, present and future evidence. This view of empirical adequacy of global theory leads Hoefer and Rosenberg to repudiate Laudan and Leplin's argument of the Variability of the Range of Observable, the Need for Auxiliaries in Prediction, and the Instability of Auxiliary Assumptions (See Section 5.2 for a detailed discussion).

> Once we have acquired empirically adequate systems of the world, that is, theories that account for all observable events, any such variability becomes *ex hypothesi* moot. Either this variability has ceased, or if some remains, this variation is assumed not to lead to conflict with the system of the world in question.
>
> (Hoefer and Rosenberg 1994, 597)

> Given a purported system of the world, no such auxiliaries are either available or needed. The theory will *ex hypothesi* include all the resources needed to derive observations, and no auxiliary theory could be added to increase its observable consequences.
>
> (Hoefer and Rosenberg 1994, 597)

Because Hoefer and Rosenberg claim that global theories are true and complete, it is natural for them to conclude that algorithmically generated rival theories are trivial and spurious. For them, theory choice is not a problem when a scientist is faced with an algorithmically generated rival to a given global theory. She is expected to discard the algorithmically generated rival, because it is an inferior redundancy of the original, true global theory. Hoefer and Rosenberg even call the algorithmically generated theory a "cheap trick", because this alternative theory is not distinct compared to the original theory.

> Other examples of cheap tricks would be theories formulated with Goodmanized predicates, instrumentalized theories that make equivalent predictions by simply discarding the unobservable substructure, theories consisting of only the observation conditionals derived from the original, and so on.
>
> (Hoefer and Rosenberg 1994, 604)

According to Hoefer and Rosenberg, the problem of theory choice comes into picture when two empirically equivalent global theories are logically incompatible, and the "world must admit of at least one empirically adequate total theory." (Hoefer and Rosenberg 1994, 604) In addition, "all actual observable phenomena must be captured."

(Hoefer and Rosenberg 1994, 605) These conditions for the genuine empirical equivalence of global theories are not without problems. First, in view of the fact that Hoefer and Rosenberg take the system of the world as a unified reality, it is inconsistent for them to claim that there exist the non-algorithmically generated empirically equivalent global rival theories (e.g. Newtonian Mechanics vs. special theory of relativity). Because global theories, according to Hoefer and Rosenberg, are true and complete, choosing between them does not make a case of epistemic difference. Theory choice is underdetermined by the rival global theories that are equally true and complete. Besides, it remains a puzzle how two equally true and complete theories could be rivals in the first place. If, according to Hoefer and Rosenberg's lines of thought, global theories are stipulated to be true and correspond to the reality, it would be absurd to obtain two rival global theories that are both true but incompatible in their world picture. Hoefer and Rosenberg have two options: either (1) they adopt a relativist position by claiming that there are more than one true theories corresponding to the world; or (2) they should discard their claim that empirical equivalence and underdetermination of theory by data do arise in global theories. If they adopt (1), they would come to a conclusion that rational theory choice is impossible in the face of two rival global theories. However, if they adopt (2), it would undermine their main objective in demonstrating that empirical equivalence and underdetermination of theory by data are a real threat in global theories. Considering the fact that they have rejected the thesis of underdetermination of theory by data in the case of local theories, the underdetermination thesis will be dismissed as false issue if they have repudiated the case in global theories.

Hoefer and Rosenberg raise another possible problem that may lead to the dilemma of theory choice: the adherence of the world to the law of excluded middle. They hold that two incompatible global theories are always taking different side in the law of excluded middle. It is clear that they are mistakenly extending the law of excluded middle in propositions to the reality. The world that we inhabit does not follow strictly the law of excluded middle. Most physicists describe the reality as chaos, and they regard the data collected from experiment as fuzzy. Besides, some physical theory (e.g. quantum physics) does not, as assumed by Hoefer and Rosenberg, take side in the law of excluded middle. A famous thought experiment in quantum physics, i.e. Schrödinger's cat, is most illustrative of this example. According to this thought experiment, a cat that is kept inside a box equipped with a particle detector and radioactive elements could be said dead and alive, at a particular point of time. This two conflicting states—dead and living, are equally real at the quantum level, and the "resulting living and dead bodies both actually exist in different 'branches' of reality" (Tappenden 2004, 158). Apparently, the example from quantum physics seems to advance the relativist view on theory, that is, a theory which favors the dead cat is equally true as a theory which favors the living cat. Both theories are incompatible yet they are underdetermined by the evidence—the observation that the cat is dead and alive at the same time. In this example, the law of excluded middle does not hold, yet the evidence-based rational theory choice is impossible. For the law of excluded middle, as seen in the example of Schrödinger's cat, is not a necessary condition that leads to the problem of theory choice. Theory choice becomes a problem when one is faced with a reality with incompatible quantum states (e.g. dead cat vs. living cat which are equally real). If, as claimed by Hoefer and

Rosenberg, the problem of theory choice is the consequence in the face of competing global theories, they have to admit that the underlying conflicting reality is a contributing factor to the dilemma of theory choice. This implies that they have to abandon their claim that the reality is a unified system of world that adheres to the law of excluded middle, consequently leading them to relativism.

As I have argued that Hoefer and Rosenberg's claim that empirically equivalent global theories lead to the problem of theory choice is indefensible, I return to discuss whether algorithmically generated theories present a genuine problem of theory choice. As mentioned above, Hoefer and Rosenberg view the algorithmically generated theories as "cheap tricks", which they claim that one should not worry about it in scientific practice. Stanford has developed Hoefer and Rosenberg's distinction between local and global theories in his discussion of Kukla's algorithmic strategy.

Stanford has categorized rival-generating algorithms into local and global varieties (Stanford 2001). The difference between these algorithms lies in the source theory from which empirically equivalent rivals can be produced. Global algorithms can "produce empirical equivalents from absolutely any theory" (Stanford 2001, S2), whereas local algorithms can produce empirically equivalent rivals from a particular theory (Stanford 2001). Despite both types of algorithm can produce an infinite number of empirically equivalent theories, Stanford claims that both global and local algorithmically generated theories are trivial. Global algorithms lead to Cartesian skepticism, while local algorithms do not demonstrate the ability of generating substantial theories.

> But this [Kukla's global algorithm] is beside the point, I suggest, for *whether or not* such farfetched scenarios are real theories they amount to no more than a salient presentation of the possibility of radical or Cartesian skepticism. While many contemporary philosophers are inclined to grant the irrefutability of such skepticism, underdetermination was supposed to represent a distinct and important problem, arising perspicuously in the context of scientific theorizing about inaccessible domains of nature and troubling *even those who never hoped to defend their scientific beliefs to the truly radical skeptic*. Thus, if Cartesian fantasies are the only reasons we can give for taking underdetermination seriously, then there simply *is no* distinctive problem of scientific underdetermination to worry about, for the worry *just is* the familiar specter of radical skepticism.
> (Stanford 2001, S3)

> But such [local algorithm generated] empirical equivalents prove too little. The sensible realist will surely insist that we are not here faced with a range of *competing* theories making identical predictions about the observable phenomena, but instead just a *single* theory being conjoined to various factual claims about the world for which *that very theory* (along with the auxiliary hypotheses we accept) implies that we cannot have any empirical evidence.
> (Stanford 2001, S4)

Stanford's primary concern about scientific theory is not whether it is real (or useful), but whether it is free from Cartesian skepticism. Any theories with a flavor of Cartesian skepticism are classified as trivial theories. This is an adventurous move, because there is a possibility that a real or useful theory will be discarded as trivial due to that theory being too "skeptical". Notably, Stanford's use of the term "Cartesian skepticism" or "skepticism" is different from the common understanding of skepticism. By "skepticism", Stanford refers to a theory which is an "all-purpose alternative to any theory" (Stanford 2001, S2). The "skeptical" theory is generated by global algorithm. According to Stanford, this Cartesian skepticism can be found in Kukla's omnipotent algorithm which has the capacity to generating infinitely many alternatives to any theory. He calls this kind of algorithm a Cartesian fantasy. Stanford criticizes Kukla for allowing the algorithm to generate infinitely many rival theories which are, at least appearing to be, beyond the epistemic possibility. For it is too good to be true that there are all-purpose alternatives to any theory.

> Global algorithms are designed to produce empirical equivalents from absolutely any theory and are perhaps best exemplified by Kukla's (1996; see also 1993) appeals to such all-purpose alternatives to any theory T as T' (the claim that T's observable consequences are true, but T itself is false), T''(the claim that the world behaves according to T when observed, but some specific incompatible alternative otherwise), the hypothesis of the Makers (the debatably coherent fantasy that we and our apparently T-governed world are part of an elaborate computer simulation), and the hypothesis of the Manipulators (that our experience is manipulated by powerful beings in such a way as to make it appear that T is true). Kukla devotes his efforts to defending such proposals from the accusation… that they are not "real theories" at all.
>
> (Stanford 2001, S2-S3)

Notably, Stanford's understanding of the genuine rival theories is the ones which can threaten the truth status of a given theory. The alternative theories which do not pose threat to a given theory are not genuine rivals. Stanford uses the Newtonian mechanics as an example to elaborate the case of spurious rival theories. He claims that one can generate from Newtonian mechanics, denoted TN(0), an infinitely many empirically equivalent rivals TN(v), "where v ascribes some constant absolute velocity to the universe" (Stanford 2001, S4) . He contends that

> …empirical equivalents of the TN(v) variety pose no threat to the *approximate* truth of our theories: if the realist believes TN(0) when one of the various TN(v) obtains, *most* of her theoretical beliefs about the relevant domain will be straightforwardly true. Thus, empirical equivalents of the TN(v) variety show at most that we would have been unjustified in taking any stand on the constant absolute velocity of the universe, not in accepting the other theoretical claims of Newton's theory.
>
> (Stanford 2001, S4)

According to Stanford, a spurious rival theory which is different from a given theory in terms of their constants does not make a sufficient case to challenge the truth status of that theory. However, this is not always true. We can imagine an existing theory *T* with a constant *c*, which has less predictive accuracy compared with an algorithmically generated rival *T'* with a different constant *d*. In addition, history of science has demonstrated that introduction of new constants may revolutionize the existing theory. Planck's introduction of *h* constant is one of the most persuasive instances. Planck's constant accounts for the behavior of black body radiation, in terms of the proportionality of the energy content of quanta to the frequency of the radiation (Polkinghorne 2002; Treiman 1999). Planck's constant is contrary to the classical explanation of radiation, showing that Stanford's claim that the difference in constant does not make a rival theory genuine is obviously untenable. Further, the algorithmically or non-algorithmically generated constants of a rival theory can validate the theory's genuineness if it is a constant of nature. Planck's constant, although it might be conceived as spurious according to Stanford's definition of genuine theory, has been proved to be one of the constants of nature (Barrow 2007). Although Planck's constant was not generated algorithmically, it is somehow possible in principle to be generated by Kukla's algorithm, which is omnipotent to generate infinitely many rival theories with varying constants. The plausibility of Kukla's algorithm to generate Planck's constant is demonstrated by the capacity of that algorithm to generate "indefinitely many empirical equivalents to any theory" (Kukla 1993, 1). There are infinitely many constants that could be generated, trivial but equally valid, for they are empirically equivalent. It is plausible that one of the algorithmically generated theories is attributed with Planck's constant. Apparently, Stanford's rejection of rival theories with varying constants, and his accusation of Kukla's algorithmically generated theories, fails to show that these theories are not a genuine rival to a given theory.

So far it seems that algorithmically generated theories could serve as non-trivial rivals to a given theory. Consequently, empirical equivalence of rival theories will be prevalent and rational theory choice becomes impossible. Extreme relativistic consequences may thus follow, because the capability of an algorithm to generate infinitely many rival theories would lead to a scenario of Feyerabendian "anything goes" in theory choice. Not only there are infinitely many true theories, there are infinitely many pragmatic options in the face of rival theories (e.g. infinitely many simple theory, elegant theory, consistent theory, etc.). Conceivably, if rival-generating algorithm has any epistemic significance (it seems so as Stanford fails to refute it), relativistic attitude will be the only rational option in theory choice. It is because in the face of infinitely many empirically equivalent rival theories, realist and antirealist criteria of choice will not only be underdetermined by empirical evidences, but also by non-empirical factors such as simplicity, consistency and so on. This conclusion is conceivably derived from the fact that the omnipotent algorithm, which can generate infinitely many rivals to a given theory, can be extended to produce infinitely many empirical equivalents and non-empirical equivalents (e.g. simplicity-equivalents, consistency-equivalents, etc.)

Of course, one may reasonably object the extension of the algorithm's capacity by stressing that Kukla's omnipotent algorithm was initially proposed to generate only the empirical equivalents. She may rebut that it is too quick, and illegitimate, to attribute non-empirical equivalents to Kukla's algorithm. Below I will show how the power of generating non-empirical equivalents can be deduced from Kukla's algorithm.

Taking one of the algorithms that is advanced by Kukla: for any theory *T*, construct a rival *T*' that entails all the empirical evidence of *T*, but against the unobservable entities of *T*. This is a general algorithm that is applicable to any theory, as the constructed rival *T*' is empirically equivalent to *T* yet incompatible with *T*. Applying the lines of thought of this algorithm, we may construct a non-empirical equivalent (e.g. simplicity-equivalent) to any theory, with the empirical equivalence preserved (e.g. an empirically equivalent rival theory with the same degree of simplicity as a given theory). This is how it goes: for any theory *T*, construct a rival *U* that encompasses the empirical evidence and simplicity of *T*, but against the unobservable entities of *T*. As opposed to *T* which has constant *c* to account for unobservable entities, *U* has constant *d*. In this case, *U* is distinct from *T* in terms of the constant that accounts for the unobservable entities. However, *U* encompasses the same empirical evidence and degree of simplicity as *T*. Now we have a non-empirical equivalent *U* to *T*, which also preserves the status of empirical equivalence. This algorithm may be extended to construct other non-empirical equivalents to *T*, such as consistency-equivalents and so on. So now we have an extended algorithm which has the capacity to produce an infinitely many empirical equivalents and non-empirical equivalents to any theory. Consequently, we have an infinitely many true theories and pragmatic theories[4]. Again, relativism ensued and anything goes in theory choice. For no matter what criteria one is holding to in theory choice, she will find infinitely many candidate rivals that fit her criteria equally well.

Four objections may be anticipated. One may rebut that, unlike the empirical evidence, the non-empirical factors such as simplicity is unquantifiable, and thus there is no way to construct a non-empirically equivalent rival *U* to any theory *T* as shown above. This objection assumes that non-empirical factors are quality, which has no clear boundary for a rival *U* to encompass. It is reasonable to claim that qualities like simplicity and elegance are non-measurable by the equipments. It is absurd to say that from a given theory *T*, which has *x* % of simplicity, *U* can be generated algorithmically to encompass the same degree of simplicity. Though it is true that the non-empirical factor such as simplicity is unquantifiable, this rebuttal does not threaten the fact that a rival *U* can encompass the simplicity of *T* as a quality attribute. To make an analogy, although temperament is unquantifiable, one can easily identify whether two persons possess the same temperament from their behaviors. Another analogy can be found in mathematics. An experienced mathematician can tell if a mathematical proof is simple and elegant, albeit she cannot reason it in a quantifiable way.

Another anticipated objection to the extended algorithm is that, given the claimed ability of the algorithm to generate empirical equivalents and non-empirical equivalents to any theory *T*, these equivalents do not surpass *T* in the evaluation of their merits. That is, both *T* and its equivalents are equally valuable in terms of predictive power, simplicity, coherence, and so on. The critic may further claim that the infinitely many empirical equivalents and non-empirical equivalents to *T* are merely variants of *T*. Even if one admits that rational theory choice is implausible in the face of equivalents to *T*, he may not be convinced by the claim that these equivalents are more valuable than *T*. The most one can conclude is that these rival theories are on the par, from all aspects. The critic may thus point out that, given the equal merits of these rivals, these infinitely many equivalents are just a trivial variant of the original theory *T*. He may thus suggest that we can safely dismiss these equivalents without loss, because the merit of *T* is equal to that of its equivalents. The critic comes to the conclusion that the problem of theory choice is solved following the dismissal of these equivalents.

To reply to this objection, the relativist may claim that the dismissal of infinitely many equivalents to *T* as trivial variation is a dangerous move, which may hinder the progress of science. She may point to the possibility that an algorithmically generated equivalent to *T* may appear to be more valuable than *T* when they demonstrate qualitative divergence in outcomes. To illustrate, it is plausible to obtain an empirical equivalent *R* which differs from *T* in terms of a constant. The constant of *R* may result in a more elegant mathematical form of *R*, or result in an improvement in the predictive accuracy for *R*. This divergence in the outcome of two rival theories suggests that the equivalents of any given theory *T* can surpass *T* in terms of theoretical merit. However, it does not make rational theory choice possible in the face of the case that algorithmically generated theory *R* is more valuable than the original theory *T*. For, relativists hold, there are infinitely many equivalents generated by the algorithm. Conceivably, we are ending up with an infinitely many possible equivalents (e.g. R_1, R_2, …, R_n) which are surpassing *T* in terms of theoretical merit. Again, we are trapped within the dilemma of theory choice. Contra to the suggestion of the critic to keep the original theory *T* and dismiss all of the equivalents, we now have *T* reasonably dismissed (because of its inferiority) yet facing with a wide range of infinitely many competing algorithmically generated equivalents.

The third anticipated objection against the extended algorithm is that, despite the omnipotent ability of the algorithm to generate infinitely many equivalent rivals to any theory, one is not actually faced with infinitely many equivalents at the moment *t* when she comes to make a decision on rival theories. The critic may argue that the moment *t* is a finite moment, say, the moment in which a scientist needs to choose a theory to explain the observed phenomena in an experiment. Due to the limitation of cognitive power, a scientist is unable to consider infinitely many rival theories at a finite moment *t*. Hence, the critic may assert, the scientist will not be in a situation of choosing among an infinitely many rival theories, in each finite moment *t*. Further, we may conceive of a situation where the scientist may face only with a theory *T* and a non-equivalent rival *R* (say, inferior in terms of simplicity, or empirical confirmation) at a finite moment *t*, a moment which is lasted before the algorithm starts generating any equivalent rivals to *T*. In this case, argued the critic, theory choice is possible even we admit the prevalence of the omnipotent algorithm.

To reply to this objection, which contends the time-lagging of the algorithm in generating equivalents to any theory *T*, the relativist may claim that the production of each equivalent to *T* is not carried out in time. As soon as a given theory *T* has been formulated, an infinitely many equivalents are produced autonomously and simultaneously, regardless of whether they have been recognized by a scientist. It is so because the algorithm does not capture time as its input variable to produce the equivalent rival theories. Because only *T* is captured by the algorithm as input variable, the produced equivalents do not emerge sequentially in time. Contra to the arguments of critic, a scientist who is in a situation of making a theory choice at moment *t* will face infinitely many equivalent rivals to any given theory *T*. Rational theory choice is thus impossible.

The last anticipated objection to the rival-generating algorithm is that it does not reflect the actual genesis of rival theory in scientific practice. The critic may argue that one cannot find such algorithm in the history of science. If such algorithm is as robust as what its proponents have claimed, it would have been used by scientists in the past to generate various alternative theories when the dominating theory fails to account for the physical phenomena. Yet its absence in the history of science implies that it is just a fantasy of thought, or being too trivial to have any significance in scientific progress, and therefore being ignored by scientists. If one is to examine the history of science carefully, he will find that the rival theories to any theory are generated in a non-algorithmic way, which requires further experiments in addition to hypotheses. The experimental elements of a rival theory are not stipulatable in an algorithm, for it requires the skill of an experimenter. The critic may further claim that any suggestion that this omnipotent algorithm is in principle plausible which may emerge in the future will reduce the omnipotent algorithm to a limited version. He may elaborate by arguing that if the algorithm did not exist in the past, say at time t_1, the assertion that it may exist in a future time t_2 will render the theory of algorithm inconsistent. For this posited algorithm is attributed with the capability to generate infinitely many equivalents to any theory at all time. Such omnipotent capability is supposed to be valid at all time in order to qualify it as a universal attribute. If a theory *T* which had existed in the past was not challenged by infinitely many algorithmically generated rival theories, the universality of the algorithm will be immediately questionable. Besides, the omnipotent status of the algorithm is also challenged because its absence in the past is a salient evidence of the impotence. Those who claim that this algorithm, which is possible in principle or it may emerge in a distant future, can hardly justify the universality and omnipotence of this algorithm.

Relativists may reply to these lines of critique by adopting two strategies. First, he may contend that the algorithm did exist in the past but it was ignored (either consciously or unconsciously) by scientists. The observation of the non-existence of the algorithm in the history of science is accountable by the fact that it was dismissed too early by scientists as trivial. Further, the accusation of scientists and philosophers (e.g. Laudan and Leplin) on the triviality of the algorithm is just the point to prove the existence of a rival-generating algorithm. Besides, the relativist may maintain that the non-usage of the algorithm in the past does not diminish the universality and omnipotence of the algorithm, for the universality and omnipotence are bearing on the existence of the algorithm, not on its usage. In addition, the fact that the algorithm was not used in the past, due to the prejudice or ignorance of scientists, does not imply that its value will not be recognized in the future, and thus become a norm of practice. By then, the problem of rational theory choice will be prevalent. Recognizing the possible rebuttal that this problem will hinder scientific progress, relativist may argue that theory choice is only possible in the relativist context. Scientists now have more rival theories to choose from, claimed relativist, which would advance science in more than one possible way, and perhaps in a better way. The relativist may now conclude that, with the prevalence of rival-generating algorithm, rational theory choice will give way to relativistic theory choice, which is more beneficial to scientific progress.

5.4 Conclusion

This chapter starts with the question of whether genuine theory choice is possible in science. Theories with distinguishable merits are a prerequisite for rational theory choice. The proponents of the thesis of underdetermination of theory by evidence claim that the indistinguishable empirically equivalent rival theories underdetermine rational theory choice. To disentangle the route from empirical equivalence to the dilemma of rational theory choice, Laudan and Leplin have rejected both the thesis of empirical equivalence and the inference from it to the thesis of underdetermination. They warn that the thesis of empirical equivalence has motivated relativism, and has a linkage with skepticism. Laudan and Leplin has stressed that no empirical evidence could ground a theory if that evidence is entailed by other rival theories.

Laudan and Leplin have proposed three theses to reject the thesis of empirical equivalence. All of them attempt to show that empirical equivalence is not a prevalent phenomenon in science. The first proposed thesis is the Variability of the Range of the

Observable (VRO). According to the VRO, the range of the observable phenomena is dependent on the state of knowledge and technological advances. The range of observable phenomena is expanded as knowledge and technologies progress. It is thus expected that there will be no stalemate empirically equivalent rival theories as progress has been made in knowledge and technology as time goes by.

The second thesis against empirical equivalence is the Need for Auxiliaries in Prediction (NAP). According to Laudan and Leplin, the NAP states that auxiliaries are needed to supplement the theories to account for the observable phenomena. Empirically equivalent rival theories may have different auxiliaries which make them distinguishable for theory choice. Rational theory choice is plausible based on the judgment of different merits of the auxiliaries.

The third proposed thesis against empirical equivalence is the thesis of the Instability of Auxiliary Assumptions (IAA). This thesis, according to Laudan and Leplin, claims that auxiliary information is as dynamic as knowledge and observable. The range of auxiliaries is augmentable and shrinkable as science progresses. Hence, rational theory choice is possible in the face of the distinguishable rival theories in terms of the changeable auxiliary assumptions.

Kukla has objected the dismissal of the thesis of empirical equivalence by Laudan and Leplin. Despite Laudan and Leplin's three theses (VRO, NAP and IAA) are meant to be applied to any two fixed rival theories, Kukla has creatively applied them to any two nonfixed rival theories in the course of scientific development. Admitting the variability of the range of observables and auxiliaries, Kukla holds that this variability does not change the fact that any theory always has its empirically equivalent rivals at any given point in time. Kukla's indexical interpretation of Laudan and Leplin's arguments not only demonstrates that the admission of the variability of observables and auxiliary assumptions fails to refute the thesis of empirical equivalence; it also persuasively confers an a priori status to the prevalence of empirically equivalent theories.

To show that empirical equivalence is plausible and unavoidable, Kukla has elaborated a case where an algorithm can be found to generate infinitely many empirical equivalents to any theory. This case has been presented in Section 5.3. The algorithm constructs rivals by preserving the empirical evidence of a theory, yet incompatible with it. Leplin and Laudan, and Hoefer and Rosenberg, have dismissed such an algorithm as trivial. They claim that this algorithm is incapable of producing epistemically significant rivals to a given theory. Another criticism of Kukla's thesis was made by Stanford who has explicitly raised his worry about the introduction of wide-spread skepticism into science by Kukla's omnipotent algorithm. He concludes that this algorithm is spurious and should not be taken seriously.

However, Kukla's opponents fail to show that the rival-generating algorithm could not produce any non-trivial rival theory. In view of the fact that the algorithm is omnipotent in producing infinitely many empirical equivalents, there is a possibility that at least a credible empirical equivalent could be generated to any given theory. The empirical equivalents would underdetermine rational theory choice. Beyond the intention of Kukla, such omnipotent algorithm may be extended to produce non-empirical equivalents (e.g. simplicity-equivalents, elegance-equivalents, etc.) to any theory. In this scenario, scientific realists and antirealists would have a hard case to argue for rational theory choice. Realists have no recourse to truth as the criterion of theory choice. Antirealists fare no better, for they cannot count on empirical adequacy, or other pragmatic criteria (e.g. simplicity and breadth of application), as a ground for rational theory choice. With the prevalence of infinitely many equivalents, theory choice is plausible only on relativistic grounds.