

Unit 4

Mill's Methods of Experimental Inquiry

Need for establishing causal relations

To establish the causal relationship is the distinguishing mark of Scientific Induction. Inductive reasoning is based on the assumption that there is a Universal Principle of Causation according to which things are connected in a systematic way. Nothing occurs accidentally. Everything that happens must have a cause. The natural and social sciences describe and explain the phenomena and events in terms of cause and effect. From the view point of practical experiences also we are constantly looking for the causes of the events happening around us. All phenomena without any exception are causally related; everything that happens has a cause, and which in turn is followed by an effect.

Nature and Definition of Cause

It is not difficult to know what cause is ? The real problem before human beings is to establish that A is the cause of B. To know that particular phenomenon, say x, is the cause of another phenomenon y is to establish a universal law. The moment Newton had discovered that the gravitational power of earth is the cause of apple falling down, he established a causal relationship and thus had given an extremely important law of gravitation. There are certain things and events whose causes are known to us, yet there are several other things whose causes are not known to us. For example, in spite of the best efforts of the scientists and doctors the exact causes of a deadly disease like cancer is not known.

Causal connection is a relation of invariable succession and hence is a stronger connection than merely a correlation. Causal relationship implies succession in time. Cause is antecedent and hence precedes the effect. Effect is consequent and hence follows the cause. The time interval between cause and effect may be very less but nonetheless gap is there. In simple terms cause is defined as invariable, unconditional, immediate antecedent of an effect.

Scientists define cause in terms of necessary and sufficient conditions. Necessary conditions are those in the absence of which the effect does not occur. For example, in the absence of oxygen, fire will not occur. But the presence of oxygen does not guarantee the fire to be there because oxygen is merely a necessary condition of fire and not the sufficient conditions of fire. The sufficient conditions are actually sum total number of necessary conditions. These total number of necessary conditions of fire are ignition, fuel and oxygen. If we wish to produce anything desirable then we must look for sufficient conditions. But if we want something not to happen, then we must remove any one of the necessary conditions.

Mill's Experimental Methods

John Stuart Mill in his famous logic book named *System of Logic* gave five Experimental Methods by which causal connections can be identified between events. Through these methods causes can be determined approximately.

Mill's five Experimental Methods :

1. Method of Agreement.
2. Method of Difference
3. Joint Method of Agreement & Difference.
4. Method of Concomitant Variation.
5. Method of Residues

All the methods are derived from the nature of causality. They are indeed a detailed statement of what scientific causality is. The nature of causality is such that,

- (a) Wherever the cause is present, the effect follows
- (b) Wherever the cause is absent, the effect is absent
- (c) Wherever the cause varies, the effect varies and their variations are proportional.
- (d) What is the cause of one thing is not the cause of a different thing.

The four factors, i.e., a,b,c,d are called the 'canons of elimination'.

These relations between cause and effect are reciprocal. It is on these canons Inductive Methods are based. They establish causal connections indirectly by rejecting causes which fail to satisfy some one of these conditions. Thus the principle on which the Experimental Methods proceed is the elimination of the irrelevant conditions which fail to fulfill the requirements of causality. Hence, the true function of the Experimental Methods is the discovery and proof of a causal connection by elimination. Induction, however, does not seek the elimination of a non-cause but the establishment of a cause. The Experimental Methods are rules of applying observation and experience in order to eliminate the accidental factors and thereby to select one phenomenon, and to prove that phenomenon to be the cause or effect of another phenomenon.

1. Method of Agreement

Mill states the canon of the Method of Agreement as follows:

"If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon."

Mill points out that this method of discovering and proving a causal connection is based on the following principle of elimination :

Note : J.S. Mill used circumstance for cause and phenomenon for effect.

"Whatever circumstance can be excluded without prejudice to the phenomenon is not connected with it in the way of causation."

In other words, if some circumstances are left out, and the given phenomenon is present, there cannot be any causal connection between them. Accordingly, it follows that if some circumstances are always present, when the given phenomenon is present, there is a causal connection between them.

In the Method of Agreement we try to discover causal connection from agreement among instances, which are called positive instances, instances in which the suggested cause and effect are both present. This method is a development over the methods of enumeration and analogy. It makes a thorough analysis of the antecedent conditions. It proceeds on the principle that: -

- (1) There is a causal relation between the antecedents as a whole and the consequent as a whole.
- (2) Whatever is not present on any occasion in which a particular consequent follows can be eliminated as not its cause.

Symbolically, the Method of Agreement may be represented as follows, where capital letters represent circumstances (causes) and small letters denote phenomena (effects) :

A B C D occur together with w x y z

A E F G occur together with w t n v

Therefore, A is the cause (or part of a cause) of w.

Concrete example :

If a number of cases of typhoid fever were to appear at about the same time in a community, one would try to discover some circumstance which was common antecedent of all the cases. Cause to be sought for, is among a limited number of circumstances. One would select the various instances with the purpose of testing the different possibilities. The water supply might first be examined. But if it were found that this was derived from entirely different sources in the different cases, we should probably conclude that the explanation must be sought elsewhere. Suppose we find that all the patients of typhoid had eaten oysters bought at the same market. If this were the only common circumstance discoverable after careful investigation we should conclude probably that the oysters were the cause of the fever. The process of analysis could be pushed still further in order to determine more exactly the precise source of infection, i.e., it might be found, that the water in which the oysters were kept was vitiated by sewer.

It is important to note that the conclusion reached by this method is greatly strengthened by micro observations and by taking as many instances as possible which are dissimilar in character. But, howsoever many and varied the instances in which A and w are found together, causal connection between them can never be proved. The whole of A may not be required to produce w. Our analysis may be incomplete, and so we may not have isolated the cause which is in A, as when we say impure water is

the cause of typhoid, when impure milk/oysters would do equally well. The real cause is something in water/milk/oysters in contaminated water.

In this method a systematic effort is made to find a single factor which is common to several occurrences for the purpose of identifying that one factor which is the cause of a phenomenon present in the occurrences. This method identifies the cause in the sense of a necessary condition.

2. Method of Difference

The canon of the Method of Difference is expressed by Mill as follows:

"If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstances in common save one, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or the cause, or an indispensable part of the cause, of the phenomenon".

The Method of Difference is based on the principle that "whatever cannot be eliminated without interfering with the phenomenon under investigation must be causally connected with the latter". In other words, that which is present in a case when a phenomenon occurs, and absent in another case when that phenomenon does not occur, all other circumstances remaining the same in the two cases, is casually connected with that phenomenon.

In this method we take two instances only. Each instance is a group of antecedent followed by a group of consequent. The two instances differ only in the circumstances (antecedent or consequent as the case may be) which is present in one and absent in the other. In all other respects, the instances are exactly the same. From this we conclude that the circumstances in which the two groups differ is the cause of those circumstances in which alone the two groups of consequents differ.

The Method of Difference may assume two forms : we may add something to the antecedents and the result is that something new happens in the consequents. Or, we may subtract something from the antecedents and something disappears from the consequents. This method is called the Method of Difference because it is the singleness of the difference that constitutes the ground of proof.

Symbolically,

(i) A B C is cause of a b c

B C is cause of b c

∴ A is cause of a

(ii) B C is cause of b c

A B C is cause of a b c

∴ A is the cause of a

In the first example, A is subtracted from the antecedents and the result is that a disappears from the consequents. In the second example A is added to the antecedents and the result is that a appears in the consequents. Hence we conclude that A is the cause of a.

Concrete example :

If a bell is rung in a jar containing air the sound will be heard at any ordinary distance. But after having removed the air by means of an air-pump let the bell be struck again. It will now be found that the sound is no longer heard. When the two cases are compared it is at once evident that the only difference in the antecedents is the presence of air in the one case and its absence in the other. Other circumstances remain the same; we conclude that the perception of the sound is causally connected with the presence of atmospheric air.

The Method of Difference plays a great part in our everyday inferences. For example, we strike a match stick against the side of the match box and there is light and fire. But a careless use of this method leads to the fallacy of *post hoc ergo propter hoc*. For example, the appearance of a comet in the sky may be followed by the death of a king, but it is wrong to conclude that the appearance of a comet is the cause of the death of the King. In practical life we depend on simple observation for the supply of instances. But in such cases the Method of Difference does not yield conclusive results because in order to comply with the special requirements of this method the instances must be supplied by experiment.

The Method of Difference is essentially a method of experiment because only experiment and not observation, can furnish instances of the special kind required for this method. In experiment we have control over the conditions and are able to vary them at will and as such we may be careful in introducing or removing only one circumstance at a time. The Method of Difference proves causation conclusively when strictly applied. It supplies tests to confirm the conclusion arrived at by an application of the Method of Agreement.

The Method of Difference is subject to following limitations: -

- (a) The Method of Difference being a method of experiment is subject to limitation to which experiment is. In experiment we can proceed from cause to effect but cannot go backwards from effect to cause. The effects are not within our control. We cannot add or subtract from them in the same way as we can add to or subtract from groups of causes.

- (b) The Method of Difference does not enable us to deal completely with the plurality of causes. The Method of Difference only proves that certain circumstance is the cause of a phenomenon in a given case, but it cannot prove that it is the only cause and that there cannot be other causes on other occasions.
- (c) The Method of Difference does not enable us to distinguish a cause from a condition. For example, granting that BC produces bc, will the introduction of A compel us to regard it as the sole cause of the new consequent a? Not necessarily, for a may be due to A combining with B and C. Thus, we cannot say that introducing of a new element is necessarily the sole cause of any change which may happen. It may be one of the conditions merely. If a dish of food be unpalatable, the addition of salt may render it palatable. But it does not follow that the agreeable taste is due to salt alone. The salt is only one condition but there are other conditions which must be taken into account in order that the entire cause may be ascertained.

3. Joint Method of Agreement and Difference.

Mill states the canon of the Joint Method thus, "If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance, the circumstance in which alone the two sets of instances differ is the effect, or the cause, or an indispensable part of the cause, of the phenomenon".

The requirements of the Joint Method are: -

- (a) A set of positive and a set of negative instances.
- (b) That both sets be drawn from the same field of investigation.
- (c) That the instances making up each set be as diverse as possible.

The joint method of Agreement and Difference has advantages over each of these methods separately.

- (1) It supplements the positive instances of Agreement by negative instances.
- (2) It applies in many cases where the Method of Difference cannot be realized, i.e., where experiment is impossible because we cannot control the conditions or produce the event at will.

Symbolically it can be expressed as :

Agreement in Presence :

(1) (Set of positive instances)

A B C is cause of a b c

A C D is cause of a c d

A D E. is cause of a d e.

∴ A is cause of a

(2) Agreement in Absence :

(Set of negative instances)

B C D is cause of b c d

D E F is cause of d e f

E F G is cause of e f g

∴ A is the cause of a

In the set of positive instances A is uniformly present in the antecedents and a is uniformly present in the consequents.

In the set of negative instances A is uniformly absent in the antecedents and a is uniformly absent in the consequents.

Concrete example :

A man observes several instances in which he eats a particular article of food and suffers from indigestion. From this set of positive instances, according to the Method of Agreement, he infers that the eating of that article of food is the cause of indigestion. He then takes a set of negative circumstances and finds that when he does not take that article of food he does not get indigestion. In this way, his original conclusion is confirmed.

Mill's example :

We observe that dew is formed on objects which radiate heat rapidly. We also observe that dew is not formed (the phenomenon does not occur) on objects which agree only in the absence of rapid radiation of heat. From this we conclude that the rapid radiation of heat is the cause of the formation of dew.

The Joint Method is also called the Indirect Method of Difference, the Double Method of Agreement or the Method of Double Agreement. It is so called because there is double agreement, agreement in presence and then agreement in absence.

Like the Method of Agreement, the Joint Method is essentially a method of observation and as such possesses all the advantages and disadvantages of observation. The advantages are that both these methods have a wide range of application and can be employed in cases where the phenomenon under investigation is beyond our control. The disadvantages are that neither of them can conclusively prove a causal connection though the conclusion of Joint Method is more probable than that of Method of Agreement because it takes note of both positive and negative instances. The Method of Agreement is frustrated by the possibility of plurality of causes, by the possibility of there being hidden and unknown circumstances which escape our observation. Further, it is unable to distinguish between causation and co-existence. But the Joint Method is more or less free from the difficulty arising out of the possibility of the plurality of causes. If the negative instances are fully exhaustive and contain all the circumstances other than what is uniformly present in the positive set, there cannot be plurality of causes.

4. Method of Concomitant Variations

Mill states the canon of the Method of Concomitant Variation as follows :

"Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation".

The Method of Concomitant Variations is based on the principle that "an antecedent and a consequent rising and falling together in numerical concomitance are to be held as cause and effect". In other words, the cause and the effect being quantitatively equal in energy increase or decrease in the one must be followed by a proportionate change in the other. Thus, if two phenomena always vary together, they are casually connected. When it is observed that certain events continue to show correspondence throughout a series of variation it is inferred that the conjunction is not accidental but indicates the existence of a causal connection.

This correlation of events may be discovered through correspondences in temporal or spatial arrangement of phenomena, in their progression, or in changes of quality and quantity. The discovery of Concomitant Variation is of importance in science, not merely because it assists us in determining what events are related as cause and effect but also because the exact form of the causal relation can thereby be rendered more defiant and satisfactory.

Concomitant Variation may be of two types.

- (1) Direct variation, in which the antecedent and the consequent vary in the same direction, that is, they rise and fall together.
- (2) Inverse variation, in which the antecedent and the consequent vary in the opposite direction, that is, the increase in the one is followed by the decrease in the other and vice versa.

1st Symbolic Example

A1 B C cause of a1 b c

A2 B C cause of a2 b c

A3 B C cause of a3 b c

∴ probably A is the cause of a

2nd Symbolic Example

A1 B C cause of a1 b c

A2 D E cause of a2 d e

A3 E F cause of a3 e f

∴ probably A is the cause of a

Concrete example :

1. A farmer establishes that there is a causal connection between the application of fertilizer to the soil and the size of the crop by applying different amounts to different parts of a field, and then noting the concomitant variation between the amounts of the additive fertilizer and the yield.
2. We observe that as heat increases, the mercury in the thermometer expands in the volume. From this we conclude that heat is the cause of expansion of mercury.
3. It is a common experience that the lower the price of a thing, the larger is the quantity bought by the consumers. In other words, if supply of a commodity increases then the prices decreases provided demand remains same.

This method has three main uses.

- (1) Where the variations are not quantitatively measurable or at any rate have not been measured, it can be used exactly in the same way as the other Methods. It can be used either along with the Method of Agreement or the Method of Difference or alone. The variations may suggest causes or eliminate causes which have been otherwise suggested. The Method of Concomitant Variation can be used in those cases where experiment is not possible.
- (2) This method can also be used in cases where the Method of Difference cannot be applied, because the phenomenon in question cannot be eliminated or removed, though it can be varied. We cannot eliminate the atmospheric pressure, temperature, but we can vary them or put

ourselves into positions where we can perceive their variations, as when we climb a mountain and find the atmospheric pressure less.

- (3) In cases where the variations are exactly measurable, the Method of Concomitant Variation gives very much more precise results than the other methods. In such cases it not only supports the other methods but it gives something which they cannot give. It establishes causal relation as well as determines the precise quantitative relation between them. The natural sciences always try to reduce qualitative relations to quantitative ones and in this the Method of Concomitant Variation helps them. For example, when the physicist says that heat is the cause of motion, he means that the amount of energy that we get in the form of heat is identical with the amount that we get in the resulting motion form, so that the relation between them is one of quantitative equivalence in the amount of energy together with a difference in its form. Any variation in the amount of energy form results in a similar variation in the motion form. To establish causal relations in this sense we have to prove not only invariable sequence but quantitative equivalence. When we arrive at such a degree of precision and exactness we can express the causal relation in the form of a mathematical formula.

5. Method of Residues

In general, this method calls attention to any remainder or residues which is left over after other portions of a complex phenomenon have been explained. This is Mill's last method and is applicable only after the work of establishing causal relations has made considerable progress.

Mill expresses its canon as follows :

"Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents."

If we are dealing with a complex set of phenomenon and we already know the cause of some of them, we conclude that the cause of the remainder is to be found among the antecedents whose effects we do not know yet. Here the procedure of analysis is followed by elimination; and the elimination is based on negation. The principle is: that which is the cause of one thing cannot be the cause of a different thing.

When the greater part of a phenomenon has been scientifically investigated and its cause is known, and there is very little other than the known cause and effect in the antecedents and consequents, this method establishes relation between the remaining antecedents and remaining consequents. But in such cases also it is desirable to test the suggested relationship by one or more of the other methods.

Symbolic Example :

A B C is cause of a b c

B C is cause of b c

It is already known that the B is the cause of b and C is the cause of c,

Therefore, A is the cause of a.

Concrete examples :

- (1) We weigh a cart with load and note the weight. We already know the weight of the cart alone. By subtracting the weight of the cart from the total weight of the cart with load, we conclude that the difference is the weight of the load.
- (2) Astronomers John C Adams and J. J. Leverrier discovered the planet Neptune by the application of this method in 1846. It was observed that the Planet Uranus presented certain anomalies in its motion - that there was a slight deviation from the path, which according to calculators would have been its orbit. The influence of the Sun and the other known planets on Uranus was calculated but it was found that as a matter of fact, Uranus did not follow the calculated path. This led to a search for the cause of deviations and they were found to be due to the influence of another unknown planet, viz., Neptune.
- (3) Pierre curie and his wife Marie Curie had discovered two chemical elements, radium and polonium by applying this method, They found that uranium ore contained much more radioactivity than could be accounted for by the uranium itself. The Curies then began to search for the source of the radioactivity. They separated minute amounts of two new highly radioactive chemical elements from tons of uranium ore which they called radium and polonium. In 1911, Marie Curie won the Nobel Prize for chemistry for her discovery of the new elements and for her work in isolating radium and studying its chemical properties.

As a general rule, the Method of Residues sets a problem rather than solves it. In certain cases the effects of all the apparent antecedents are known but they do not suffice to explain the facts before us. Hence, we assume that there is some unsuspected cause which accounts for the residual phenomenon, as the unexplained remainder is called. The more exact our observations and analyses are, the more likely we are to notice such residual phenomenon and the more loudly they call for explanation. Thus, the Method of Residues suggests the need for investigation to discover a cause rather than it suggests

what the cause is. To suggest the need for a search for hitherto unsuspected causes has been its main function in the history of science.

The special feature of the Method of Residues is that it can be applied only when we have made some progress in our knowledge of causation. This method contains an element of deduction, nevertheless, it is an inductive method because it yields conclusions that are only probable and cannot be validly deduced from their premises. The Method of Residues may be regarded as a special modification of Method of Difference because the principle underlining both the methods is the same.

We can sum up our considerations of the Inductive Methods as :

- (1) They apply only after a great deal of preliminary work in the form of observation and analysis has been performed. The conclusion at which they arrive are not more general than the premises from which they start. They eliminate or disprove part of the premises and leave the rest standing.
- (2) They give, not certainty, but varying degrees of probability.
- (3) They apply only where we can observe the cause or the effect, or where we can experimentally analyse the effect into its causal conditions.
- (4) They apply to the scientific, not to the non-reciprocating causes. As applied to such causes the methods give invalid results.
- (5) They deal with phenomenon in comparative isolation, with particular recurring connections. They do not unify or organize phenomena into system. Hence the connections which they force upon us are often comparatively unintelligible and call for further explanation.

Limitations of Mill's Methods :

J.S. Mill believed that his Experimental Methods were tools with which causal relations may be discovered and canons with which causal connections may be proved. But he was wrong on both counts. The Methods are indeed of the greatest importance, but their role in sciences is not so majestic as he used to think.

The Experimental Methods are important for the establishment of causal relations but such claims on their behalf are no more than exaggerations. The Methods alone can neither discover nor can prove, causal relations between two facts. The Methods essentially make use of observations and experiments so they cannot prove causal relations. Proof is possible only in the field of mathematics. Sciences (natural or social) do not prove, they only establish the laws. Since mathematics deal with the relation of

ideas, proof is possible there, but sciences deal with facts which are observed to collect data and establish natural laws.

Moreover, even when this preliminary work of collecting data and then analyzing and synthesizing them has been completed, the Methods do not prove causal connections. They can only give further confirmation or added probability to the connections already suggested. They narrow down the field of possible causes. And in some cases their main value is to suggest causes which can be further tested by other methods. Elsewhere Mill himself grants and says that "the four methods have little more in their power than to supply premises for, and a verification of, our deductions." Therefore Mill's claim that his canons are "methods of proof" must be rejected, along with his claim that they are 'the methods of discovery'

Questions

1. Explain and illustrate the Method of Agreement. Discuss its merits and demerits.
2. The Method of Difference is essentially a method of experiment. Explain
3. The Joint Method of Agreement and Difference has advantages over the Method of Agreement alone or the Method of Difference alone. Explain
4. The Method of Concomitant Variation differs from the other Methods of Experimental Inquiry. Discuss.
5. Explain the Method of Residues. How is it different from the Method of Difference?
6. Discuss critically whether Mill's Inductive Methods are methods of proof or methods of discovery or both.
7. Discuss briefly the limitations of Mill's Methods of Experimental Inquiry.