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Billiard balls: Symmetries are puzzling, asymmetries are hard to come by

(For Miciko)

"Any thing may produce any thing." Hume, A Treatise of Human Nature

Billiard balls

Rereading Hicks's book on causality,[1] I was led to rereading Hume, then Kant, and finally, Leibniz (and a bit of Hegel). Hicks takes Hume to be singling out two characteristics of causality:

– one, that the cause comes before the effect (which Hicks and everybody else takes to mean "in time" for Hume); and

– two, that causality is determined counterfactually (no effect, if not for the cause).

He is wrong in his interpretation of Hume, I think, on both counts.[2]

Both, Hicks and Hume, however, at least in the treatment of the role of time, differ from the Wiener-Granger (information based) causality.[3] Where the starting point is that causes occur ahead of effects – the information about the cause precedes the information about the effect in time; or, to put it differently, they cannot be

[1] J. R. Hicks, Causality in Economics. Basil Blackwell, 1980. This is not an exceptionally good book on this subject. It is of interest because it recasts Hicks' fundamental contributions in economic theory in Value and Capital and Capital and Time in the causal language. The same ideas of simultaneity and equilibrium are to be found in the work of Frisch, Haavelmo and Samuelson and indeed in Smith, Ricardo, Marshall and Keynes as I document with quotes from their work throughout this essay. See e.g. Heckman on Haavelmo.

[2] I mostly rely on the Treatise on Human Nature here, the quote and the example, which are from the Enquiry, notwithstanding. This is a companion piece to my essay on Causes and Counterfactuals: Simple Ideas where I rely more on An Enquiry Concerning Human Understanding. While there are differences in formulations, those in the latter work being smoother and less shocking, there is no difference or evolution in the fundamentally sceptical view of causality and the power of induction.

[3] See C. W. J. Granger, Essays in Econometrics. Collected Papers. Volume II. Cambridge University Press, 2001. See Appendix 2 for Wiener.

contemporaneous. Contiguity, in space, plays no role as far as I can tell. Apparent instantaneous causality is just an instance of the existence of the common cause, for Granger. If there were instantaneous causation, it is believed that the asymmetry between causes and effects would be lost, i.e. causes could not be discerned from effects. And forecasting from present causes to future effects would not be possible. That does not exclude feedback loops, i.e. the effects switching places with the causes in the future. In addition, this kind of causality does not support counterfactual claims. Thus it has limited usefulness for policy advice. Wiener in The Theory of Prediction points out that predicting the effects of interventions is different from, may I say, Humean observations (see the quote and comments in Appendix 2 below).

Thus, given that Granger's theory of causality is used for forecasting rather than explanation, every causal impact comes with a time lag – is the infamous "action at a distance"; though it is just the information that lags, no act of causation is actually implied. Where the distance in time is arbitrarily large and is mainly dependent on the frequency of the available data collection.

Hicks' major contribution in this book is that causality can be contemporaneous. That is not an idea that is new with him. So, he faults Hume with the lack of understanding of contemporaneous causality. Though the equilibrium analysis on which it rests is central to classical economics, to which Hume contributed significantly, as indeed to economics in general.

For Hume, causality is a relation. There is nothing in any thing which distinguishes it as a cause or as an effect. The causal relation is characterised by two features: succession (asymmetry) and contiguity (symmetry). Causes precede effects and the two need to be close to each other. It is taken that he means that succession is in time while contiguity is primarily in space. But that is arguably not what he means.

Occasionally (primarily in the Enquiry), Hume takes the example of two billiard balls hitting each other. And clearly, cause and effect can be discerned, if at all, only at the very moment when the balls touch each other and no time elapses between the one ball hitting the other and the other moving away. So, there is, we induce, a causal relation between the movements of the two balls, with the cause preceding the effect and the two being contiguous. Though, at the precise moment when the cause produces the effect, they, the cause and the effect, are symmetrical in respect to both time and space – there is no precedence in time and no distance in space between the two. They appear interdependent.

This is clear if we look at the impact of the still ball on the moving one. There is the causal impact of the moving ball on the still one and indeed of the still one on the moving ball. In the case of the latter, there is no lapse of time between the cause and

the effect. But there is none in the case of the moving ball too, as the effect happens at the same time as the cause, i.e. when the running ball hits the still one.

Anticipating somewhat one of the main points to be made later, Hegel in The Science of Logic does not use the billiard balls example, but he does point out the reciprocal or interdependent relationship of cause and effect which the example highlights. The courses of both balls are altered by the impact and Hegel suggests that the interdependency of cause and effect can be dealt either with a *cæteris paribus* condition or with an equilibrium condition. He does say cause is effect and effect is cause repeatedly, which does sound dialectical, but the point he makes of the two being interdependent is rather conventional and easy to spot in the billiard balls example. And in any case, in a relation, both sides are simultaneously present by definition, which is what Hegel wants to highlight, I think, as he progresses to the concept of causation (see the quotes in Appendix 4).

It ain't necessarily so: Analytic *a posteriori*

"Perhaps 'twill appear in the end, that the necessary connexion depends on the inference, instead of the inference's depending on the necessary connexion." Hume, A Treatise of Human Nature.

Hume in the Enquiry despairingly:

"… (I)f there be any relation among objects which it imports to us to know perfectly, it is that of cause and effect. On this are founded all our reasonings concerning matter of fact or existence. By means of it alone we attain any assurance concerning objects which are removed from the present testimony of our memory and senses. The only immediate utility of all sciences, is to teach us, how to control and regulate future events by their causes. Our thoughts and enquiries are, therefore, every moment, employed about this relation: yet so imperfect are the ideas which we form concerning it, that it is impossible to give any just definition of cause, except what is drawn from something extraneous and foreign to it. Similar objects are always conjoined with similar."

Causal relation is one of necessitation, i.e. if cause, then effect, but we have no understanding of that necessity. Kant set out to determine how is it that an effect necessarily follows from a cause. But not analytically, so that the idea of the effect is contained in the idea of the cause (when you say cause you say effect; something Hegel will point out *ad nauseam*), but should be the idea, in Hume's meaning, of the necessary relation, which is to say it needs to be synthetic. And if synthetic propositions were possible *a priori*, not just from impressions or data, then the necessary relation of cause and effect could be identified empirically, could be

induced. Not just by custom born of repetition, but reason would connect cause with effect necessarily. And Hume's problem of understanding is solved.

Kant (in the Prolegomena and in the first Kritik) argues that time, the succession in time, is of no help. Causal connection cannot be induced from the time order of appearances of causes and effects. Cause and effect are given simultaneously in reason; the asymmetry of time serves only as the representation of the logical asymmetry of the causal relation, the effect not bringing about the cause (something Hegel contests, at least conceptually; check Russell on that same point below) – but no actual time needs to elapse for the cause to be followed by the effect.

Causality is an asymmetric relation, as is before and after in time, but cause and effect occur simultaneously in reason, with cause logically preceding the effect, but the causality of the cause, as Kant puts it, spends no time to produce the effect. Reverting to time, or rather to the asymmetry of causes preceding events in time, would mean relying again on induction, which was the problem that needed to be solved. Hume makes this point over and over again in the Treatise.

This distinction between, in this case, logical asymmetry *a priori* and, in this case, empirical symmetry *a posteriori* is of course crucial to Kant, though the distinction is not unique to him.

Indeed, Kant provides an explication of the causal relation as the category of pure reason, of pure theory let us say, arguing for mathematics to be all about synthesis *a priori*. An equation, for example, is not a tautology, and it is not analytic, but is a synthesis of its elements (something, I think, Wittgenstein will argue in Philosophical Investigations, though in a different way). So, the equality sign makes the two sides of the equation symmetric, but the inputs and the result are distinct concepts (as he puts it) and provide for an asymmetric order between the two sides of the equation.

The asymmetry is in the order by which we solve the equation, what we do first to get the result afterword.

This is then the same as the causal order. Succession in time, in steps rather, when going from one to the other side to solve the equation is the temporal succession of going from the cause to the effect, though *a priori,* in an equation, they are present simultaneously and are interdependent. And, indeed, there are usually a number of ways to solve an equation. I take it that substitution of terms in an equation is an instance of the analytic *a priori* (which Quine famously criticised in his Two Dogmas of Empiricism; but arguably Hegel already provided the criticism). To jump to where we are now, graphical causal methods substitute the symmetrical equality sign with the arrow to represent the causal asymmetry (more on that in Causes and Conterfactuals: Simple Ideas).

Kant distinguishes between what is happening in an equation and what is happening in experience. If one were to go from equations to impressions or *vice versa*, that would involve a contradiction. One is *a priori*, the other is *a posteriori.* This is the point of the criticism of metaphysics:

Imposing metaphysics on physics is the subject of the criticism, but the outcome of the criticism is not to impose physics on metaphysics.

Both, manipulating equations and connecting causes and effects, are synthetic not analytic tasks, but one does not get actual causes and effects out of an equation. The two must be kept separate on pain of contradiction. Hume makes the same point, though Kant thinks that he does not. In fact, that is crucial to Hume's understanding of causality because it assumes necessity, i.e. only if there is a cause, there is an effect, so cause is necessary for effect (again Hegel will say that effect is necessary for cause, conceptually, or by definition – saying effect is saying cause also).

And, for Hume, while *a priori*, in logic and mathematics, there is necessity, *a posteriori*, in science and in understanding, there is none. Consequently, nothing contradicts anything in reality, unlike in reason.

Take an example that might be of interest to the information based theory of causality. Substitute the left-hand side of an equation with Bob and the right-hand side with Alice. So, Alice sends a message to Bob who answers when he receives it. Bob's answer is implied in Alice's question, cause implying the effect, so we know the answer before Bob comes back with it. So, constructing a causal e.g. equation (or implication or most generally a relation) *a priori* is synthesising and time plays no role, except metaphorically – cause implies effect and not *vice versa* (which Russell for one disputed). Now, Hume's question was how does the causal relation allow us to know Bob's reaction implied in Alice's message, an analytic problem *a posteriori*, how do we know that Bob's answer will not contradict the one that is given by logic or mathematics? Assume Bob came back with a different answer, our reasoning or calculation would still be correct, but it would be contradicted by evidence.

It is not the evidence which would be contradictory, as there is no contradiction in nature, only in logic and mathematics. Thus, we apply theories to data, not data to theories; we falsify, not verify.

The reason that Kant misunderstands Hume, I think, is that Kant rules out analytic *a posteriori* judgements as contradictory. Once the causal relation, e.g. between the two billiard balls is established and formalized, e.g. in an equation or in a set of equations, how do the mathematical manipulations apply to new empirical facts and circumstances? E.g. to forecasts or to interventions, to acts. The procedure of calculation is analytic, as only variables or parameters are being manipulated and

results checked, but they are supposed to be applicable to impressions, or empirical data, and to interventions. They should produce effects from causes once proper values are plugged in or intended actions are performed. One should be able to anticipate the future, which Hume thought was much more important than remembering the past.

For example, how are forecasts read out of an equation which summarises a causal relation from past data? Hume thought that we rely on what we develop as a habit, as a custom after repeated experience. Or to put it differently, we rely on induction from experience, on empirical generalisations, which are more or less what one calls common sense. One notes however that the customary connections of causes and effects happen in memory where the before and the after of the cause and effect i.e. their succession in time, in real time that is, plays no role.

We just happen not to have memory of the future, as Russell points out.

So, effects are produced from causes *a priori*, by sheer logical or mathematical theorising, but should be valid and informative *a posteriori*. Effects have to follow necessarily from causes *a posteriori*, which is to say in fact, not just *a priori*, in reason, or in theory. That is contradictory to Kant if theorising is purely analytic. However, all that even synthetic judgements *a priori* provide is just the theory of causality, let us say, but no empirical causal relation, no actual causes or effects, which have to be induced from the data, as one would say now. This is because we have no access to things in themselves, which if we had might allow us to distinguish causes from effects by the properties of the things that are causally connected. But, as we have no access to things in themselves, any thing may produce any thing.

So, for Kant the fundamental question is: How are synthetic *a priori* judgements possible?

While for Hume the key question, I think, is: How are analytic *a posteriori* judgements possible?

Given that any thing can produce any thing. And Hume's question is central to any scientific idea of causality.

He gives the negative or rather sceptical answer to the question, i.e. analytic *a posteriori* judgements are impossible, though never contradictory, as there is no empirical necessity. For Kant, if synthetic *a priori* judgements are possible, then empirical necessity between cause and effect can be ascertained. Kant takes Hume to be, as in the quoted passage above, despairing about the inability of reason to discover necessary relations, e.g. of causation, and thus cannot discover necessary relation between cause and effect in empirical data, in impressions. But Hume

rejects necessity altogether, except the analytic necessity, as in logic or mathematics.

This is because nothing is contradictory in fact, only in reason.

The key difference between Kant and Hume is, I think, mediated by Leibniz' logic. Kant still wants the empirical relations not to be contradictory the way they should not be *a priori*, thus syntheses in both theoretical and empirical worlds, those that are *a priori* or respectively *a posteriori*, need to respect the law of non-contradiction. If synthetic *a priori* propositions must not be contradictory, that brings in necessity between causes and effects. And if synthetic *a posteriori* propositions are consistent with those *a priori*, then there is necessary connection between empirical causes and effects.

So, the law of non-contradiction applies to things, to facts, to reality, to the empirical, and not only in reason. What does not work in logic, does not work in reality too.

For Hume, there is no empirical necessity and thus no contradiction in anything empirical.

Any thing can produce any thing; any thing can be a cause or an effect.

To cause and effect, Hume and Hicks add an equilibrium condition which is missing in Kant. One could argue, though, that the categorical imperative, that rules the moral world, the practical reason, is such an equilibrium condition. This is a Leibnizian addition that I will come to.

The billiard balls of economics

Back to Hicks. He thinks in economics: Supply and demand at a price. That is similar to the billiard balls example.

When a trade is made, it is indiscernible whether supply or demand had caused the price to settle where the trade was made. The fact that one moved before the other, does not help. Also e.g. in a bargaining set up, or in the game-theoretical set up in general, the fact that the seller's offer preceded the buyer's agreement does not help to identify that the former caused the latter (more on that in Causes and Counterfactuals: Simple Ideas).

Indeed, even if we knew the supply schedule and the demand schedule as the price changed and thus could identify in the data the parameters of the equations of supply and demand as functions of the changing price, we still could not identify the cause from the effect.

Here is Samuelson in Foundations of Economic Analysis arguing like Hicks in Value and Capital and than in his book on causality:

“The only sense in which the use of the term causation is admissible is in respect to changes in external data or parameters. As a figure of speech, it may be said that changes in these cause changes in the variables of our system. An increase in demand, i.e., a shift in the demand function due to a change in the data, tastes, may be said to cause an increased output to be sold. Even here, when several parameters change simultaneously, it is impossible to speak of causation attributable to each except in respect to limiting rates of change (partial derivatives).”

Hicks of course, as Arrow and Debreu later, clearly distinguishes partial from general equilibrium in Value and Capital: the effect in partial equilibrium, e.g. supply change due to the change in price, may be reverted in general equilibrium, e.g. due to change in demand due to the changes in other prices that the change in supply leads to. So, general equilibrium is different from the partial one. And causal dependences are partial, that is are valid *cæteris paribus.*

In a simple supply and demand set up, in one market or in an economy, take that the quantity demanded, Qd, depends on the price, p, and on one or more exogenous variables, μd. And that the quantity supplied, Qs, depends on the price, p, and on one or more exogenous variables, μs. The two sets of exogenous variables are different and independent of each other. Parameters are a and b.

$$Qd = ap + \mu d \qquad (1)$$

$$Qs = bp + \mu s \qquad (2)$$

$$Qd = Qs \qquad (3)$$

The quantity demanded needs to equal the quantity supplied to identify the price at which the trade will be made. This is not an accounting identity, i.e. Say’s Law, which is always satisfied, but an equilibrium condition, i.e. Walras’ Law, which is satisfied only in the equilibrium (there is no excess demand); the distinction was made as clear as it can be by Haavelmo, but in the context important for the general topic of causation it goes back to Leibniz (as far as I can tell). Along the path towards the equilibrium, we can identify the cause from the effect, i.e. whether excess demand or excess supply are driving the price, which, cause and effect, are contemporaneous at the equilibrium.

So, if out of equilibrium e.g. Qs falls short of Qd, at the given price, due to the change in μs, the price will have to adjust, increase in this case (in partial equilibrium not necessarily in general equilibrium as Samuelson points out in the above quote), to reach the equilibrium level where demand equals supply. So, we should rewrite the equations 1 to 3 to show explicitly, with reduced form equations, the causal link

between μs and Qs and the causal chain to prices all the way to the equilibrium where supply equals demand at that price. This is as in Simon, Koopmans, Wald, and the Cowles Commission irrespective of the differences between their specific theories of causality.

Without the equilibrium condition, the change in the exogenous variables or for that matter in the endogenous ones or in the parameters or even in the function will not identify the cause or the effect. The reason being that it will not support counterfactual claims. Which is the point made by Hicks. And he argues that Hume rejected causal counterfactuals. Kant, I think, makes the same claim about Hume, though in a different way – Hume does not, according to Kant, allow for synthetic *a priori* claims. Which of course are all counterfactual as they are *a priori*.

This goes to the centre of the issue of causality – that of necessity. Hume's problem was not with the synthetic *a priori* judgements, but with the analytic *a posteriori* judgements, i.e. with induction. Kant thought that analytic *a posteriori* propositions were contradictory, so false. One needs to separate the analytic judgement which is always *a priori* from the synthetic judgement which can be both *a priori* and *a posteriori*, i.e. theoretical or inductive respectively.

To repeat, for Kant, the key question is how are synthetic *a priori* judgements possible, to account for empirical causal necessity, while for Hume the key question is how are analytic *a posteriori* judgements possible, given that we do not have an idea of causal necessity, as we have no impression of causality. And the latter goes directly to the issue of counterfactual causal claims (I go into more detail in my essay Causes and Counterfactuals: Simple Ideas).

Why not nothing

To address that issue, I think, Hume developed the equilibrium analysis. Most notably in his theory of money, interest, and trade. He assumes, counterfactually, that the amount of money doubles and then traces out the equilibrium effects on prices, incomes, and trade. All the before and the after happenings, as well as all the counterfactual claims, are purely theoretical, *a priori*, (or experimental as he puts it following Newton I assume; Haavelmo and the Cowles Commission will emphasise that theoretical models are thought experiments centuries later), i.e. taking place entirely within the model.

So, Hicks is wrong (similarly Lewis) to argue that Hume requires causal claims to be counterfactual. They are, in Kant's sense, synthetic *a priori* judgements or propositions. But the necessity with which the effect follows the cause should not be confused, as Kant warns, with the empirical necessity. Which, for Hume, is not there.

Within the model, e.g. when manipulating an equation or a set of equations, necessity is nothing more than consistency, the lack of contradiction. E.g. if the external variable in equation 1 changes, the quantity changes, and thus the price to maintain the equilibrium of supply and demand. Or, if the price is fixed by e.g. policy interventions, the causal effect of that policy can be read out from the violation of the equilibrium condition.

For Hume, necessity and the counterfactual claims are in the model, they are not empirical. And causality is purely empirical, thus not necessary.

Here is Hicks on the use of equilibrium method for forecasting (compare with the quote from Haavelmo in Appendix 2):

“A model of this” expectations equilibrium “kind is not realistic; it makes no claim to be realistic. We are just to use it as a standard of comparison with the actual. For the historical application, at least, it is not inappropriate. We admit that in actuality, in ‘1975’, things that were unexpected did happen, so that there was no such equilibrium during that year. But the model is to show us what *would have happened* if some cause had been different. It would seem fair to say that since it is our model, our construction, it should not admit of unexpected events, since from our point of view nothing in the past can be unexpected. So, the model can be, indeed should be, in equilibrium; though reality is not.” Haavelmo makes the same point forcefully and influentially as discussed in Appendix 2 below.

Now, I think Leibniz introduced the equilibrium condition with the notion of sufficient reason. Here is the famous quote from his Principles of Nature and Grace:

“Thus far we have spoken as simple *physicists*: now we must advance to *metaphysics*, making use of the *great principle*, little employed in general, which teaches that *nothing happens without a sufficient reason*; that is to say, that nothing happens without its being possible for him who should sufficiently understand things, to give a reason sufficient to determine why it is so and not otherwise. This principle laid down, the first question which should rightly be asked, will be, *Why is there something rather than nothing*? For nothing is simpler and easier than something. Further, suppose that things must exist, we must be able to give a reason *why they must exist so* and not otherwise.”

So, while things happen according to efficient causality (physics), which is to say a cause produces an effect, the change produced needs to be in accordance with the final causality (metaphysics), it has to satisfy the sufficient reason, which takes into consideration all the available information to make sense of whatever must exist, given all there is, which is akin to an equilibrium condition, which Leibniz called harmony or perfection, and we can call equilibrium. Indeed, he thought that change or rather the dynamics that is the effect of some causal impact will accord with

maxima or minima (of a differential equation) to arrive at an equilibrium (of course much discussed by classical economists and also by Frisch and more than anybody else by Samuelson, and of course Hicks). This has been very much misunderstood because it was taken to mean that everything that happens is for the best in the best of all possible worlds. In fact, things as they happen may indeed disturb the equilibrium, so efficient causality may keep the world in disequilibrium all the time. Still, we need the equilibrium condition to determine how much out of sync the reality is.

And of course, equilibrium is neither good nor bad in itself.

Russell in his Principles of Mathematics points to the need for an equilibrium condition in Leibniz in a different way, i.e. by arguing that there are paradoxical consequences if it is missing:

“If we admit (what seems undeniable) that whatever occupies any given time is both a cause and an effect, we obtain a reason for either the infinity or the circularity of time, and a proof that, if there are events at any part of time, there always have been and always will be events. If, moreover, we admit that a single existent A can be isolated as the cause of another single existent B, which in turn causes C then the world consists of as many independent causal series as there are existents at any one time. This leads to an absolute Leibnizian monadism – a view which has always been held to be paradoxical, and to indicate an error in the theory from which it springs. Let us, then, return to the meaning of causality, and endeavour to avoid the paradox of independent causal series.”

Kant, I think, relies on equilibrium type of reasoning when he discusses the practical reason. The categorical imperative gives the equilibrium condition for moral behaviour. Rational, which is to say acting, purposeful animal spirits, or simply people, will act in any number of ways, but consistency (which is to say the possibility of universalisation of the principles of individual actions) requires that all the individual actions are ascribed moral values with the view of them, the particular actions, satisfying or not the categorical imperative, i.e. the general principle of morality, of what we owe the others, what we owe to each other, and thus to ourselves. We may fail in doing our duty, perhaps as a rule, but we need the categorical imperative as an equilibrium condition to know that we have done right or indeed have failed in our duty.

That does not mean that categorical imperative will be satisfied in everyday moral life, but it is needed if we want to assign moral value to behaviour, which is to say to actions of people.

Moral equilibrium is the basis for the assignment of moral or any other responsibility for the consequences of actions.

Probable necessity

Back to billiards.

If the running ball were to stop suddenly at any point on its journey towards the still ball, that would not be a scandal or a miracle for Hume (as there is no empirical necessity). It would go against our expectations, but those have been developed based on repeated observations of billiard balls, they are based on Hume's custom. There is no necessity in those happenings and in their repeated observations. Induction is concluding from custom – a synthetic *a posteriori* judgement.

The cause and the effect in this deterministic setting are contiguous. In space in any case. But then clearly also in time. In terms of time and space, the cause and effect are symmetrically positioned. The question is where the asymmetry comes from, given that the relation of causation is asymmetric.

Now, introduce probability as indeed Hume does. Start with the quote from Keynes in Treatise on Probability:

"But, after all, the essential relation is that of 'independence for probability.' We wish to know whether knowledge of one fact throws light of any kind upon the likelihood of another. The theory of causality is only important because it is thought that by means of its assumptions light can be thrown by the experience of one phenomenon upon the expectation of another."

At any point in time before the moving ball hits the still one, any number of things can interfere (which is why there are so many stories in the philosophical literature about all kinds of funny things that can happen on the way to e.g. shooting guns and killing people), which we summarise by considering probable causes. The problem, again a rather basic logical one, is that in general the relation of probable causality is not transitive, as is not the causal relation as Russell points out in the quote above. The point Hume actually makes, though in a convoluted way.

Marshall, while developing the partial equilibrium analysis, which allows for causal relations to be relied on, was quite clear about the difficulties of allowing for causal relations to be transitive (to anticipate, this is the general problem with instrumental variables or with actions and interventions in general; more in Appendix 2 and Causes and Counterfactuals: Simple Ideas):

"Let us then turn to examine the chain of causation in which Jevons' central position is formulated in his Second Edition, and compare it with the position taken up by Ricardo and Mill.

He says (p. 179):

"Cost of production determines supply.

Supply determines final degree of utility.

Final degree of utility determines value."

Now if this series of causations really existed, there could be no great harm in omitting the intermediate stages and saying that cost of production determines value. For if *A* is the cause of *B,* which is the cause of *C,* which is the cause of *D;* then *A* is the cause of *D.* But in fact there is no such series."

This is in a deterministic setting. In the probabilistic setting, that is quite clear. Time, here a Kantian and not a real one, carries transitivity along, but as the cause and the effect happen at the same point in time while before and after they are just probable to happen, time's determinism is of no help. Moving from one moment in time to another along the route from the cause to the effect involves recalibration of probabilities due to possible changes in circumstances.

Thus, what was quite probable at one point in time may become less probable at the next moment on the way from causes to effects.

Generally, transitivity requires necessity, which however there is not in the empirical data and thus cannot be induced.

Here is Marshall on that:

"It is sometimes said that the laws of economics are "hypothetical." Of course, like every other science, it undertakes to study the effects which will be produced by certain causes, not absolutely, but subject to the condition that *other things are equal,* and that the causes are able to work out their effects undisturbed. Almost every scientific doctrine, when carefully and formally stated, will be found to contain some proviso to the effect that other things are equal: the action of the causes in question is supposed to be isolated; certain effects are attributed to them, but only *on the hypothesis* that no cause is permitted to enter except those distinctly allowed for. It is true however that the condition that time must be allowed for causes to produce their effects is a source of great difficulty in economics. For meanwhile the material on which they work, and perhaps even the causes themselves, may have changed; and the tendencies which are being described will not have a sufficiently "long run" in which to work themselves out fully."

In general, a cause produces an effect in the context which may be that of the Savage's "small world" of a sample of data or indeed of the universe. So, if C for

cause and E for effect and μ for the rest of the everything, i.e. for *cæteris paribus*, then we can write a causal equation or function if that is what we want to use as:

$$E = C + \mu; \text{ or}$$

$$E = f(C, \mu) \qquad (4)$$

for C is the cause of E *cæteris paribus* (which leads to the all causes model, of which more in my essay Causses and Contrafactuals: Simple Ideas). And then all the work that needs to be done, as in an experiment, is on making sure that the universe does not interfere in the work of C on E. Hume indeed suggests that experiments allow for the identification of causal relations; it is the understanding that is the problem, as was clear to Kant.

That leads to Haavelmo's causal policy implication:

$$E E|C = F(C) \qquad (5)$$

I.e. expected, *E,* effect given the cause is a function of the cause under experimental conditions.

So, the whole world needs to stand aside for one billiard ball to move the other billiard ball or bounce of it. Which does not make sense really because the two balls need to come together and end up at rest after the collusion eventually. So, the world needs to provide for the causal dynamics and for the equilibrium. Which is I think Leibniz's sufficient reason at work.

Thus, a causal proposition is a random equation or function like 4. Where everything is exogenous to the cause and the effect.[4] And with that, causes can be exogenous to the effects, can be a reduced form equation or function, so that the needed asymmetry can be asserted. Russell in Principles of Mathematics points to the key problem with causality if *cæteris paribus* condition is introduced, as it must, or an equilibrium condition is introduced, as it must:

"One general principle, which is commonly stated as vital to Dynamics, deserves at least a passing mention. This is the principle that the cause and effect are equal. Owing to pre-occupation with quantity and ignorance of symbolic logic, it appears to have not been perceived that this statement is equivalent to the assertion that the implication between cause and effect is mutual. All equations, at bottom, are logical equations, i.e. mutual implications; quantitative equality between variables, such as cause and effect, involves a mutual formal implication. Thus the principle in question

[4] In their paper on "Exogeneity", Engle, Hendry, and Richard show how hard it is to formalise the *cæteris paribus* condition.

can only be maintained if cause and effect are placed on the same logical level, which, with the interpretation we were compelled to give to causality, it is no longer possible to do. Nevertheless, when one state of the universe is given, any two others have a mutual implication; and this is the source of the various laws of conservation which pervade Dynamics, and give the truth underlying the supposed equality of cause and effect."

Russell dismisses, initially, or qualifies, later, the whole idea of causality for other reasons too. One being the assumption of the one-sided temporal asymmetry. Which is crucial for historical causality. Take the two billiard balls again. At equilibrium, before or after the causal incident, their whole history up to the equilibrium is given. So, we can go backwards and establish the causal connections which led to the temporary equilibrium that they are at. So, causality can be established from the future to the present and the past as much as from the past to the future. The causal asymmetry can go together with the asymmetry of time either way. As the casual event is instantaneous or contemporaneous anyway.

Going backward in time, looking at history, is not helpful to e.g. economic analysis. As Hicks points out, most of the historical economic dependencies happen within the same period of time. And certainly, temporary equilibrium and disturbances, as in Hume's monetary theory, are theoretical exercises which hopefully help explain data, which is historical. Otherwise, there is fatalism, which Hume rejected in his criticism of religion.

More general argument against historical approach to causality is Russell's. If the cause is to produce the effect, that it needs to do always, which is why it cannot be induced from historical records. Otherwise, these are individual causal implications, which are clearly important if responsibility for consequences is to be assigned, but those are not useful either as explanations or as guides for action. More on that in Appendix 2.

Now, in structural theory of causality, e.g. Haavelmo's or Simon's (more on that in Causes and Counterfactuals: Simple Ideas), Hume's example of the billiard balls is useful. Both balls can be seen as causing effects, interactively. The moving ball disturbs the still one, while the still one changes the course of movement of the running one. All at the same moment in time. So, Simon's structuralism would start with a set of equations that describe the two balls and then focus on the one or the other effect or indeed on all the effects. Equations are symmetrical, while the causal effects are asymmetrical though timeless. Also, clearly, they allow counterfactual claims to be made. If we can figure out the equilibrium condition, which is to say where the balls happened to have been before and where they are going to end up at.

The problem with contemporaneous causality is how much space do we need between the two balls at the moment when they impact each other? In equilibrium, as Leibniz would say, all of it, or as much as there is. All the dynamics in between is descriptive, as Russell discussed and the quote above suggests.[5] Put differently, as the time interval, the asymmetry that it brings to the causal relation, is not relevant, how do we determine the space interval between the cause and the effect and the symmetry that comes with it? If succession is irrelevant due to interdependence, does contiguity matter at all? In economics, how far away from each other need the markets to be for demand and supply to determine the equilibrium price on all the markets, i.e. for the equilibrium condition to assert itself?[6] That is the question about the laws of nature.

Hypotheses non fingo

Hume says in the quote from the Enquiry above:

"The only immediate utility of all sciences, is to teach us, how to control and regulate future events by their causes."

In the Treatise he argues that the interest in the future far outweighs whatever interest we might have in the past, in history. Indeed, some crucial events or cultural landmarks from the distant past stand out in our memory, connected together as in a story, esthetically perhaps one might say, while there is the vivid and strong practical, i.e. rational interest in what is to come in the future.

Memories and expectations differ somewhat like dreams and plans, like stories with the ends that make sense on one hand and intentions with expected outcomes on the other. Generally, as we cannot induce causes from immediate experience, from experiments as Hume calls them, we cannot induce them from information stored in our or in collective memory, from any number of experiments that history awards us with. So, while we might be interested in the causes of effects, science is really about the effects of causes – our theoretical activities are guided by our practical interests.

But how can we construct an experiment, actual or theoretical, and not only detect causal links, but have an idea of causality in the sense that we can account for future events, let alone "control and regulate" them? We could hypothesize or forecast, but

[5] Russell discusses time and space intervals in quantum set-ups in his The Analysis of Matter. Also, in a different way, in The Analysis of Mind.

[6] On time and space intervals see Russell in The Analysis of Matter.

that is not in the experiment. So, the experiment needs to reveal a regularity, a law, in order to be used for control and regulation.

In that, Hume and Kant are in agreement. One does not have to endow the laws of nature with any kind of finality *a la* Leibniz, but without laws of nature we are left with hypotheses, which after Newton *non fingo*, they are not really satisfactory. The laws of nature, however, are not causal, but explanatory. Thus providing not so much the guide to interventions, but the stability that allows for our *a priori* intentions to be validated by *a posteriori* outcomes - the former being analytic, the latter empirical.

So, Hume constructed his models of markets and money and of policy interventions in order to observe the laws of practical life which allow for outcomes to accord with the models. Their added advantage is that they assume interdependence and speak to the general equilibrium as it is going to be called.

Miracles: There is no logic to nature

"The logical simplicity characteristic of the relations dealt with in a science is never attained by nature alone without any admixture of fiction." Frank Ramsey

Hume says that we induce regularity from similarity between repeated events which follow each other: "Similar objects are always conjoined with similar." There is no logic to that.

Every single instance, e.g. of billiard balls crashing into each other is an experiment. Hume also talks about each observation being an experiment. Repeated observations, or singular experiments, lead to the regularity of similar events having similar consequences. There is, however, no necessary connection between causes and effects or we cannot find that necessity in the repeated experimentation that we perform either by action or by observation. As every necessity that we conceive can be falsified by an unexpected occurrence. The stability of similarities can be disturbed by a change in the circumstances or by the change in our perspective on what is similar and what is not.

In discussing miracles, i.e. events which go against the expectations thus breaking the empirical generalisations on which we rely to go from causes to effects, Hume argues that there is nothing in the cause that is not in the effect, no external intention or action. So, if indeed there is a miraculous event, it should be observed and reported by many, and repeatedly. Nothing beyond the regularity of similar causes being followed by similar effects can be observed in any occurrence and no special faculty is needed to make the observation however unexpected or miraculous it might be.

We do however induce the regularity from repeated individual experiments, or observations. That regularity does not provide for necessary connection, but is explanatory. So, the custom to connect similar with similar, individual observation or experiment with another, is what we refer to when we rely on our memory or form an expectation. Our memory can fail us and expectations can be disappointed, but they are explanatory to the extent that anything is.

The explanation works by subsuming an individual instance under the general rule, e.g. in the following way:

Whenever x then y, *cæteris paribus*	(7)
There is x	(8)
Then y.	(9)

In other words, because x is always or as a rule followed by y, that explains why y follows x.

To challenge the explanation, it is not enough to show its dependence on circumstances, on the *cæteris paribus* condition, but to show that the rule, the regularity, the explanation does not work even in the cases in which it has been taken on the authority of experience to work. Thus, the law is not causal, it is explanatory. It does not rely on any kind of necessary relationship between the cause, x, and the effect, y.

For an explanation to fail, an inconsistency is needed, an inconsistency between the explanation and the observation is required. And as nothing is inconsistent in nature, the inconsistency needs to be either in the explanation or between the explanation and the data. Thus, Kant's synthetic *a priori* judgement needs to be free of contradictions, while explanations cannot be dependent on miracles, on events which cannot be repeatedly observed so that regularity might be established.

Still, as nature is not required to be consistent with any regularity we induce from whatever we observe, from appearances, that consistency, i.e. the possibility of explanation, is in some sense miraculous. All these individual experiments or observations together with their regular repetitions, all that is miraculous in the sense that it is not necessarily congruent with any explanation, however logical, that we might be able to concoct.

The failure of an explanation, however, is less of a problem than the ease with which explanations can be taken to be supported by the evidence. The advantage of individual causal claims is that those can be falsified by not being corroborated by evidence and observations. So, miracles can be rejected. However, for explanations we need accounts which cover multitude of events or observations or experiments,

which will require a more elaborate model or theory in order at least to ensure that data that does not matter is put aside and that all the relevant interrelations are taken on board.

Then the problem is that, by Duhem-Quine Theorem, the more elaborate the model, the easier it is to identify it in the data. This is because theories or models provide sufficient reasons for the way things are or, conversely, theories are under-determined by data and accumulation of data is not a way to rule out any theory. In a way, one needs a miracle to rule out a theory that has convinced the people of being explanatory of the reality that is being observed.

One way in which miracles are indeed helpful is to observe a natural experiment (or controlled one, but those are rare in social sciences) which challenges the model as a whole, not one isolated causal regularity. In a way, tests to the stability of the theory or the model is needed. If one can identify the theory while observing a crisis of some sort, which threatens the model as a whole, one may indeed hope to have found the explanation which one is looking for.

As the theory would have encoded the laws of nature in its interrelationships.

The laws of nature would then be the stability or the equilibrium conditions, the mechanics rather then the dynamics of nature, which is explanatory for the relationships and thus, given the theory, an effect in nature will follow the natural cause analytically. Thus making it possible to “control and regulate future events” which would provide the justification of science that Hume looked for at least from the point of view of human nature.

So, Hume’s despair for the idea of causality is motivational. How are laws of nature possible, would be one way to formulate the question he wants to find an answer to. Induction from experience, which gives rise to “unphilosophical probability”, supports empirical generalisations only, which can as well be prejudicial as they can be clarifying. Though they are used as guides to action.

However, at least when discussing economics and politics, especially with the view to potential policy interventions, he constructs a series of theoretical models, e.g. of money, trade, ideological conflicts, partisanship, or differences in demographic developments, which are supposed to capture the law-like regularity which support the explanations for observed causal relations, which is to say repeated succession of proximate events which are similar enough. So, while there is no necessity to be found or to be imputed, there is law-like regularity rather than just empirical generalisation or inference to be relied on in order to explain and predict.

If we check the prices in one market, we know the prices in the other markets. Indeed, we need to check the prices, as sellers or buyers, for those to be given, they

are only probable before they are revealed.[7] If prices deviate from market to market, we look at other markets to account for the discrepancy. Also, the market we check does not only reveal the price of the same commodity across all markets, but the prices of all other goods too, assuming that the general equilibrium condition of no excess demand is satisfied.

Now, in all the cases, the law of one price is satisfied. In the sense that the law is implied and is helpful to the explanation of the price data that we collect at any particular point of time or period. This is not a causal law, it is a regularity which provides an explanation, or part of an explanation, of apparent causal relations in the market. The law does not impose itself on the prices, it is satisfied by the price system.

So, we can say that trading reveals the prices and that we know the prices on all the markets once we know the prices on one market because – in explanatory and not causal terms – of the equilibrium condition.

Similarly with the billiard balls. Once we start the ball rolling we know where the two balls will end at and indeed where all the billiard balls will lend at. And as long as we know the laws of nature, we can explain how it is that we know where the billiard balls will end up being as soon as we know the data that we need to calculate their trajectories. The actual, empirical deviations, when observed, are due to unaccounted for or changed circumstances, on the *cæteris paribus* condition not being satisfied. But the laws of nature are satisfied in those cases too.

One could argue that the same applies to information based interaction between Bob and Alice or to any histories of information flows. The signal and the response do not need to succeed each other nor do they have to be contiguous. They need to satisfy the laws of nature, or rather we can understand the connection between Bob and Alice by relying on the natural law which their communication certifies. No casual necessity needs to exist between Alice's signal and Bob's response. Regularity which goes with the laws of nature is what explains whatever we observe the two events to be. There is no necessity that those should come out one way rather than another.

Nature does not have to respect logic.

To clarified the role of laws of nature of the moral world, Russell's take on causality is helpful:

[7] See K. Arrow, Methodological Individualism and Social Knowledge. American Economic Review 84 (1994): 1-9.

“I have spoken hitherto of independent systems of *n* particles. It remains to examine whether any difficulties are introduced by the fact that, in the dynamical world, there are no independent systems short of the material universe. We have seen that no effect can be ascribed, within a material system, to any one part of the system; the whole system is necessary for any inference as to what will happen to one particle. The only effect traditionally attributed to the action of a single particle on another is a component acceleration; but (a) this is not part of the resultant acceleration, (b) the resultant acceleration itself is not an event, or a physical fact, but a mere mathematical limit. Hence nothing can be attributed to particular particles.”

The law is the sufficient reason, if one wants to refer to Leibniz. Or, it is not the efficient cause. The sufficiency, however, is not the one of an implication, it is not functional. Indeed, if one were to frame the relation between the causal connections and natural laws, then causality would be in implication of the natural laws, the laws themselves are not necessary implications of causal relations. Or, they, the laws, would be explanatory for the apparent similarities or empirical regularities. Kant’s synthesis *a priori* is about the laws of reason, which should prove explanatory for the world out there.

So, basically, and I think similar to Popper (in The Logic of Scientific Discovery), there are no causal laws, laws explain causal connections as they appear in experience or in scientific research.

At the dawn of econometrics, Frisch (in 1930) makes clear the point which indeed is what Hume and Kant were arguing for:

“So far I have avoided the word ‘cause’, and for most purposes it would be perfectly possible to do without it altogether. This would have the advantage of avoiding much confusion and superficiality which has been introduced into the discussion of the logic of science by this scholastic term. However, it would probably be impossible to rid the language of this notion, so we had better take it up and see what it contains. The everyday conception of a cause is animistic. We think of a cause as something that governs or directs the general phenomenon in much the same way a general is directing his troops. Obviously we have gotten this idea from a psychological introspection of ourselves. We know that in many circumstances we have the ability of influencing the course of events by exerting our own willpower. And on this pattern we have built the fiction of governing causes. In other words, we think of a cause as something imperative which exists in the *exterior world*. In my opinion this is fundamentally wrong. If we strip the word cause of its animistic mystery, and leave only that part which science can accept, nothing is left except *a certain way of thinking*, an intellectual trick, a shorthand symbol, which has proved by itself to be a useful weapon, legitimate or illegitimate, in our fight with nature and social institutions. As I see it the scientific (as distinguished from the scholastic), problem of causality is essentially a problem regarding our way of thinking, not a problem

regarding the nature of the exterior world. The scientific (as distinguished from the scholastic) answer to the question ‘what is a cause?’, does not read: it is such and such a phenomenon. If any scientific answer is possible it must read: it is such and such a way of thinking.”

Causality is dependent on the laws of nature, which are captured by the theoretical model which supplies the explanation of the facts and their dynamics.

The model, however, is underdetermined in the sense that it is sufficient to provide the explanation, but the empirical data by itself does not either confirm it or rule it out conclusively. The question is not so much whether laws or regularities are needed, but how are “unphilosophical” empirical generalisations to be rejected in favour of the scientific laws? And given that logic is not enough to rule out scientific explanations and any number of those are consistent with the world as it is given to us, how are laws of nature identified?

Hume’s answer is that repeated experimentations or persistent evidence and not miracles is the way to discover the ways of nature. Leibniz’s sufficient reason is present in the experimental data the issue is how is it to be discovered?

Take again the example of price determination in economics. Any number of market transactions will not give us the prices at which goods are exchanged only the ways in which they change. So, for explanatory purposes rather than to find out the causes for price movements, one takes that (i) supply equals demand at the price, and (ii) people economise, i.e. react to changing prices in the way that is consistent with their interests and means. Thus one arrives at the explanation by equilibrium analysis. The analysis is explanatory, not descriptive.

We can get to equilibrium analysis axiomatically, e.g. as in Arrow-Debreu general equilibrium model, but though the model may prove explanatory, every consistent theory will prove explanatory, and of course all the inconsistent ones too. The issue if how are laws of nature discovered, those that are explanatory and also true to the actual world? In that miracles may indeed play a role in the way in which Hume deals with monetary shocks and their general equilibrium consequences. The miracles are experiments which can be repeated and thus confirmed inductively, but which are not implied by the causal or other empirical generalisations accepted customarily.

No amount of causal connections, of similar events following similar events, will transform empirical generalisations, habitual explanations, into laws of nature. One needs exceptions that can be repeatedly observed by everybody in varying circumstances to grasp the sufficient reason, the equilibrium explanation, or the laws of nature.

What Russell misses in his book on Leibniz is the equilibrium condition. What also a lot of interpretations of Hume's scepticism miss is his reliance on empirical generalisations and ultimately on law-like explanations. Perhaps most similar to the covering law model or what is called structural in economics. An equation, possibly encoding causal relationship, perhaps represented by a directed graph, will be structural if it is valid generally. Thus allowing the manipulation of the causes to get the effects, precise or expected. Assuming that those are general *caeteris paribus*, that would be consistent with the Cowles Commission, e.g. Hurwicz' understanding of structural relationship, e.g. equation or function. Then, if the relationship is applicable under all conditions, that would be generalisation of a structural relationship or would be a natural law. There still could be any number of competing natural laws that explain the data of interest.

What was important to classical economists was to make moral sciences scientific. Which meant to abandon the reliance on causal explanations in favour of law-like explanations. The problem with causality, as Hume argued, is that it leads to explanations which lead in one way or another to some kind of a conspiracy theory with the ultimate conspirator pulling the strings. Kant made that point clear with his antinomies, which are contradictory theories which cannot be ruled out on the basis of being contradictory. The facts need to adjudicate. And for that to be possible, stability or regularity needs to be assumed or discovered, which is to say there have to be laws of nature of ethics which can explain facts and actions.

Thus, the explanatory irrelevance of causal connections and the search for the invisible hand, which is to say for laws of nature or ethics. For that, the equilibrium condition is useful. Assume that we have information about prices, then we can calculate the demand and supply from the equilibrium condition. We can then check the data to see whether there is excess demand or supply or a shortfall of one or the other. Or look for whatever causes the particular shortfall to occur. That is the explanatory use of the equilibrium condition or of what Leibniz called the sufficient reason.

Only, the law is under-determined. It explains, but does not necessarily regulate. It explains in the following way. Assume that we can measure supply or demand or prices, then we will also measure the other values too. Also, if we want to intervene, e.g. by increasing the demand, we will know the values of the other variable. All of that, *cæteris paribus*, assuming that is the autonomy of the particular small world we are considering.

So, in the supply and demand system of equations 1 to 3, the equilibrium condition is sufficient to identify the causes and the effects given the data, but that particular equilibrium condition is not implied by the data on supply and demand and the prices. Any number of other equilibrium conditions might do. It is a law, but any number of laws might do as well.

Thus the natural laws are under determined. The model of the economy or the universe is needed for the particular laws to be consistent with the data. The true model of the actual world requires the appropriate experiment to be identified. That would then allow the analytic *a posteriori* applications to be applied.

The law, the invisible hand, is not the necessary condition and is not imposed, it is not itself a cause, it is satisfied. It is the sufficient condition, but is model dependent, which is to say it is not unique. But there is no explanation based solely on causality except if one is prepared to accept, contrary to Hume, that there is something more in the cause which is not in its effect, that there is one or the other type of intervention which holds the world together or rather controls the chain of causes and effects from the beginning to the end.

Classical economists and rational philosophy I think were scientific by rejecting causal explanations in favour of law-like ones.

Appendix 1

The invisible hand

Stiglitz says: “Adam Smith's invisible hand may be invisible because, like the Emperor's new clothes, it simply isn't there; or if it is there, it is too palsied to be relied upon”.[8] Does Smith claim anything different?

He mentions the invisible hand three times.[9] Once in The History of Astronomy:

“For it may be observed, that in all Polytheistic religions, among savages, as well as in the early ages of Heathen antiquity, it is the irregular events of nature only that are ascribed to the agency and power of their gods. Fire burns, and water refreshes;

[8] J. Stiglitz (1991), “The Invisible Hand and Modern Welfare Economics”, NBER Working Paper No. 3641. More on the palsied hand in J. Stiglitz (1985), “Information and Economic Analysis: A Perspective”, The Economic Journal 95 (Supplement): 21-41. For a detailed survey of the incentive economics as an alternative to a Smithian economics J. Stiglitz (2003-2004), “Information and the Change in the Paradigm in Economics Part 1 and Part 2”, The American Economist 47: 6-26 and 48: 17-49.

[9] E. Rothschild (2001), Economic Sentiments: Adam Smith, Condorcet and the Enlightenment. Harvard University Press. She thinks that Smith’s use of the term invisible hand is ironic. That is probably correct if it is taken to aim at chiding the ignorant. Also E. Rothscild, A. Sen (2006), “Adam Smith’s Economics” in Knud Haakonssen (ed.), Cambridge Companion to Adam Smith, 319-365. Cambridge University Press. In addition, it is worth reading J. Tobin (1991), “The Invisible Hand in Modern Macroeconomics”, Cowles Foundation Discussion paper No. 996 and R. Coase (1976), “Adam Smith’s View of Man”, The Journal of Law and Economics 19: 529-46.

heavy bodies descend, and lighter substances fly upwards, by the necessity of their own nature; nor was the invisible hand of Jupiter ever apprehended to be employed in those matters. But thunder and lightning, storms and sunshine, those more irregular events, were ascribed to his favour, or his anger. Man, the only designing power with which they were acquainted, never acts but either to stop, or to alter the course, which natural events would take, if left to themselves. Those other intelligent beings, whom they imagined, but knew not, were naturally supposed to act in the same manner; not to employ themselves in supporting the ordinary course of things, which went on of its own accord, but to stop, to thwart, and to disturb it. And thus, in the first ages of the world, the lowest and most pusillanimous superstition supplied the place of philosophy."

The second time in The Theory of Moral Sentiments:

"The produce of the soil maintains at all times nearly that number of inhabitants which it is capable of maintaining. The rich only select from the heap what is most precious and agreeable. They consume little more than the poor, and in spite of their natural selfishness and rapacity, though they mean only their own conveniency, though the sole end which they propose from the labours of all the thousands whom they employ, be the gratification of their own vain and insatiable desires, they divide with the poor the produce of all their improvements. They are led by an invisible hand to make nearly the same distribution of the necessaries of life, which would have been made, had the earth been divided into equal portions among all its inhabitants, and thus without intending it, without knowing it, advance the interest of the society, and afford means to the multiplication of the species."

The third time in The Wealth of Nations:

"But the annual revenue of every society is always precisely equal to the exchangeable value of the whole annual produce of its industry, or rather is precisely the same thing with that exchangeable value. As every individual, therefore, endeavours as much as he can both to employ his capital in the support of domestic industry, and so to direct that industry that its produce may be of the greatest value; every individual necessarily labours to render the annual revenue of the society as great as he can. He generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it. By preferring the support of domestic to that of foreign industry, he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention. Nor is it always the worse for the society that it was no part of it. By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it. I have never known much good done by those who affected to trade for the public good. It is an

affectation, indeed, not very common among merchants, and very few words need be employed in dissuading them from it."

In the first case Smith argues that the invisible hand is employed out of ignorance: when events cannot be explained by regularities they are referred to the action of the invisible powers, which, clearly, do not exist. The presumption is that this invisible hand is motivated in the same way in which the visible hand of people is motivated. That raises the question of whether there are some laws that govern human behaviour that cannot be immediately applied to irregular events and thus out of ignorance are ascribed to, the visible hand of, human action. Smith does not say, as often quoted, also by Stiglitz, "as if led by an invisible hand", because the term "invisible hand" is already a metaphor, which is to say that it means that it is like the hand exists, but it does not.

The two other references to the invisible hand are really about the fallacy of explanations by actions of the visible hand.

In the passage from the Theory of Moral Sentiments Smith argues that the rich cannot consume all that much so that either their moral reformation or redistribution of resources could lead to an appreciable increase in the consumption of the poor. So, the distribution of wealth does not matter for the determination of the inequality of income and consumption.[10] The actions and the motivation of the rich and the poor do not matter for the distribution of welfare, which is determined by the invisible hand, which is just a metaphor for the laws of distribution, which unlike the invisible hand exist.

In the most often quoted passage from The Wealth of Nations, Smith uses the invisible hand as a synonym for deductive explanation (one could say that invisible hand leads one from premises to conclusions, though of course the latter are implied in the former). He first argues that in an accounting sense, if individual income is increased, national income is increased too. Then he argues for the same conclusion in the causal sense: if the aim of the individual enterprise is to increase one's income, the unintended effect will be an increase of the national income. This applies to a closed as well as to an open economy. Clearly the latter case has been debated

[10] An important exploration of this issue is in R. Dworkin (1981), "What is Equality? Part 1: Equality of Welfare" and "What is Equality? Part 2: Equality of Resources", Philosophy and Public Affairs 10: 185-246; 283-345. Stiglitz criticises this theory of distribution, though he does not refer to Smith in many places including in J. Stiglitz, "On the Economic Rile of the State" in A. Heertje (ed.), The Economic Role of the State. Basil Blackwell.

the most, but Smith argues that not much improvement will come from additional reliance on the visible hand of political intervention.[11]

So, Smith uses the term invisible hand to suggest that it is misguided to look for the act of a hand in whatever goes on because the hand that determines the outcomes of individual and political actions does not exist. Regularities or laws, however, which govern individual and political actions, do exist.

How about the argument that the invisible hand is too palsied to be relied upon? First, Smith does not say that the invisible hand works for the individual and common good only, which is what most of the interpretative discussion, by Stiglitz too, is about. He says that this is so in some instances and that the invisible hand does not always lead to bad overall outcomes. He is sceptical about the possible outcomes of political actions for the very reason that the invisible hand, that is law-like regularities, may lead to bad outcomes of political actions, that is of actions that have the increase of the public interests as their primary objective. In both cases: of individual actions with public consequence and of public actions with individual consequences, the outcome may be different from that which was intended - different in quality, i.e. good or bad, as well as in quantity.

However, second, Smith does believe that there are law-like regularities and that for that reason they are not palsied, i.e. not robust. Individual and political actions indeed can appear palsied, as not being led by the invisible hand, if their outcomes are explained by their motivations and not understood to follow from general laws.

So, yes the invisible hand does not exist and for that reason cannot be palsied.

Appendix 2

Not to explain, to change

Take the two billiard balls again. The difference between the causal powers of the two is that in the case of the running ball there is the player who initiated the action. So, there is the first mover so to speak, there is the causal intervention, following the intention, that changes the course of events. In the case of the still ball, there is its causal impact on the ball running towards it, but no intervention or intention behind its causal powers. So, what is the explanatory power of the intention that intervenes

[11] For a Smithian type of an argument see P. Krugman (1987), “Is Free Trade Passé?”, Journal of Economic Perspectives 1: 131-144. Keynes interprets classical economics as arguing for negligence of the changes in the trade balance and that clearly applies to Hume and Smith.

causally? Or is the explanation advising the intervention, the intending change in the way the things are to where they should be?

Practically all recent work on structural causality and on policy interventions is an elaboration of this argument in Haavelmo's 1943 paper on "The Statistical Implications of a System of Simultaneous Equations":

"Assume that the Government decides, through public spending, taxation, etc., to keep income, r_t, at a given level, and that consumption u_t and private investment v_t continue to be given by (2.5) [$u_t = \alpha r_t + \beta + x_t$] and (2.6), [$v_t = k(u_t - u_{t-1}) + y_t$] the only change in the system being that, instead of (2.7), [$r_t = u_t + v_t$] we now have

(2.7') $r_t = u_t + v_t + g_t$,

where g_t is Government expenditure, so adjusted as to keep r constant, whatever be u and v, as given by (2.5) and (2.6). (2.7') then does not, impose any new restriction upon u and v, beyond that which is expressed by (2.5)-(2.6). Then, from (2.5) and (2.6) it is readily seen that

(4.5) $E\,(u_t \mid r_t) = \alpha r_t + \beta$

(4.6) $E\,(v_t \mid u_t - u_{t-1}) = k(u_t - u_{t-1})$.

That is, to predict consumption u_t and private investment v_t under the Government policy expressed by (2.7') we may use the "theoretical" equations obtained from (2.5) and (2.6) by omitting the error terms x_t and y_t. This is only natural, because now the Government is, in fact, performing "experiments" of the type we had in mind when constructing each of the two equations (2.5) and (2.6)."

Compare to Wiener on prediction:

"As an application of this, let us consider the case where $f_1(a)$ [effect] represents the temperature at 9 A.M. in Boston and $f_2(a)$ [cause] represents the temperature at the same time in Albany. We generally suppose that weather moves from west to east with the rotation of the earth; the two quantities 1 – C [C means cause] and its correlate in the other direction will enable us to make a precise statement containing some of this content and then to verify whether this statement is true or not. Or again, in the study of brain waves we may be able to obtain electroencephalograms more or less corresponding to electrical activity in different parts of the brain. Here the study of the coefficients of causality running both ways and of their analogues for sets of more than two functions *f* may be useful in determining what part of the brain is driving what other part of the brain in its normal activity. This is the key phrase, as the method does not intrinsically involve the introduction of artificial stimuli into different parts of the brain. The danger of introducing such stimuli is that by their intensity and brusqueness they may tear new paths through the brain which are not

followed by its normal activity and which may be considered in a certain sense artifacts."

Take Hume's case when new gold mine is discovered and gold is money. That will grow the economic activity and then cause the prices to rise thus re-establishing the relative prices that prevailed before the amount of money increased. Indeed, in Hume's model, whenever supply of gold increases, production temporarily increases, and inflation eventually follows. There is, one could conclude, the causal relation between the change in the amount of gold and the change in the price level. That, however, would not be the case if gold were not money. Indeed, new mines were sought, at least in part, because gold was money. Once gold is not money, the effort put into finding new mines changes and in any case the price level and inflation are not dependent on the amount of gold outstanding or respectively mined. So, the causal connection between gold and prices is dependent on the roles they play in the drama that is Humean economics.

The model could be generalised by just putting money where gold was; in other words we could take the relations to be structural, meaning general. And then assume that money is controlled by the authority and is thus exogenous to inflation and economic activity. Then experiment *a la* Haavelmo.

But then there is Wiener's problem. External intervention disturbs the natural order of the way things are. Preferably there are natural experiments, which include within them the interventions too. So, we need models with interventions which are intentional, i.e. are ends-means models; we need policy models, which are advised in their intentions (ends) and executions (means) by the explanations of the way things are as they are governed by the laws of nature or by the laws of ethics or social conduct in this case.

So, assume people playing billiards. Assume that they understand the rules of the game and are being taught how to play as best they can, then basically their actions will be endogenous to the game of billiards and indeed to the nature or the mechanics of things and to their natural laws.

So, assuming supply and demand of an economy as a whole, of monetary economy at that, monetary policy, i.e. interventions by the monetary authorities will be represented by some general equilibrium model where e.g.:

$$p = Qs + \mu s \quad (9)$$

$$Qd = p + r + \mu d \quad (10)$$

$$r = p + Qs - Qd + a \quad (11)$$

The r is the interest rate set by the central bank with the view to stabilising inflation at the desired rate with supply equal to demand, Q. The real interest rate (r-p) needs to be positive, e.g. by a constant a.

The deviations from the equilibrium values are explained by this model or its mismanagement. Assume barter economy, then by Walras Law, supply would equal demand. Intervening with the introduction of money, policy is needed which conforms with the Walras Law in the monetary economy. We could experiment with the model by increasing the amount of money as much as it is needed for barter economy to re-establish itself. Which is the way of performing an experiment which reveals the equilibrium condition as well as causal connections within the model.

Hume's model achieves the same by varying the amount of gold, which in his model is money. The model is useful as the explanation of how the monetary economy works, is it helpful in formulating a policy advice? If it does not matter whether gold or a piece of paper is money, and if there is historical evidence of the impact of the change in money supply or in the interest rate in the money market, then it is advisable that the appropriate monetary intervention is required if the predictable effect is desired. This is almost like saying that whenever a cause, then an effect given sufficient historical evidence of their causal dependence.

How stable is the model? That depends on its generality, which is another way of characterising it as structural. Put differently, it depends on its explanatory power remaining intact even if it is dramatically challenged, e.g. by a deep crisis. For instance, does it survive in instances of hyperinflation or if it is subjected to a comprehensive financial planning with sticky prices, i.e. as in a command economy with protectionist trade policy. If it does, then one can argue for the model surviving and being useful as the tool of analytical *a posteriori* policy advising. Then explanation helps advising the policy of change.

So, the advise for policy change depends on the stability of the explanation, on whether the model on which the explanation is based is structural in the jargon. What does structural mean? Hurwicz in the very influential paper on The Structural Form of Interdependent Systems (1966) argues that: "(T)he structural form is defined relative to a class of modifications". An explanation is structural to the extent that it can deal with the new data. An intervention is structural if it can be relied on to advise a cause of action with predictable consequences. The explanatory side is law-like while the practical side is causal. The latter relies on the former.

To see the relation, one can ask why do political actors need Das Kapital or the General Theory to guide their decisions and policies? Why leave the barricades to study? And how much do you need to know? Hurwicz says that the answer to these questions depends on what is to be done: the generality of the explanation is dependent on the practical, on what is it that is to be done. The action determines

the generality of the explanation that is needed, i.e. the structure or the stability that is needed for the desired change to be possible and thus the required action to be advisable.

The debate between Sargent and Sims on the advisory use of econometrics is instructive here. Sargent advises the benevolent dictator who could change the rules of the game, while Sims advises the party in power within a democratic system which can intervene to get what it wants on the basis of the historical knowledge of what works. Sargent's benevolent dictator chooses between two optima, where the one has better prospects than the other. Sims' party in power chooses the instrument which will deliver the desired outcome on the assumption that it conforms with the persistence of the optimum. None are based on the understanding of the laws of political action, so are not structural or, which is the same thing, are not general.

Appendix 3

Equilibrium dynamics

Frank Knight in Statics and Dynamics:

"In the interest of clearness as to the nature of the relations and adjustments involved, we first call to mind some of the uses of the notion of equilibrium in connection with natural phenomena.

At first sight the idea of static conditions may seem to be merely that of *cæteris paribus*, but a little reflection will show that frequently much more is involved. It is true that the study of the causal relation, or correlation, between any two magnitudes which are involved in an interrelated system requires that the other be held constant. In the more precise language of mathematics, causality is a functional relation involving a large number of variables and the relation connecting any two, when separable at all, is a partial derivative which is a function of all the others and at best can only be stated independently by each of the others by giving each of the others some fixed value. In a general case the relation of dependence may be mutual for all the variables in a function. But in real examples the relation is not typically mutual and elements which are to be treated as variable and those which are to be treated as fixed cannot be chosen arbitrarily. Equilibrium in nature is generally a phenomenon of adaptation in a real sense; one group of factors adapt to another group (as well as to each other); as between the groups, the adjustment is predominantly or wholly in one direction; rather typically, particularly in economics, the framework factors themselves are in motion independently, as already

suggested, dragging the adapting group behind them instead of moving to meet the latter.[12]

The most common example borrowed from nature to illustrate static equilibrium in economics is that of water tending toward its level. Here there is no room for question as to the separation between the process and its setting, between the factors changing and the factors in relation to which they change. The "given conditions" are (1) the quantity and fluid properties of the water and (2) the shape and size of the drainage basin or system of interconnected containers in which it is free to move under the influence of (3) the force of gravity. What is variable is the position of the water or the various portions which make up its fluid mass. (The illustration is also in point in connection with the questions raised in the first part of this paper, the analogical meaning of gravity and inertia and the various sorts of friction and of the actual character of the process which might take place under slightly different conditions.)

What interests us here is merely the character of an equilibrating change. There is a fixed or presumptively fixed sort of conditioning factors and a process which moves toward a state of rest by establishing equilibrium with relation to the given conditions. The prevalence of this general type of situation in the world is striking. The wind, for another example, results from a disequilibrium in the atmosphere, a difference in pressure corresponding to the difference in water level, and its blowing operates to equate the pressure and bring the process to a stop. Electric current is a similar flow from high to low "potential." All the movements and processes of ordinary observation seem to represent a flow of energy "downhill" and toward a level at which it would be at rest. Most of them are finally derived from the redistribution of the solar heat energy, which itself gives every indication of having the same character. Its flow perpetually maintains the disequilibria which causes the flow of water and air, and hence the phenomena of life. The fundamental cosmic mystery is the origin and destination of a universe which science pictures as an irreversible reaction. (If the analogy of a frictionless system holds, the solar energy must complete a circuit sometime, in some way, but that is not our problem here.)

In economics we are chiefly concerned with equilibrium not as a state of rest but as a *process* in equilibrium, with a slower process forming the "given condition" within

[12] All the possible types are met with in economics. The relation between price and cost illustrates an adjustment which is mutual as to direction of movement but with such a difference in speed and range that it is generally justifiable to say that cost of production "determines" price and not inversely. Changes in the cost of any one commodity reflect the relative movement of all competing industries using the same resources in production, and hence are likely to be small in comparison to the change in price in the process by which the two are brought to equality. It seems inevitable and correct to speak of the relatively fixed magnitude as cause, as we say the level of the water in the ocean controls that in the bay, or earth attracts the falling apple, or that we tie the boat to the bank, even though the relation is mutual.

which a more rapid one takes place and tends toward a moving equilibrium. Thus the flow of solar energy and the form, position, and movement of the earth condition the complete circular process of evaporation of water from the ocean and its return flow thither through the streams. This circular process is in equilibrium when the amount of water reaching the sea is the same as the amount leaving it by evaporation, and, when at every point in the complex circuit, the quantities arriving and leaving are equal, the flow neither expanding nor contracting. It is obvious that after any change in the solar radiation or any of the numerous other given conditions, all of which do in fact undergo changes, a considerable interval must elapse before equilibrium will be established. It follows that the system never really is in equilibrium ("moving equilibrium") at any point; but its tendency toward such a state is the main feature to be made clear in scientific description of it. (The role of friction and inertia in producing a lag in the adjustment of processes toward a moving equilibrium with their given conditions is considerably different from the case of tendency toward stationary equilibrium, but the differences need not be elaborated here.)

In economics, as previously remarked, this general type of relation is exemplified in a series of stages. The notion of a series of "cases" in price theory, extending from short-run to ultimate long-run is especially familiar in the great work of Marshall, who recognizes four main "cases" in his price theory.[13] Some modifications of his results appear necessary in the light of a systematic survey of the material from the special viewpoint of the principle here under discussion; detailed contrast between our cases and Marshall's is not called for, but a few significant divergences will be noted in passing. There seems to be a hiatus in his series at the very beginning, at the short-run end. His scheme does not take sufficient account of the fact that in the actual fixation of the prices of commodities which have a highly organized market and a definite price at a moment, the market is made and the price at any moment fixed, not by owners of supply and prospective consumers (as is assumed also in the mathematical systems), but by a class of professional traders who come in between these primary groups. This fact makes it needful to introduce an additional stage in price theory, with its own given conditions and position of equilibrium."

Appendix 4

Causality *per definitionem*

In Science of Logic, Hegel discusses causality rather comprehensively, though in a colourful language which sounds profound to some. He goes from causality as an analytic proposition, to the reciprocal action and reaction of causes and effects, and ends with the freedom of action and thus of causality in history. He basically covers

[13] Principles of Economics, book v, chap. v, especially sec. 8.

the essential logic of causality with the Leibnizian sufficient reason providing the equilibrium condition. The part where he discusses the definition of causation disposes of some common misunderstandings of the relation of causation.

“Reciprocal action realises the causal relation in its complete development. It is this relation, therefore, in which reflection usually takes shelter when the conviction grows that things can no longer be studied satisfactorily from a causal point of view, on account of the infinite progress already spoken of. Thus in historical research the question may be raised in a first form, whether the character and manners of a nation are the cause of its constitution and its laws, or if they are not rather the effect. Then, as the second step, the character and manners on one side and the constitution and laws on the other are conceived on the principle of reciprocity : and in that case the cause in the same connexion as it is a cause will at the same time be an effect, and vice versa. The same thing is done in the study of Nature, and especially of living organisms. There the several organs and functions are similarly seen to stand to each other in the relation of reciprocity. Reciprocity is undoubtedly the proximate truth of the relation of cause and effect, and stands, so to say, on the threshold of the notion; but on that very ground, supposing that our aim is a thoroughly comprehensive idea, we should not rest content with applying this relation. If we get no further than studying a given content under the point of view of reciprocity, we are taking up an attitude which leaves matters utterly incomprehensible. We are left with a mere dry fact; and the call for mediation, which is the chief motive in applying the relation of causality, is still unanswered. And if we look more narrowly into the dissatisfaction felt in applying the relation of reciprocity, we shall see that it consists in the circumstance, that this relation, instead of being treated as an equivalent for the notion, ought, first of all, to be known and understood in its own nature. And to understand the relation of action and reaction we must not let the two sides rest in their state of mere given facts, but recognise them, as has been shown in the two paragraphs preceding, for factors of a third and higher, which is the notion and nothing else. To make, for example, the manners of the Spartans the cause of their constitution and their constitution conversely the cause of their manners, may no doubt be in a way correct. But, as we have comprehended neither the manners nor the constitution of the nation, the result of such reflections can never be final or satisfactory. The satisfactory turn and turnabout (– not causes, but) factors of causation, in each of which – just because they are inseparable (on the principle of the identity that the cause is cause in the effect, and vice versa) – the other factor is also equally supposed.”

“The effect is therefore *necessary*, because it is the manifestation of the cause or is this necessity which the cause is. – Only as this necessity is cause self-moving, self-initiating without being solicited by another, *self-subsisting source of production out of itself*; it must *effect*; its originariness is this, that it is because its immanent reflection is a positing that determines and conversely; the two are one unity.

Consequently, an effect contains nothing whatever that the cause does not contain. Conversely, *a cause contains nothing that is not in its effect*. A cause is cause only to the extent that it produces an effect; to be *cause is nothing but this determination of having an effect,* and *to be effect is nothing but this determination of having a cause*. Cause as such entails its effect, and the effect entails the cause; in so far as a cause has not acted yet or has ceased to act, it is not a cause; and the effect, in so far as its cause is no longer present, is no longer an effect but an indifferent actuality.

(...) Now in this *identity* of cause and effect the form distinguishing them respectively, as that which exists in itself and that which is posited, is sublated. The cause is extinguished in its effect and the effect too is thereby *extinguished*, for it only is the determinateness of the cause. Hence this causality which has been extinguished in the effect is an *immediacy* which is indifferent to the relation of cause and effect and comes to it externally."

Appendix 5

Young Russell against causality

Much in this note has been influenced by Russell's criticism and then his rejection of the usefulness of causality in his early work. When it comes to the role of time, Russell makes the point that for the validity of the causal implication, reference to time, to specific time, is irrelevant. His argument is simple. As causality requires that whenever the cause, also the effect, the validity of that proposition is time invariant. It is valid universally. Individual causal connections are instances of general causal claims, or laws.

This is how he puts it in Principles of Mathematics and in Our Knowledge of the External World.[14]

First:

"A causal relation between two events, whatever its nature may be, certainly involves no reference to constant particular parts of time. It is impossible that we should have such a proposition as "A causes B now, but not then." Such a proposition would merely mean that A exists now but not then, and therefore B will exist at a slightly subsequent moment, though it did not exist at a time slightly subsequent to the

[14] His discussion of causality in later work e.g. in The Analysis of Matter and The Analysis of Mind is not substantially different, but is somewhat more complex as he tries to take general relativity and quantum mechanics into account.

former time. But the causal relation itself is eternal: if A had existed at any other time, B would have existed at the subsequent moment.

Thus "A causes B" has no reference to constant particular parts of time. Again, neither A nor B need ever exist, though if A should exist at any moment, B must exist at a subsequent moment, and *vice versa*. In all Dynamics (as I shall prove later) we work with causal connections yet, except when applied to concrete cases, our terms are not existents. Their non-existence is, in fact, the mark of what is called rational Dynamics. To take another example: All deliberation and choice, all decisions as to policies, demand the validity of causal series whose terms do not and will not exist. For the rational choice depends upon the construction of two causal series, only one of which can be made to exist. Unless both were valid, the choice could have no foundation.The rejected series consists of equally valid causal connections, but the events connected are not to be found among existents. Thus all statesmanship, and all rational conduct of life, is based upon the method of the frivolous historical game, in which we discuss what the world would be if Cleopatra's nose had been half an inch longer."

Then:

"When the geologist infers the past state of the earth from its present state, we should not say that the present state *compels* the past state to have been what it was; yet it renders it necessary as a consequence of the data, in the only sense in which effects are rendered necessary by their causes. The difference which we *feel* in this respect, between causes and effects is a mere confusion due to the fact that we remember past events but do not happen to have memory of the future.

The apparent indeterminateness of the future, upon which some advocates of free will rely, is merely a result of our ignorance. It is plain that no desirable kind of free will can be dependent simply upon our ignorance; for if that were the case, animals would be more free than men, and savages than civilised people. Free will in any valuable sense must be compatible with the fullest knowledge. Now, quite apart from any assumption as to causality, it is obvious that complete knowledge would embrace the future as well as the past. Our knowledge of the past is not wholly based upon causal inferences, but is partly derived from memory. It is a mere accident that we have no memory of the future. We might – as in the pretended visions of seers – see future events immediately, in the way in which we see past events. They certainly will be what they will be, and are in this sense just as determined as the past. If we saw future events in the same immediate way in which we see past events, what kind of free will would still be possible? Such a kind would be wholly independent of determinism: it could not be contrary to even the most entirely universal reign of causality. And such a kind must contain whatever is worth having in free will, since it is impossible to believe that mere ignorance can be the essential condition of any good thing. Let us therefore imagine a set of beings who

know the whole future with absolute certainty, and let us ask ourselves whether they could have anything that we should call free will."

And putting things together:

"A cause, considered scientifically, has none of that analogy with volition which makes us imagine that the effect is compelled by it. A cause is an event or group of events, of some known general character, and having a known relation to some other event, called the effect; the relation being of such a kind that only one event, or at any rate only one well-defined sort of event, can have the relation to a given cause. It is customary only to give the name "effect" to an event which is later than the cause, but there is no kind of reason for this restriction. We shall do better to allow the effect to be before the cause or simultaneous with it, because nothing of any scientific importance depends upon its being after the cause.

If the inference from cause to effect is to be indubitable it seems that the cause can hardly stop short of the whole universe. So long as anything is left out, something may be left out which alters the expected result. But for practical and scientific purposes, phenomena can be collected into groups which are causally self-contained, or nearly so. In the common notion of causation, the cause is a single event—we say the lightning causes the thunder, and so on. But it is difficult to know what we mean by a single event; and it generally appears that, in order to have anything approaching certainty concerning the effect, it is necessary to include many more circumstances in the cause than unscientific common sense would suppose. But often a probable causal connection, where the cause is fairly simple, is of more practical importance than a more indubitable connection in which the cause is so complex as to be hard to ascertain.

To sum up: the strict, certain, universal law of causation which philosophers advocate is an ideal, possibly true, but not known to be true in virtue of any available evidence. What is actually known, as a matter of empirical science, is that certain constant relations are observed to hold between the members of a group of events at certain times, and that when such relations fail, as they sometimes do, it is usually possible to discover a new, more constant relation by enlarging the group. Any such constant relation between events of specified kinds with given intervals of time between them is a "causal law." But all causal laws are liable to exceptions, if the cause is less than the whole state of the universe; we believe, on the basis of a good deal of experience, that such exceptions can be dealt with by enlarging the group we call the cause, but this belief, wherever it is still unverified, ought not to be regarded as certain, but only as suggesting a direction for further inquiry."

"In the motions of mutually gravitating bodies, there is nothing that can be called a cause, and nothing that can be called an effect; there is merely a formula. Certain differential equations can be found, which hold at every instant for every particle of

the system, and which, given the configuration and velocities at one instant, or the configurations at two instants, render the configuration at any other earlier or later instant theoretically calculable. That is to say, the configuration at any instant is a function of that instant and the configurations at two given instants. This statement holds throughout physics, and not only in tne special case of gravitation. But there is nothing that could be properly called "cause " and nothing that could be properly called " effect" in such a system."

Russell in On the Notion of Cause:

"Given some formula which fits the facts hitherto – say the law of gravitation – there will be an infinite number of other formulae, not empirically distinguishable from it in the past, but diverging from it more and more in the future. Hence, even assuming that there are persistent laws, we shall have no reason for assuming that the law of the inverse square will hold in future; it may be some other hitherto indistinguishable law that will hold. We cannot say that every law which has held hitherto must hold in the future, because past facts which obey one law will also obey others, hitherto indistinguishable but diverging in future. Hence there must, at every moment, be laws hitherto unbroken which are now broken for the first time. What science does, in fact, is to select the simplest formula that will fit the facts. But this, quite obviously, is merely a methodological precept, not a law of Nature. If the simplest formula ceases, after a time, to be applicable, the simplest formula that remains applicable is selected, and science has no sense that an axiom has been falsified. We are thus left with the brute fact that, in many departments of science, quite simple laws have hitherto been found to hold. This fact cannot be regarded as having any *a priori* ground, nor can it be used to support inductively the opinion that the same laws will continue; for at every moment laws hitherto true are being falsified, though in the advanced sciences these laws are less simple than those that have remained true. Moreover it would be fallacious to argue inductively from the state of the advanced sciences to the future state of the others, for it may well be that the advanced sciences are advanced simply because, hitherto, their subject-matter has obeyed simple and easily-ascertainable laws, while the subject-matter of other sciences has not done so.

The difficulty we have been considering seems to be met partly, if not wholly, by the principle that the time must not enter explicitly into our formulae. All mechanical laws exhibit acceleration as a function of configuration, not of configuration and time jointly; and this principle of the irrelevance of the time may be extended to all scientific laws. In fact we might interpret the " uniformity of nature" as meaning just this, that no scientific law involves the time as an argument, unless, of course, it is given in an integrated form, in which case lapse of time, though not absolute time, may appear in our formulae. Whether this consideration suffices to overcome our difficulty completely, I do not know; but in any case it does much to diminish it."