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Abstract: The Needham Question (i.e. the question why modern science has not developed in Chinese civilization but only in Europe) has drawn a substantial amount of criticism. Despite its apparent innocuousness, influential sinologists have written devastating critiques of it. These criticisms fall into two main categories. The first denies the validity of the central concepts by means of which the question is formulated (e.g. ‘science’ or ‘civilization’). The second calls into question (1) the legitimacy of asking for explanations of absences (i.e. of events that did not occur), (2) the legitimacy of citing absences as explanations (i.e. citing negative facts in explanations), and (3) whether the Needham question can be answered, even if asking for explanations of absences and citing absences as explanations are both legitimate. In this article, we take into account the former criticism, in order to arrive at a new starting point: dividing the Needham Problem into its various sub-questions. We then tackle the latter criticism by calling upon the contemporary philosophy of causation. We will argue that, according to certain theories of causation, the sub-questions under discussion can be answered, and we will clarify how they can be argued for.

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Joseph Needham’s *Science and Civilisation in China* is deeply admired by sinologists and historians of science. Nevertheless, the question that led Needham to study the history of Chinese science has drawn a substantial amount of criticism. This question, known as ‘Needham’s Grand Question’, but also simply as ‘the Needham Question’ or ‘the Scientific Revolution Problem’, initially appears rather innocuous: Needham considered the essential problem to be “that of why modern science had not developed in Chinese civilization (or Indian) but only in Europe?” In addition, he sought an explanation for China’s greater technological efficiency (compared to Europe) before the development of modern science.¹ Needham sought these explanations predominantly in so-called ‘inhibiting factors’, which effectively prevented a rise of modern science in China.² There is no truly standardized form of Needham’s Grand Question, but the one listed above contains most of its notable (and controversial) features.³

Despite its apparent innocuousness, influential sinologists have written devastating critiques of this ‘Scientific Revolution Problem’. Nathan Sivin, Angus Graham and Roger Hart have all identified flaws in the assumptions behind the question.⁴ Sivin and Graham question (1) the legitimacy of asking for explanations of absences (i.e. of events that did not occur), (2) the legitimacy of citing absences as explanations (i.e. citing negative facts in explanations), and (3) whether the Needham question can be answered, even if asking for explanations of absences and citing absences as explanations are both legitimate. Roger Hart takes another approach: influenced by developments in the general history of science, he denies the validity of the central concepts of Needham’s Question: ‘science’ and ‘civilization’.

In general, philosophers of science can set themselves different aims when investigating a scientific practice (in this case: the practice of historians that try to answer Needham’s question). They can criticize the practice (show that it is problematic), defend it against criticism put forward by other scientists or philosophers (show that the practice is legitimate, contrary to what others say), and they can try to improve the practice (by formulating suggestions on how to tackle the problems). In this paper we will do the first two things. Firstly, we will summarize Roger Hart’s critique, in order to arrive at a new starting point. We will argue that his

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¹ Needham, 1972, p. 190.
² Needham, 1954.
³ Sometimes, the Needham Question is also taken to include the converse of this question—i.e. why China was technologically superior to Europe in earlier times. However, this question will not be discussed here.
approach leads one to abandon the larger question in favor of a myriad of sub-questions. That is the critical part of the paper. Secondly, we will investigate whether these sub-questions can be answered keeping the critiques of Sivin and Graham in mind. In our attempt to resolve the problem of absences as explananda or explanans, we will call upon the contemporary philosophy of causation. Thereby, we hope to avoid a number of pitfalls that can result from an unclear understanding of what precisely a cause is. We will use two types of causation theories: production theories of causation and difference-making theories of causation. We will argue that, according to theories of the second type, the sub-questions under discussion can be answered. That is the defensive part of the paper, where we show that the practice of investigating the sub-questions is legitimate. The defensive part of the paper also contains a section on how to argue for the causal claims that occur in the explanations. In order to show that the practice of investigating the sub-questions is legitimate we should not only clarify the meaning of the causal claims used in the explanations, we also have to clarify how they can be argued for.

1. Fragmenting the Problem

In its original form, Needham’s Grand Question makes a number of significant assumptions about the proper units of historical analysis. The question is predicated on the acceptance of the concepts of ‘science’ and ‘civilization’. By drawing upon constructivist studies of science, Roger Hart has argued that both of these concepts are very difficult to define or even circumscribe. This renders the Needham problem a bad question.

Hart remarks that historical work using the term ‘science’ has often left that word undefined, as though the existence and use of the concept were sufficient proof of its historical validity and coherence. Some authors have referenced a ‘scientific methodology’ or claimed one particular aspect of science to be the essence of science. Axiomatization and deduction are favorite choices for this claim. Hart argues that these choices are based on selective readings of a number of influential scholars (including the Greeks, Galileo, Descartes, Bacon and Newton). Contrary to such claims, “there are good reasons to believe that the required definition of science cannot in fact be made.” A definition of science would have to carry within itself a demarcation criterion—a criterion to determine what is science and what is not. In order for the definition to be adequate, this criterion must be valid both transhistorically and transculturally. Hart undermines the possibility of such a definition by drawing upon the work of Thomas Kuhn, Paul Feyerabend, Richard Rorty and

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5 Hart, 1999.
This point is no longer disputed in the history of science; it has been particularly influential in the constructivist tradition. However, even though ‘science’ cannot be characterized more rigidly than as a family resemblance, it is possible to identify a number of key elements of science as it has played a role in society. In order to do this, one would need to point out the rapid social, technological and conceptual developments in Europe. Over the course of four centuries, (1) scientists have established themselves as almost irrefutable intellectual authorities across the world, (2) inventions such as antibiotics, the nuclear bomb and the internet have changed the face of the earth, and (3) the conceptual frameworks of the sciences have been (and still are) altering faster than they ever have before. The supposition that Needham’s Grand Question concerns these developments is what makes it so interesting. If modern science had not had such a grand impact on the entire world, it would never have drawn so much historical attention. The problem remains quite similar to the one Joseph Needham found himself engaged with many decades ago. What demanded explanation then, and what still demands explanation now, is the unseen degree of social, technological and conceptual change in Europe in comparison to China. (Of course, the notion of modern science discussed here is the form of science historically developed in Europe; we do not presume to declare it the only form of modern science possible.)

If it is impossible to draw upon a unitary concept of science or a monolithic Western or Chinese culture, an explanation of these social, conceptual and technological developments becomes far more complex. Then, among other things, it becomes necessary to determine how social positions, institutions, technologies, methodologies and conceptual frameworks have developed, and explain how these have contributed to later developments. Among other things, these questions will concern the origins of gentlemen-scientists, scientific societies, the telescope, controlled experiment and the mathematical approach to the study of nature. Needham’s question is thus fragmented into questions of the form ‘Why was [a specific, well-definable^ social position, institution, technology, methodology or conceptual framework] developed in Europe, but not in China?’ A similar suggestion is made by Mark Elvin:

> It is drawing attention to a method that offers a fruitful way of disaggregating a question into more manageable

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^8 Two excellent overviews of this tradition are found in Pestre, 1995, and Golinski, 2005.

subquestions, namely how far premodern Chinese thinkers had developed the various styles of thinking that have in the long run, as they have combined with each other, proved crucial to the growth of a distinctively ‘modern’ science.\textsuperscript{10}

Mark Elvin bases his approach on the ‘styles of scientific thinking’ found in Crombie (1994); his examples of methodological innovations include hypothetical modeling, the probabilistic style of reasoning, the experimental style of reasoning, taxonomy, etc.\textsuperscript{11} In the following sections, we will investigate the legitimacy of questions of the form described above.

Hart’s conceptual deconstruction is not limited to ‘science’ alone; he also undermines the concept of ‘civilization’. If there are such “supraregional entities called civilizations”, then in order to define them, it would be necessary to identify essential features of these civilizations, which must have remained constant over time. For instance, if there is such a thing as European civilization as usually defined, its features would have to be shared between ancient Greece and, for instance, early modern Italy. Given that this is quite unlikely, civilization is not a proper unit of analysis for historical inquiry.\textsuperscript{12} Two answers present themselves to this problem: civilizations can either be viewed as family resemblances, or reduced to mere geographical locations.

If one views civilizations as family resemblances in a way similar to the above approach to science, the essentialist connotations of the word vanish. However, it also makes the Needham problem incredibly difficult to pose, as it makes “Chinese civilization” and “European civilization” very vague entities.

However, by replacing civilizations with mere geographical locations, one can avoid this debate. Rather than discussing ‘Western civilization’ or ‘Chinese civilization’, one can merely talk about Europe and China. While geographical borders are fluid, the two regions can be sufficiently distinguished so as to not form a problem for Needham’s Grand Question.\textsuperscript{13}

\textsuperscript{10} Elvin 2004, p. xxviii.
\textsuperscript{11} It is important that these social positions, institutions, technologies, methodologies and conceptual frameworks must be of a level that is sufficiently specific to define properly, but remains sufficiently vague as to not be too specific to one particular culture. Crombie’s examples (upon which Elvin draws) provide a good middle ground.
\textsuperscript{12} Hart, 1999, pp. 90-93.
\textsuperscript{13} To a certain degree, such a geographical redefinition might even be unnecessary, as Mark Elvin has argued. While civilizations vary strongly over time due to both internal developments and external interactions, the same is the case for
2. Causation and Absences

Given the problems with the concept of ‘science’, we have abandoned that term in favor of more easily defined concepts such as ‘the matematization of nature’ and ‘controlled experiment’. While these terms still describe a variety of different practices, such concepts are far more coherent than ‘science’, and can be circumscribed relatively clearly. It then remains to be seen whether or not the structural critiques of Sivin and Graham apply to these questions—and if so, to what extent.

Graham and Sivin question a fundamental presupposition of the Scientific Revolution Problem. They do not believe that it is legitimate to ask why China did not have a Scientific Revolution: they deny the validity of causation by absence and causation of absences. The reasoning behind this skepticism towards absences applies to our sub-questions about aspects of science just as it applies to the question about the Scientific Revolution as a whole. In order to determine whether their skepticism is warranted, we will analyze these sub-questions in terms of the contemporary philosophy of causation.

Historians rarely render their concepts of causation explicit. Usually, such an explicit definition is irrelevant to their trade. In a discussion of the possibility of answering a particular causal question, however, an explication of these concepts is worthwhile. After all, not all historians refer to the same concept when they discuss causation.

 Philosophers of causation have developed many theories of causation. For our purposes, they can be grouped into process theories of causation (also known as production theories) and difference-making theories of causation (the latter group includes probabilistic theories, counterfactual theories and certain regularity theories). The content of some of these theories will be explained in the sections that follow. What is important now is that we regard these theories as tools for analyzing scientific practice: philosophy of causation as it has been practiced during the last decades has resulted in a well-filled toolbox which we can now use to ana-

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individuals, who also change continually under these influences. Therefore, Elvin concludes that writing on the history of a civilization need not be any more problematic than writing a biography; Mark Elvin, personal communication, 2011.

14 Frank Ankersmit has voiced discontent about the fact that contemporary philosophers of history are not conversant with the terms of the contemporary philosophy of science; see Ankersmit, 2005. Anton Froeyman has expanded on this argument in Froeyman, 2009, in which he also describes which theories of causation are best fit for which types of historiographical work.
lyze historical practice, more precisely the practice of answering the sub-
questions of the Scientific Revolution Problem.\textsuperscript{15}

In the next two sections, we will try to clarify what type of causation
be involved if an historian of sciences puts forward a causal claim as
an answer to a sub-question originating from Needham’s Grand Ques-
tion. Clarifying which concept of causation is used is helpful in two ways:
(1) it becomes clear what the meaning of the causal claims is, and (2) by
further clarifying precisely what is asked for, one can learn the type and
extent of argumentation and evidence required to justify the answer to
the question.

Many of Needham’s critics have taken the presupposed fact that ques-
tions involving absences cannot be answered as one of the greatest flaws
of the Needham Problem—and hence of the sub-questions described
above. If, however, it can be shown that these questions can be answered
properly for one (or more) coherent account(s) of causation, then this
critique falls dead in its tracks—even if another account of causation
might leave these questions unanswerable.

3. Causation as Production

Proponents of production or process theories, the most influential of
which are Wesley Salmon and Phil Dowe, generally defend them as fun-
damental accounts of causation—purportedly, they describe causation as
it exists in the external world.\textsuperscript{16} Insofar as other causal claims are true,
they are so only because they supervene on a description of a causal pro-
cess.

The idea for causal processes originated with Wesley Salmon, but Phil
Dowe’s version is now more influential. Therefore, we shall begin with a
short description of Dowe’s theory. According to Dowe, “for there to be
causation, there must be a set of causal processes and interactions, under-
stood in terms of conserved quantities linking a cause with its effect.” He
defines causal processes and interactions as follows: “A causal process is
a world-line of an object that possesses a conserved quantity.” And
“A causal interaction is an intersection of world-lines that involves ex-
change of a conserved-quantity.”\textsuperscript{17} A world-line is the collection of points
on a space-time diagram representing the history of an object. An object
can be anything found in the ontology of science (particles, waves,
fields, ...) or common sense (chairs, buildings, people, ...). A conserved

\textsuperscript{15} See Hall, 2006; De Vreese, 2006; and Weber and De Vreese, 2009, for more
on this approach to the philosophy of causation.


\textsuperscript{17} Dowe, 2004, p. 189.
quantity “is any quantity that is governed by a conservation law, and current scientific theory is our best guide as to what these are.”

Dowe’s reliance on conserved quantities indicates his focus on the physical sciences. Regardless of its merits, it is not applicable to historiographical inquiry. While Salmon’s theory is characterized by an intent to model the physical sciences as well, it can be applied just as easily to the biomedical sciences, the social sciences and historiographical inquiry.\textsuperscript{19} We present a slightly adapted version of Salmon’s first theory.\textsuperscript{20} According to this theory, there are two essential aspects to causation: the innovative aspect (the acquisition of new properties) and the conservative aspect (properties are preserved). The first is accounted for by the concept of ‘causal interaction’, while the second is accounted for by the concept of ‘causal process’. Let us start with causal interaction:

\begin{enumerate}
\item At $t$ there is a causal interaction between objects $x$ and $y$ if and only if
\item there is an intersection between $x$ and $y$ at $t$ (i.e. they are in adjacent or identical spatial regions at $t$),
\item $x$ exhibits a characteristic $P'$ in an interval immediately before $t$, but a modified characteristic $P$ immediately after $t$,
\item $y$ exhibits a characteristic $Q'$ in an interval immediately before $t$, but a modified characteristic $Q$ immediately after $t$,
\item $x$ would have had $P'$ immediately after $t$ if the intersection would not have occurred, and
\item $y$ would have had $Q'$ immediately after $t$ if the intersection would not have occurred.
\end{enumerate}

While this definition incorporates most of the basic ideas of Salmon’s theory, it differs in one important point: Salmon’s original theory considers an interaction to occur between two causal processes, while this definition considers it to occur between two objects. Dowe suggested this modification.\textsuperscript{21} We follow this suggestion because it does not change the theory substantially (processes are world-lines of objects) and it makes the theory congruent with common sense ontology in which objects (rather than processes) are the basic entities.

Now we turn to causal processes. Salmon divides processes (world-lines of objects) into causal processes and pseudo-processes. Causal pro-

\textsuperscript{18} Dowe, 2000, p. 91.
\textsuperscript{19} See Weber, 2007.
\textsuperscript{20} Salmon, 1984.
\textsuperscript{21} Dowe, 1992.
cesses are capable of transmitting marks, pseudo-processes cannot transmit marks. Mark transmission is defined by Salmon as follows:

Let P be a process that, in the absence of interactions with other processes, would remain uniform with respect to characteristic Q, which it would manifest consistently over an interval that includes both of the space-time points A and B (A ≠ B). Then a mark (consisting of a modification of Q into Q', which has been introduced into process P by means of a single local interaction at point A, is transmitted to point B if P manifests the modification Q' at B and at all stages of the process between A and B without additional interventions.22

An example of a process is the movement of a material object. Moreover, it is a causal process: the underlying object has a capacity to transmit marks. But the material object itself is not a causal process, since it is not a process. The movement of an object is a causal process, but the moving object itself is not.

By means of the concepts of causal interaction and causal process it is possible to model certain types of historical claims quite adequately. Anton Froeyman has argued that causal process theories such as this one are good models of causation as it is used in historical narratives. By historical narratives, Froeyman means historical work characterized by the following four features: causal coherence, having a definite beginning and ending, a ‘plot’ and a central subject. Clarifying the concept of ‘causal coherence’, he says “a series of descriptive statements is coherent because every statement is the effect of the one it immediately follows.” Thus, “a narrative forms what can be described as a ‘causal chain’.”23 He follows Hayden White in defining a plot as “a structure of relationships by which the events contained in the account are endowed with a meaning by being identified as parts of an integrated whole.”24 The other two features are sufficiently clear. Froeyman has emphasized that three of the four features of narratives are shared by causal processes: “both causal processes and narratives need some kind of ‘central subject’ or ‘object’ which remains constant throughout the development of the process. (…) causal processes also have something of a plot. (…) The only difference between (historical) narratives and causal processes seems to be that causal processes do not seem to require a definite ending and a beginning.”25

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fore, Froeyman concludes that historical narratives are a subset of causal processes.

As process theories provide a good model for causation as used in historical narratives, they are adequate to explicate the meaning of causal claims which historians put forward as answers to questions of the structure 'Why was [a specific, well-definable social position, institution, technology, methodology or conceptual framework] developed in Europe?', which is the first part of the questions we are concerned with. These questions were of the form 'Why was [a specific, well-definable social position, institution, technology, methodology or conceptual framework] developed in Europe, but not in China?' It remains to be seen whether or not causal process theories can provide a good model for analysing the meaning of answers to questions of the form 'Why was [a specific, well-definable social position, institution, technology, methodology or conceptual framework] not developed in China?' We argue that the answer to this is negative. The reason is that, according to causal process theories, prevention and omission are not causation.

Ned Hall has argued elaborately that to assume otherwise leads to several conflicts within one's theory of causation. He invokes the following example:

Suzy and Billy have grown up, just in time to get involved in World War III. Suzy is piloting a bomber on a mission to blow up an enemy target, and Billy is piloting a fighter as her lone escort. Along comes an enemy fighter plane, piloted by Enemy. Sharp-eyed Billy spots Enemy, zooms in, pulls the trigger, and Enemy’s plane goes down in flames. Suzy’s mission is undisturbed, and the bombing takes place as planned. If Billy hadn’t pulled the trigger, Enemy would have eluded him and shot down Suzy, and the bombing would not have happened.26

Billy’s pulling the trigger did not produce the bombing, rather it neutralized a state-of-affairs that would have prevented the effect from occurring. The occurrence of the bombing was dependent on Billy’s pulling the trigger, but not produced by it. In this example, the effect counterfactually depends on the cause, but there is no mechanism linking cause and effect. Counterfactual dependence “seems to be the only appropriate causal relation for such ‘negative events’ to stand in.”27

Interpreted from the point of view of production, causes must produce a positive fact, and only positive facts can cause anything at all.

Therefore, if one wants to interpret answers to the sub-questions of Needham’s Grand Question as referring to causation as production, one runs into difficulties: there are no chains of causal processes and causal interactions leading to ‘something not coming to pass’. If causation is understood in this sense, Graham and Sivin’s point stands: one does not investigate why something failed to occur. When causation is understood as production, one must only consider positive facts as causes or effects. Rather than asking why a particular social position, institution, technology, methodology or conceptual framework was not adopted in China, one must ask why another was adopted. If causation is interpreted from the point of view of causal process theories, one can give an answer to questions like ‘how did it come to be that astronomical practices in China were purely instrumentalist?’ or ‘how was controlled experiment developed in Europe?’ One cannot answer questions like ‘why were astronomical practices in Europe not purely instrumentalist?’ or ‘why was controlled experiment not developed in China?

4. Causation as Difference-Making

Difference-making theories start from the idea that a cause somehow makes a positive difference for its effect. This idea can be elaborated in different ways. On the one hand, there is John Mackie’s INUS account in which the difference-making idea is combined with the idea that there is always a regularity under which a causal relation can be subsumed.28 On the other hand we have probabilistic and counterfactual approaches, which do not presuppose an overarching regularity.

We will use Ronald Giere’s probabilistic theory here as a tool for our analysis. This theory defines causation on the level of populations. While the theory can be extended to various types of variables, Giere presents a version of his theory that only considers binary variables. Therefore, in what follows, C is a variable with two values (C and Not-C), and so is E (with values E and Not-E). Giere then defines causation in populations as follows:

“C is a positive causal factor for E in the population U whenever \( P_X(E) > P_K(E) \).

C is a negative causal factor for E in the population U whenever \( P_X(E) < P_K(E) \).

C is causally irrelevant for E in the population U whenever \( P_X(E) = P_K(E) \).”29

29 Giere, 1997, p. 204.
X is the hypothetical population which is obtained by changing, for every member of U that exhibits the value Not-C, the value into C. K is the analogous hypothetical population in which all individuals that exhibit C are changed into Not-C. \( P_X(E) \) and \( P_K(E) \) are the probability of E in respectively X and K. Probabilities are defined as relative frequencies (Giere takes U to be finite, i.e. causal claims are about finite populations).

An example might clarify this. If we claim that smoking (C) is a positive causal factor for lung cancer (E) in the Belgian population (U), this amounts to claiming that if every inhabitant of Belgium were forced to smoke there would be more lung cancers in Belgium than if everyone were forbidden to smoke. The converse is the case for the claim that smoking is a negative causal factor. Causal irrelevance is a relation between variables (represented in bold) rather than a relation between values of a variable (like the first two relations). If we claim that “smoking behavior” (C) is causally irrelevant for “the occurrence or absence of lung cancer” (E) this means that we believe that in the two hypothetical populations the incidence of lung cancer is equally high.

There is no reason why absences cannot be causes according to Giere’s probabilistic account. Traditionally, it has been claimed that the lack of the notion of a divine lawgiver was one of the reasons why modern science did not originate in China. We have indicated our reasons for not asking about the origins of modern science above, and hence, we shall instead consider the more humble claim: “the lack of idea of a divine lawgiver was a reason for the absence of the notion of laws of nature in China.”

A Gierean claim that is relevant in this case is: C (= the notion of a divine lawgiver) is a positive causal factor for E (= the notion of fixed laws of nature). This reduces to: ‘in X (= a population where everybody believes in a divine lawgiver), there will be more individuals who believe in fixed laws of nature than in K (= a population where nobody believes in a divine lawgiver).’ This, in turn, means that the absence of the notion of a divine lawgiver is a negative causal factor for the idea of fixed laws of nature. That is so because, in general, Giere’s theory has the property that if C is a positive causal factor for E in U, not-C is a negative casual factor for E in U (this property follows logically from the definitions). It is there-


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30 Our sole concern in this example is the form of the question; we do not claim that the absence of a divine lawgiver is or is not a cause of the Scientific Revolution or one of its constitutive parts. Elvin (personal communication, 2011) has noted that the current argument concerning divine lawgivers is more complicated, and has pointed out that it is treated more thoroughly in the contributions of Elvin and Harbsmeier in Vogel and Dux, 2010. The above example is simplified and is provided only to illustrate how Giere’s theory can be applied to the Needham Problem.
fore clear that absences do not behave any differently from positive causes in this theory.

This reconstruction in terms of Giere’s theory does not suffice to make the sub-questions legitimate. We also have to show that it is possible to give good arguments for such claims. That will be done in the next section. Hence, we now shift our attention from the meaning of the causal claims to the way they can be argued for.

5. Arguing for Probabilistic Causal Claims

In the biomedical sciences, Gierean causal claims about populations are supported or rejected on the basis of randomized experiments (e.g. tests of the efficiency of drugs) or prospective or retrospective studies (e.g. epidemiological research into the causes of diseases). The same goes for the social sciences (e.g. pilot studies to tests the efficiency of social policy measures, and prospective/retrospective studies investigating the causes of certain social phenomena). These methods are not available when we try to answer sub-questions of the Needham question. What we need here is a historical thought experiment.

While one cannot use thought experiments to estimate $P_X(E)$ or $P_K(E)$ quantitatively with any degree of precision, one can establish relatively convincingly whether $P_X(E)$ is larger than, smaller than, or equal to $P_K(E)$. To illustrate this, consider the following claim:

The Japanese irrigation projects in the 1930s in Taiwan caused a breakdown of the joint-family system in rural areas of the island.

As it stands, this is not a claim about a causal relation in a population in Giere’s sense. There is a population ( Taiwanese peasants in the 1930s) and the effect variable (being part of a nuclear family or being part of an extended family) is a property that every person in the population has. The problem is the cause variable. If we equate this with “the perception of living in a country with a reliable supply”, it fits Giere’s scheme. By equating these two causes, it is assumed that these members know that there is an irrigation network, and that they take that into account in their decision making. In this way, the initial causal claim is what we would call “probabilified”: it is given a probabilistic interpretation. This interpretation can be stated as follows:

The perception of reliable water supply by the peasants in Taiwan in the 1930s caused a breakdown of the joint-family system in rural areas of the island.

Probabilification has an important advantage: we can set up a thought experiment to support the claim. Let us see how this works. Our example
is taken from Little (1991, p. 141), who, in turn, relies on Pasternak (1978). Till 1930, a joint-family system was dominant in rural areas of Taiwan: parents and married sons continued to live together and farm their holdings together, rather than dividing into two or more nuclear families. From 1930 on, there is a continuing trend toward divided families. Pasternak explains this change in family structure as a rational adaptation to a change in circumstances of the rural economy: the availability of reliable irrigation water. Indeed, Taiwan was invaded by Japan, and the Japanese established large-scale irrigation projects in the 1930s. An adherent of this explanation must accept one of the causal claims above.

Whether we accept this claim (in its probabilistic interpretation) or not depends on our answer to the following question:

(I?) What would have happened if the Japanese had irrigated half of Taiwan, and randomly distributed the farmers over the irrigated and non-irrigated parts.

We call questions like this one ‘experimental questions’, because they ask what would happen if a randomised experiment were performed. Some of the possible answers to this specific question are:

(I-) The irrigated part and non-irrigated part would have evolved identically with respect to family structure.
(I+) The irrigated part would have evolved towards nuclear family more rapidly than the non-irrigated part.
(I++) The irrigated part would have evolved towards nuclear family; the non-irrigated part not.

Obviously, (I-) leads to the rejection of the claim, while the (I+) and (I++) support the claim.

Suppose we want to do a real randomized experiment to test these claims. Then we will have two problems. First, and one can hardly overestimate the importance hereof for historiography, we are too late: the appropriate experiment (involving actual division into irrigated and non-irrigated parts, and random division of all Taiwanese peasant over the two parts) was in principle possible 70 years ago, but now it is too late. The second problem is that actually performing the experiment would be unethical.

In many cases in which, for some reason, real experiments are impossible, thought experiments can offer a way out. They allow us to answer experimental questions without actually realising the experimental nor the control group. In the Taiwan example, (I+) can be supported by the following argument:
(1) In both parts (irrigated and non-irrigated) an equally substantial part of the population makes rational decisions about family structure.
(2) In both parts, normal friction in social life (e.g., between sisters-in-law) occurs often and with equal frequency.
(3) In the irrigated part, farmers are convinced that the irrigation system protects them against crop failure due to drought.
(4) In the non-irrigated part, farmers know that, in a nuclear family system, their rice crop will fail (due to insufficient labour supply) if there is less than 15 days of consecutive rainfall.
(5) In the non-irrigated part, farmers know, in a joint family system, their rice crop will fail (due to insufficient labour supply) if there is less than 10 days of consecutive rainfall.
(6) Periods of more than 10 but less than 15 days of consecutive rainfall occur often.

Conclusion

(I+) The irrigated part evolves towards nuclear family more rapidly than the non-irrigated part.

In this argument, we reason with imaginary cases: both the experimental and control group are virtual, and we argue about what would happen if they were real. But there is an important difference between the groups: the characteristic property of the experimental group (irrigation) was present in the real world. We will come back to this immediately.

Answering an experimental question without actually realizing the experimental nor the control group is possible because of the ‘bottom-up’ approach: we start from assumptions about how rational decision making and/or irrational psychological mechanisms determine the behavior of individuals in a social group. Then the assumptions are used to infer a causal relation at the higher level, the level of the population. This micro-reduction is the surrogate that is used for observations in the experimental and in the control group. Historical thought experiments can work in principle because they use this surrogate. More precisely, the way is as follows:

(1) We know what would happen in the experimental group, because its characteristic property has been present in the real world: the result in the experimental group would be the same as in the real world (e.g. evolution towards nuclear family).
(2) We do not know why this result occurred in the real world, only that it occurred.
(3) We try to find out which mechanism produced the result in the real world (and thus would produce the result in the experimental group).
(4) We use this mechanism to argue that the result would be different in the control group.

In order to avoid misunderstanding, there are a few points we want to stress. First of all, the example we have given involves rational decision making (i.e. people take into account the consequences of their actions). However, there is no reason to exclude other mechanisms—e.g. norm guided behavior—which also make the average behavior of the population predictable. For instance, a thought experiment could start from the assumption that all or most people behave in accordance with the role expectations attached to their social roles. Second, not all thought experiments which use the trick of probabilification are equally good. The quality of such thought experiments is a gradual matter, influenced mainly by two factors:

(1) The strength of the assumptions. A thought experiment that uses strong rationality assumptions (e.g. perfect information about the market, perfect insight in economic theory, perfect and extremely quick calculations) is far less convincing than a thought experiment which uses weak rationality assumptions (e.g. the assumption that individuals somehow take into account the consequences of their actions) because it is much more likely that a large majority of the population satisfies the weak assumptions.

(2) The size of the population. The bigger the population, the less the effect a deviant individual has on the average behavior of the group.

We conclude that it is in principle possible to answer questions of the form ‘Why was [a specific, well-definable social position, institution, technology, methodology or conceptual framework] developed in Europe, but not in China?’, provided that these answers can be translated into claims about populations. And when arguing for an answer one is confronted with two additional issues:

(1) Can one establish sufficiently weak assumptions that make the average behavior of the group predictable?

(2) Is the population sufficiently large?

The extent to which these conditions are fulfilled is a variable matter, and might differ significantly for different sub-questions of the Scientific Revolution Problem. Nonetheless, there is no principal reason why they cannot be answered. A. C. Graham (1973) once suggested that while it is possible to identify the absence of snow as an inhibiting factor for the invention of skis, it is impossible to identify inhibiting factors for the developments of modern science. We will see whether or not that is the case in the following conclusion, but we have established that there is no
reason to accept this claim for the sub-questions of Needham’s Grand Question, and have indicated how this identification is possible.

6. Summary and Concluding Remarks

We have agreed with Roger Hart in claiming that terms such as ‘science’, ‘modern science’ and ‘civilization’ are improper concepts for historiographical inquiry. Reacting to this, we pondered whether certain sub-questions are conceptually sound—that is, whether or not a concept of causation can be found by which these questions can be answered. We proposed to fragment Needham’s question into questions of the form ‘Why was [a specific, well-definable social position, institution, technology, methodology or conceptual framework] developed in Europe, but not in China?’ We have found that, if one understands causation as production, one cannot answer these questions properly. However, if one understands causation as difference-making (more specifically: as probabilistic causation in populations in the way defined by Ronald Giere), there is no principal reason why these questions cannot be answered—although practical considerations might interfere. We have explained how claims put forward as answers to these sub-questions can be justified.

One might wonder whether Needham’s Grand Question can be redefined as a conjunction of its sub-questions, which, as we have seen, can be answered. If one were to redefine Needham’s Grand Question in terms of its constituent sub-questions, the question would have to refer to causes interpreted as difference-making, as that is the only sense by which they are answerable. However, as there is no clear definition of ‘science’, any conjunction of sub-questions will fall short. For instance, answering the question ‘Why did Europe develop controlled experiment, the mathematical approach to nature and the concept of laws of nature, while China did not?’ is possible. However, if one abbreviates this to ‘Why was modern science developed in Europe, but not in China’, one postulates an arbitrary, a-historical definition of modern science. There is no exhaustive list of sub-questions to which it can be reduced. And without an exhaustive list of such sub-questions, one cannot construct the thought experiments required to establish the answer to the total question. Therefore, the Needham Question, as originally formulated by Needham, cannot be answered.
References


