Magic and empiricism in early Chinese rainmaking

A cultural evolutionary analysis

Ze Hong

Joseph Henrich

Department of Human Evolutionary Biology

Harvard University

Abstract

Protocols aimed at rainmaking have been a recurrent sociocultural phenomenon across societies and back into history. Given the scientific understandings of precipitation indicate that such protocols were likely entirely ineffective, why did such rainmaking protocols repeatedly emerge and persist, sometimes over millennia even in populations with writing and record keeping? To address this puzzle, many scholars have argued that these protocols were not instrumental at all, and that their practitioners were not really endeavoring to bring them. Here, taking advantage of the wealth of historical records available in China, we argue to the contrary, that rainmaking is best viewed as an instrumental, means-end activity, and that people have always placed strong emphasis on outcomes of such activities. To account for persistence of rainmaking, we then present a set of cultural evolutionary explanations, rooted in human psychology, that can explain why people's adaptive learning processes did not result in the elimination of ineffective rainmaking methods. We suggest that a commitment to a supernatural worldview provides theoretical support for the plausibility of various rainmaking methods, and people often over-estimate the efficacy of the rainmaking technologies because of statistical artefacts (some methods appear effective simply by chance) and under-reporting of disconfirmatory evidence (failures of rainmaking not reported/transmitted).

1. Introduction

Ever since the advent of agriculture, rainfall has played a crucial role in people's lives (Rockström et al., 2009; Wahlquist, 2009). Historically, rainfall was often a matter of life and death in any society that relied on farming or pasture for subsistence. Thus, a lack of rain in seasons when crops needed water posed a serious threat to farmers regarding their survival; in societies with complex political hierarchies, the stability of the state hinged on rain (Chaney, 2013; De Châtel, 2014; Kebbede & Jacob, 1988; Jianyong Li et al., 2017). An influential hypothesis on Chinese dynastic change, for example, proposes that changes in Chinese dynastic powers may have been affected by a lack of precipitation mediated through popular unrest (Zhang et al., 2008)

Given the enormous importance of rainfall for subsistence, there have always been strong incentives to produce rain when needed. Societies across the world and throughout history attempted exactly this; in his masterpiece "the Golden Bough", James Frazer devotes an entire chapter to the magical control of the weather: the peasants in Russia, the tribal men in New Guinea, the Omaha Indians in North America, and many other traditional societies' rain making activities are all described in vivid detail. More recent ethnographic work further suggests the widespread nature of efforts (Başgöz & Basgoz, 1967; Ruppert, 2002; Schoeman, 2006).

The historical and cross-cultural recurrence of rainmaking itself is not puzzling. After all, when there is a problem, it is not surprising that people try to solve it. What is puzzling is that we as modern readers know that almost[1] all rainmaking attempts were *ineffective.* That is, assuming modern science is to be trusted, the ancients' rainmaking efforts did not exert any influence on weather. The real question is thus this: why did people engage in a costly and time-consuming activity that objectively does not achieve its explicit aims? Anthropologists have been keenly aware of this problem, and there has been a long-standing debate regarding such seemingly ineffective actions and the implications for human rationality (Horton, 1993; Tambiah, 1990). On the one hand, Tylor, Frazer, and their intellectual predecessors claim that magic shares the same fundamental goals as science: to explain, predict, and possibly control the natural world.

On the other hand, many scholars have reacted against Tylor and Frazer's interpretation. Levy-Bruhl (1926), for example, suggests that "primitive" men have a fundamentally different thinking mode in which mental processes are powered by emotion rather than reason, and ritual activities are best described as "mystical participation" rather than "rational action". Durkheim (1912/2008) divides the world into two radically contrasted categories, the sacred and the profane, and posits that although the profane simply refers to the everyday ordinary, sacred objects and actions are characterized by a sense of awe and respect in virtue of their being symbols of societies. This distinction was later taken up by many thinkers such as Radcliff-Brown and Max Gluckman who suggest that the two categories requires different kinds of interpretations: while the profane may be interpreted as "logical-empirical" through means-end decision calculus, the sacred requires a kind of sociological explanation. In short, the reaction

[1] To our knowledge, there has been no rainmaking effort that is scientifically plausible until the 19th century.

against the naïve Tylor-Frazer reading of ineffective actions in traditional societies is that the actions are not really trying to achieve their alleged goals—they are not instrumental. These actions may be a result of emotion, respect for tradition, power dynamics in the community, or other non-instrumental factors.

Let us step back and place rainmaking into this larger context. The naïve Tylor-Frazer position on this would simply be that people engage in rainmaking activities to produce rain. For the symbolic-sociological proponents, the key issue is whether rainmaking may be viewed as a type of profane, instrumental activity. Wittgenstein famously thinks it may not (Wittgenstein, 1967). For him, the native rainmaker does not really think he can make rain. In other words, he does not act out of "opinion" but rather "instinct", and his actions serve not as genuine instrumental effort but a kind of emotional discharge of anger and anxiety. Later authors also often emphasize the sociological and symbolic functions of rainmaking activities (Mbiti, 1970; Ngara, 2012), but rarely dismiss their instrumentality entirely. Surely, it would be very difficult to completely ignore the instrumental aspect of rainmaking; as will be shown, much historical evidence strongly suggests that various kinds of rainmaking were used as instruments to induce rain.

As a population with a long and continuous literary tradition, China provides an ideal case for a close examination of rainmaking. Due to the large amount of historical material, there have been many studies on Chinese rainmaking that focus on specific historical periods, and the recent digitized database of Chinese texts has enabled more quantitative assessment of elite history and culture (Sturgeon, 2006). Here we take advantage of such information and offer a detailed analysis of rainmaking in China. The rest of the paper is organized as follows. In part one, we summarize major theories of rain in early China and the corresponding rain-inducing activities, we argue that the majority of rainmaking activities are best understood as an instrumental effort; in part two, we focus on the pre-modern period (in particular the Tang and the Song dynasties, 618-1276 CE) and offer a cultural evolutionary analysis of various rainmaking methods by focusing on their perceived efficacy. We argue that there has always been a great deal of empiricism in rainmaking despite a prevailing supernatural worldview that sustains the plausibility of many methods, and propose a mechanism for how the same set of psychological learning mechanisms that produces adaptive cultural products and protocols nonetheless can generate and maintain maladaptive and costly actions like rainmaking. To preview, some methods will appear efficacious simply by chance even if one meticulously tracks their successes and failures, and under-reporting of rainmaking failures further contributes to the overestimation of various rainmaking methods' efficacy.

2. Folk theories of rain and rainmaking in early China

Like many traditional societies, pre-modern China had elaborate theories about weather phenomena such as precipitation and winds. For analytic convenience, we divide the theories into two large categories: "personal gods" and "impersonal forces". This distinction will help us better conceptually organize the myriad of theories and understand the associated actions to produce rain.

2.1. "Personal gods" theories of rain

Various kinds of "personal god" theories prevailed China during different periods of time. Generally, a personal god refers to an anthropomorphic, intentional agent that has human-like dispositions and may respond to human desires and concerns (Bering, 2012; Boyer, 2001) as a result of our species' mentalizing capacity and other related cognitive intuitions such as dualism (Chudek et al., 2018; Frith & Frith, 2012). This means that these gods can be pleaded with, manipulated, bribed and even coerced. Regarding rainmaking, the gods involved are often perceived to either be able to control weather phenomena or be the direct cause of rain. As such, to ask for rain is to negotiate with these gods. The corresponding rainmaking activities therefore become sensible if and only if we treat the underlying controlling or causative agents to be human-like entities with the additional capacity of making rain. In traditional China, these agents could be deceased ancestors or local deities (deceased famous individuals who serve as "protectors" of a geographic region), or dragons (detailed description of these personalized gods can be found in Supplemental Information).

The key takeaway here is that the way people interact with these gods closely resembles human-human interactions. The most striking example is perhaps threat/coercion, as can be seen in the following quote from Taizu (1328-1398 CE), the first emperor of the Ming dynasty:

> The Deity lives off this soil, but it will not sympathize with my people. Now I make a covenant with the Deity that within three days it must rain. If it does not rain, then I will ruin the Deity's shrine. (*Ming Waishi*[2])

Here, the emperor is exercising his authority and treats the local deity as an inferior. Similar instances were recorded for lower officials as well; sometime between 1068 and 1083, a local magistrate brought an image of a deity to his office and vowed: "if it does not rain in three days, I will destroy your temple." (*Taizhou jinshilu*[3]). The recorded outcome of such threats varies; in the former case it was recorded that rain indeed came within three days (presumably due to the emperor's supreme authority) while in the latter the outcome was not specified. There were also occasions where the deities got angry at the threat and retaliated with natural disasters (Cohen, 1978).

2.2. Impersonal forces theory of rain

In addition to the numerous theories of rain that involve human-like agents, there was also theorizing on the impersonal forces that produce rain. Generally, these "impersonal forces" theories of rain rely on principles of sympathy and correspondence, and the literati (mostly Confucians) preferred this type of explanation to those based on personal gods. Note that these forces are not purely mechanistic in the modern sense but often appear mysterious in nature and may respond to human actions in rather moralistic ways (Ding, 2009; Wong, 2011). Thus, the distinction between personal and impersonal rainmaking agents can be murky. (this is common with cosmic forces, see Willard et al. 2020).

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[2] 明外史.

[3] 台州金石录 (a record of inscriptions from Taizhou).

Broadly, these impersonal forces theories of rain can be divided into "Interactions Between Heaven and Mankind", a Confucian view of the causal structures of the universe (Wong, 2011), and various sympathetic magic techniques to produce rain. "Interactions Between Heaven and Mankind" maintains that there is a resonance between Heaven and the actions of men, especially the political leaders as they are viewed as the representation of Heaven[4]. When the leaders err (usually in the form of bad governance), Heaven may send disasters or portents (灾异). Sympathetic magic theories of rain in traditional China, on the other hand, operate based on the principle of "like stimulates like", as the early Han scholar Dong Zhongshu (179-104 BCE) explicitly theorizes:

> …the beautiful invokes the beautiful, the evil invokes the evil; [this is because] things of the same kind respond to each other. A horse neighs and other horse neigh; a cow moos and other cows moo. When kings and emperors rule well, there will appear beautiful and auspicious things; when their rule is about to end, there will appear monstrous spirits and ghosts. Therefore things of the same kind stimulates each other: as such, dragons cause rain, fans get rid of heat… (*Chunqiu Fanlu*, *chapter 57*)

We can see from the above paragraph that the claim "dragon causes rain"[5] is situated in a larger sympathetic magical framework. More generally, Dong Zhongshu also discussed rainmaking vis-a-vis the *yin-yang*[6] principle. Because rain is considered *yin,* to induce it is to use its own kind -- things that are also *yin*. He therefore recommended rainmaking efforts[7] such as 1) women should appear in public places whereas men should remain in their house; 2) A town should close its southern gates[8] and open those on the north[9], and 3) prohibition on the lighting of fires. As Bodde (1964) points out, the rainmaking efforts documented in *Chunqiu Fanlu* is more likely to be Dong's own scholastic formulation than actual activities performed by the general populace. The core idea of employing sympathy to induce rain, however, persisted throughout imperial China till as late as Qing dynasty (1644-1912) (Liu 2013).

3. Rainmaking as an effort to produce rain

The above description of theories of rain and rainmaking methods already hints at the instrumental nature of rainmaking in early China. For the sake of completeness, we offer a few additional notes to further support this claim.

3.1. Problem-solving style instructions on rainmaking

In most Chinese dynasties rainmaking was performed on both a regular and *ad hoc* basis (Snyder-Reinke, 2020); that is, in addition to the annual rituals in which the emperors and

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[4] Chinese emperors are often referred to as Tianzi (天子), literally, Son of Heaven.

[5] Of course, this depends on the belief that dragon and rain are of the same kind.

[6] In traditional Chinese culture, *yin* and *yang* are a pair of complementary concepts and are perceived to be a fundamental attribute of any material objects. *Yin* usually refers to the feminine, negative, moist and cool, whereas *yang* refers to the masculine, positive, dry and hot.

[7] See Chunqiu Fanlu, chapter 74. Interestingly, Dong Zhongshu also talks about applying the same principle to stop rain, that is, to release or expose things that are *yang*, e.g. men or fire. See *Chunqiu Fanlu*, chapter 75.

[8] This very technique was used as late as 1892 (Snyder-Reinke, 2020).

[9] In traditional Chinese culture, south is associated with *yang* and north is associated with *yin*

officials pray for abundant harvest and good weather, rainmaking was also performed when there was a drought. As a ritual that has been repeatedly performed since antiquity, there has been plenty of transmitted "how-to" texts on rainmaking. The transmitted instructional texts on these rainmaking often have a distinctive problem-solving flavor: If it does not rain, do A; If it still does not rain; do B. If it still does not rain; do c… For example, the following rainmaking instructions appear in the official dynastic record of Sui (隋书):

> If there is a drought after the fourth month of the year, then [one shall] pray for rain, and do the following seven things (policy-issues such as improving criminal justice and reduce taxation)…make the local officials bath and fast for three days and pray for the state (*sheji* 社稷); if it does not rain after seven days, one needs to pray all over again. If it still does not rain after the three procedures, then pray to the local deities that often bring cloud and rain.

Such detailed instructions can also be found in popular rainmaking manuals such as *The Divine Farmer's Book of Praying for Rain* (*shennong qiuyu shu* 神农求雨书), which specifies the relevant rain-inducing action based on dates. Plan A is usually some kind of rain dance; if it fails then plan B (closing southern gate of the town and place water outside[10]) is carried out; if it still fails then plan C (e.g., exposing shamans/spirit mediums under the sun) is carried out, and if plan C fails again there is plan D (piling up firewood on the sacred mountain and burning it). Indeed, the stepwise style of these instructions is reminiscent of how modern mechanics or IT guys fix a car or a computer; they keep trying things until something works.

3.2. Willingness to try alternative methods

In traditional China, both government officials and commoners were willing to try a variety of methods in hope of rain. Because the Chinese society was never under centralized theological control like Christianity or Islam, lay Chinese people often had very pragmatic attitudes towards religious matters. As such, their attitude towards various methods of rainmaking was anything but dogmatic. If rain does not arrive after praying to deity A they often switch to a different deity without much hesitation (Hansen, 2014). Such attitude is exemplified by the phrase in *Classic of Poetry* (诗经) complied over two thousand years ago "there are no deities not honored, no sacrifices withheld" in the context of dealing with a lasting drought.

Although state Confucianism has a theory about the causes of natural calamities (that drought and other disasters are intimately linked with the ruler's politics), government officials are often quite willing to incorporate local beliefs and practices, experiment with occult technologies, and sometimes employ traveling rainmakers. Indeed, the extensive records of rainmaking leaves the overwhelming impression that these officials are willing to try anything to save their people (and their jobs). One particularly telling example occurred in the year 1004 AD[11], when Emperor Zhenzong (真宗) invited a western monk (胡僧) who successfully used dragon images to summon rain during a drought. After the success Zhenzong made the following

[10] This is clearly reminiscent of Dong Zhongshu's method.

[11] By this time Confucianism has firmed established as the state orthodox philosophy, and such sympathetic magic actions would certainly be deemed as illegitimate.

comment: “although [the method] is ridiculous, yet for saving people from drought, it is not to be avoided.”[12] Though Emperor Zhenzong who presumably received a classic education likely shared the philosophical views of most Confucian scholars, he was not dogmatic about rainmaking and was willing to try seemingly odd methods to obtain rain.

Lower officials were likely even more pragmatic and utilize a succession different methods (including praying to different deities) until finally rain arrived. In the drought year of 1078, the famous essayist and historian Zeng Gong (曾巩), when serving as the governor of Fuzhou (福州), tried five different rainmaking methods from sympathetic magic to praying to local deities over a period of 20 days (Huang, 2011). Ordinary people similarly asked a number of deities for rain, and the deities that “successfully”[13] produced rain were thanked, venerated and sometimes brought to other geographic regions by their worshippers (Hansen, 2014).

3.3. Contemporaneous skepticism towards rainmaking

A central concern of any instrumental activity that claims to achieve specific goals is whether it indeed achieves those goals. For modern readers, we cannot help but wonder about the effectiveness of these exotic rainmaking methods: is it really true that natural phenomena are linked with the emperor’s rule, or an image of a dragon would attract a real dragon that brings rain? We suggest the ancients had the same concerns, although skeptical comments were perhaps less likely to be recorded or transmitted in written texts.

The fact that people were willing to try many different rainmaking methods in a sequential fashion (as shown above) already indicates that some methods were trusted more than others. Naturally, one would try what he perceives to be the most effective methods first and then attempt alternative methods down the effectiveness scale while also taking cost and benefit into consideration. If a particular method repeatedly fails to bring rain then skepticism naturally arise. Such skepticism, however, rarely leads to a complete rejection of the underlying theory, as failures can be easily explained away by attributing it to accidental ritual errors or the incompetent practitioner. On the other hand, skepticism can also arise from theoretical plausibility even in the absence of empirical data. More historical details of ancient skepticism towards rainmaking rituals can be found in the Supplemental Information, and for the sake of illustration let us examine the following comments on the rainmaking rituals from the Confucian scholar Xunzi (310-235 BCE):

> If we sacrifice and it rains, what does it mean? I say: it does not mean anything. It is the same as not sacrificing and having it rain. When the sun is eaten by the moon [i.e., when there is an eclipse], we save it; when Heaven has a drought, we sacrifice; we engage in crackmaking and milfoil divination and only then decide a great event. But we do not thereby obtain what we seek; we are placing culture (wen 文) upon it. Therefore, a gentlemen takes this as culture, but the hundred families (lay people) take it as divine (shen 神). To take it as culture is auspicious; to take it as divine is inauspicious[14].

[12] Original text: 虽不经，然为民救旱, 亦无避也.See *Song Huiayo Jigao* 宋会要辑稿 *chapter 18*.
[13] In this context, “success” simply refers to the temporal contiguity of prayer/offerings and rain.
[14] *Xunzi*, Chapter *Tianlun*, (Puett 2002)’s translation.

Here Xunzi tells us that although we should accept sacrifice and other divinatory rituals as a kind of cultural tradition as such, there is no intrinsic connection between human action and natural phenomena. In particular, Xunzi suggests that rain will arrive regardless of whether sacrificial rituals are performed. While the educated gentlemen realize that it is merely a cultural tradition, lay people really believed that sacrifice leads to rain through some divine intervention, which Xunzi speaks of disapprovingly.

4. The cultural evolution of rainmaking: all magic and no empiricism?

Like most other culturally transmitted practices, various rainmaking protocols are subject to cultural selection processes that influence their differential spread (Fog, 1999; Mesoudi, 2005). The exact mechanism of this evolutionary process is still under some scholarly debate (Claidie et al., 2014; Claidière & Sperber, 2007; J. Henrich & Boyd, 2002), yet it is generally agreed that there are some basic principles that describe the transmission of cultural practices. For instrumental activities such as rainmaking, the probability of it being adopted by others in the community often depends on its perceived efficacy. In a recent article, Singh (2017) suggests that the cultural success of many shamanistic practices can be attributed to the plausibility of their appearance; that is, certain practices were more likely to be adopted because they appear more plausible with regard to achieving people's goals, possibly due to some universal cognitive mechanisms. Many evolutionary minded anthropologists take a similar approach and offer adaptive accounts of why the human mind finds particular cultural representations attractive (Boyer and Ramble 2001; Miton, Claidière, and Mercier 2015; Gervais, Norenzayan, and Henrich 2011; Henrich and Boyd 2002; Norenzayan et al. 2014).

This kind of explanation has been broadly applied to ineffective technologies such as magic and divination. Indeed, one proposed defining feature of magic is that it is "non-empirical", in the sense that people supposedly do not care much about whether the means employed really produced the desired ends or not (Levy, 1966). We suggest, however, that although it is certainly true that beliefs and cultural practices may spread successfully because they fit our psychological intuitions, there has always been a great deal of empiricism involved in any instrumental activity, and rainmaking is no exception. Specifically, outcomes of different rainmaking methods matter, and the same psychologies (e.g. payoff-biased cultural transmission as well as trial and error learning) that enable the spread of adaptive cultural practices are still at work when people evaluate different rainmaking methods.

This empiricist attitude towards rainmaking methods, however, does not guarantee optimal behavioral outcomes. Specifically, why did people not realize that rainmaking does not actually work and instead adopt rational inaction, a "do-nothing" strategy, given that rainmaking rituals often incur significant time, effort, and material cost? We suggest that the failure to adopt the obvious "do-nothing" strategy may be largely a result of the overestimation of the efficacy of certain rainmaking methods, partly due to statistical artefacts (chance operating in small samples) and underreporting of failed rainmaking attempts.

4.1. Payoff biased cultural transmission in rainmaking

The focus on the outcome of rainmaking, both at the individual level and at the state level, can be clearly seen from both primary historical records and secondary sources. Simply put, people paid serious attention to outcomes of rainmaking and preferentially adopted methods with more perceived success. This particular psychology is usually referred to as "payoff biased cultural transmission" and plays an important role in adaptive cultural evolution (Boyd & Richerson, 2009; Kendal et al., 2009). In the context of rainmaking in early China, three aspects are particularly illustrative.

First, there was often competition among various methods. In medieval China (Tang and Song dynasty, 618-1276 AD) where a myriad of Buddhist, Daoist, and other local popular religious practices and beliefs co-existed, neither government officials nor ordinary folk had strong commitments to any single deity or religious doctrine, especially on practical matters such as rainmaking (Wang 2006). As a result, there existed a wide range of possible methods to choose from in times of drought, and these methods were often in a "market competition" situation where the efficacy of different methods and the competence of different specialists were compared (Wang 2016).

Second, the evaluation criteria for judging good from bad methods strongly depends on their outcomes, which always serve as good evidence for efficacy. In his extensive treatment of medieval Chinese rainmaking, Capitanio (2008) describes a genre of literature known as "evidentiary miracles", which refers to the collection of successful rainmaking anecdotes. As the author suggests, these stories likely serve as rhetorical devices to convince people of the power of respective practitioners and/or their methods. Hansen (2014) similarly emphasize the importance of *ling* (efficacy[15] 灵) in individuals' decisions regarding which deity to whom to offer prayers. In evaluating the efficacy of various rainmaking methods people not only focused on the eventual outcomes but also on the timing of the rain. In other words, temporal contiguity matters; a method that is followed by immediate rainfall would be deemed more efficacious and credible than one with delayed rain. Many famous historical cases such as that of the King Tang emphasize the immediacy of rain after the ritual is conducted. In official Chinese dynastic records, entries that involve rainmaking frequently mention the timeliness of rain with words like "the very day" (是日) and occasionally more dramatic stories where rain fell during the ritual or right after the ritual. Sometimes explicit time limits were placed on specialists who claim to have to power of inducing rain were made; for example, when emperor Daizong of the Tang dynasty ordered the Buddhist monk Amoghavarjra to make rain, he made the timing requirement very explicit: "If it rains within three days it will be due to your magic power. If it rains after three days, the credit will not be yours." (*Song Gaoseng Zhuan*[16]) In a sense, rainmakers are placing a dangerous bet when promising to induce rain, because although success can bring fame and fortune, failure often means severe punishment (sometimes death). During a drought in the Jin dynasty, a diviner reported to emperor Zhangzong (1200 AD) that she had been informed by

[15] *Ling* is sometimes translated as "supernatural efficacy". This is, however, imposing western categories on Chinese concepts. Although *ling* is most often used to describe the efficacy of what we would categorize as supernatural entities and technologies, it is also used to describe fully natural methods such as herbal medicine.

[16] 宋高僧传 (Biographies of eminent monks of Song)

someone in her dream that sufficient rain would fall in three days. Unfortunately, no rain occurred after three days, and the diviner pleaded guilty to the emperor[17].

Third, in some historical periods the state was directly involved in spreading rainmaking methods that have proven successful by outcome, and the Song dynasty is a particularly illustrative example. During this time popular local deities were generally deemed illegitimate (淫祀) by the state, and people worshipping them could potentially be penalized; however, the government could grant titles to these deities which then obtain legitimate status (正祀), and receive both official endorsement and sometimes funding (for repairing temple, etc.) (Pi, 2005). The criteria for granting titles to local deities seems to be primarily based on efficacy in terms of realized positive outcomes. Emperor Shenzhong's order in the year 1074 AD was very explicit: "for all deities and temples that are efficacious and responsive to prayers, if they are famous and do not have official titles yet, titles will be granted. Those that already have titles but not publicly praised should also be advertised to the public."[18] Hansen (2014)'s comprehensive study on Chinese medieval popular religion strongly supports this view with many historical details. What is particularly striking from Hansen's descriptions is that the title granting for local deities involve a lengthy verification process. Local people would request a particular deity to be officially recognized by making a request to the county magistrate who checks the power of the deity by sending local leaders and their deputies who would check whether the claimed miracles really took place and examine the deity's history of responding to prayers. If the report on deity's miracles was favorable, the magistrate would petition a fiscal intendant who then reported to the central government and explained what steps had been taken to verify the deity's power. The final reports could be extremely detailed and sometimes event included the names of witnesses that the inspectors interviewed.

Aside from granting titles to deities with apparent records of success, the Song state also endorsed rainmaking approaches based on sympathetic relationships. A very popular method involved the use of lizards because of its physical resemblance to dragon. This "lizard rainmaking method" (蜥蜴祈雨法) was mentioned to the emperor by an administrator who emphasized its efficacy by invoking his personal experience with its successful application (Qi, 2018). A few years later when a drought occurred the method was officially proposed. It was tried and worked, and the government subsequently endorsed and promoted this method as an effective way to induce rain to be applied at local levels[19]. For some time this method was so popular that there was a shortage of regular lizards and people resorted to using geckos instead (Jiang, 1981)—again relying on sympathetic relationships (geckos resemble lizards).

In other dynasties where rainmaking activities were less centrally organized, we observe instances of lower officials serving as disseminators of "effective" rainmaking methods. During the Qing dynasty, for example, local officials had a remarkable degree of freedom to choose from existing methods and revise them (Snyder-Reinke, 2020). The rainmaking method invented by the mid-Qing scholar Ji Daqui serves as an typical example: Snyder-Reinke (2020) records

[17] Jin shi, chapter 101.
[18] *Song Huiyao, Li, chapter 20.*
[19] *Xu Zizhitongjian Changbian, chapter 281*

multiple instances where local officials heard about the method, tried it and the method proved successful, and then decided to disseminate the method through textual instructions.

From the above historical analysis we can see that if some method within the possibility space were indeed effective (hypothetically speaking), they would almost certainly have been identified by the Chinese. Given that none of the methods was effective, then, why did people not adopt the obvious strategy of "do-nothing"? Granted, this strategy is not as cognitively salient as some of the elaborative rainmaking rituals that are often performed and public, yet we have seen that people did questioned the efficacy of these methods and certainly entertained the possibility that doing something is no better than doing nothing (See Supplemental Information). In the following sections we suggest two factors to help explain the persistence of ineffective rainmaking activities, i.e. some methods may appear effective purely by chance, many rainmaking failures may have been under-reported.

4.2. Empirically successful rainmaking method purely by chance

Statistics as a discipline was formulated and mathematized rather late in history (MacKenzie & Stigler, 1988) and the concept of chance was poorly understood before the mid-seventeenth century (Hacking, 2006). One aspect of rainmaking that many modern readers may fail to appreciate is that evaluating the efficacy of rainmaking methods is in fact a non-trivial statistical challenges which requires carefully controlled experimentation and analyses. Our scientific understanding of the world tells us that none of the ancient rainmaking methods work; for people without such theoretical commitments, however, they are faced with an inferential problem similar to what is now referred to as "multiple testing" (Rupert 2012). Briefly, the problem is that when a large number of hypotheses were being considered simultaneously without controlled measure such as the Bonferroni correction (Armstrong, 2014), some hypotheses may appear statistically significant simply due to chance.

In the context of rainmaking, this means that some rainmaking methods may appear to be effective because many different methods are available in the market and some happen to obtain a successful track record by chance. Note that as a cultural species, people's ideas about what might work is mostly culturally transmitted which, combined with individuals' idiosyncratic local environments, creates a large number of available methods. Below we use a little formalism to demonstrate this phenomenon and provide some numerical intuitions.

Suppose there are N methods of rainmaking (identical in terms of their efficacy) under consideration. Each method is "experimented" n times with the probability of "success" being p. The probability density distribution of the total number of success of each method is a binomial distribution with parameter p and n. The expected number of methods with k out of n success (a success rate of k/n) is thus

$$\binom{n}{k} \cdot p^k \cdot (1-p)^{(n-k)} \cdot N$$

Figure 1 provides a graphical illustration of the above equation. If the probability of success of each method p is set to be the same as chance, we observe that although most methods have a success rate lower or close to chance, there will be quite a few methods with success rate

significantly higher than chance. For example, if the chance of rain is 0.3, among the 100 rainmaking methods we expect ten with 50% success rate, four with 60% success rate, and one with 70% success rate merely as a result of randomness. Therefore, some rainmaking methods may appear very efficacious not because they actually influence weather but because of chance.

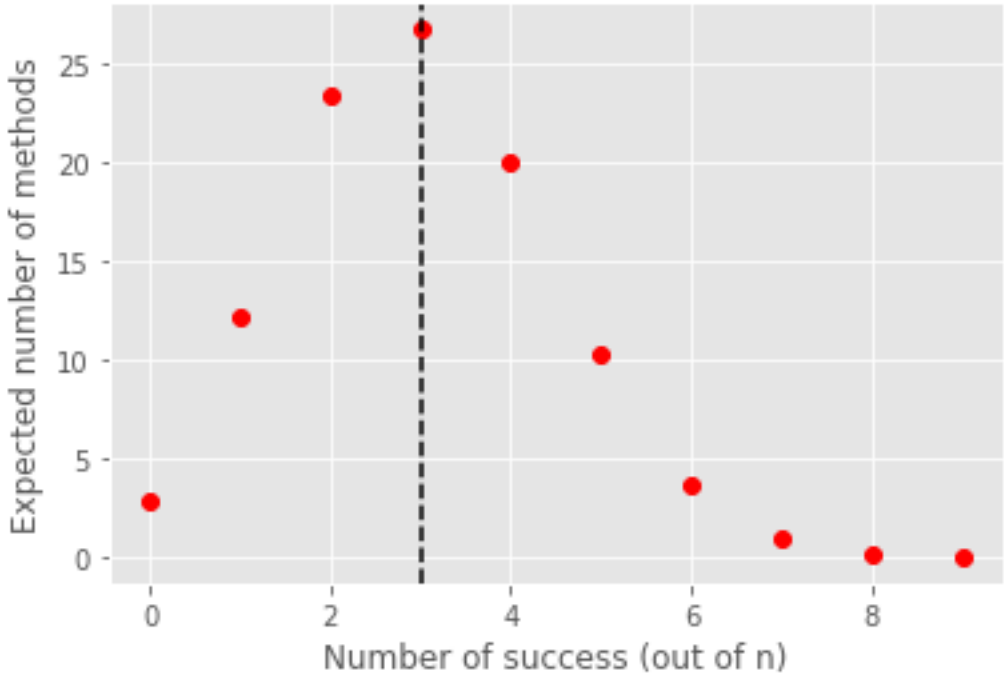

Figure 1. The graphical representation of equation (1) with illustrative parameter values: n = 10, p = 0.3, N = 100. The expected number of successes purely by chance (x = 3) is denoted by the dashed line.

4.3. Under-reporting of disconfirmatory instance

A second reason why the efficacy of rainmaking protocols may be perceived to be higher than it actually is (chance) is that many of the rainmaking failures are not reported and thus not transmitted overtime. There is evidence that some people may have been aware of such under-reporting issues; for example, the Song historian and philosopher Lü Zuqian (1137-1181 AD) made the following statement when commenting on the Confucian text *Zuo Zhuan* (~500 BCE):

> Some people ask: "Zuo's record of crackmaking and milfoil divination cases were so amazing and spectacular; given such predictive accuracy, why are there so few [records] of them?" The answer: "from the Lord Yin till Lord Ai was a total of two hundred and twenty-two years. Kings, lords, dukes, the literati and the commoner perhaps made tens of thousands of divinations, and only tens of the efficacious cases were recorded in Zuo's book. These tens of the cases were collected in Zuo's book and therefore feel like a lot; if they were dispersed into the two hundred and twenty-two years it would feel extremely rare. If divination cases were of deceptive nature or had failed predictions， they would not have transmitted during their time and not be recorded in the book. I do not know

> how many tens of thousands of them were missed. If we had all of them [recorded], they would not be so rare. (*Donglai Zuoshi Boyi*[20])

Similarly, the famous Ming politician Zhang Juzheng (1525-1582 AD), commented on the then popular practice of geomancy:

> Some people say: "Geomancers' words (predictions) often turn out to be true. If [they do] not [possess real abilities], how could they foresee what is going to happen in the future?" This statement is not true…Suppose there is a place here, let three geomancers predict [whether it is suitable for place a tomb]; one says it is auspicious, one says it is inauspicious, and the third says it is first auspicious followed by inauspiciousness… If it turns out auspicious people will say the first geomancer made accurate predictions; if it turns out inauspicious they will say the second geomancer made accurate predictions, and auspiciousness followed by inauspiciousness will be said to be predicted by the third geomancer. People transmit cases of accurate predictions and not cases of inaccurate predictions. That's why [predictive] failures are not heard and successes by chance stay/exist [in our society]. (*Zangdi lun*[21])

Although Lü Zuqian and Zhang Juzheng are talking about divination and geomancy, the same argument can be easily applied to other instrumental activities such as rainmaking. To obtain some quantitative information on the possible under-reporting of the rainmaking failures, we compiled a dataset using the digitized Chinese dynastic historical records[22] from the Chinese Text Project (ctext.org). Specifically, we searched for keywords 祈 (to pray/request) and 祷 (to pray), collected all instances involving the prayer for rain/snow to occur or stop, and recorded whether an outcome was specified as well as the number of days it took from performing the ritual to the occurrence of the desired effect (e.g. rain, snow, or clear sky).

Table 1: Rainmaking data from Chinese dynastic records

[20] 东莱左史博议.
[21] 葬地论.
[22] Books used for keyword search: Jin shu (晋书), Nan shi (南史), Bei shi (北史), Sui shu (隋书), Jiu Tangshu (旧唐书), Xin tangshu (新唐书), Song shi (宋史), Jin shi (金史), Yuan shi (元史), Ming shi (明史), Qing shigao (清史稿).

		Outcome & Accuracy				
Dynasty	*date*	*Total ritual attempts*	*Rain ritual success*	*Rain ritual failure*	*Success rate*	*% outcome unreported*
Pre-Han	*Before 220AD*	*17*	*15*	*0*	*88.2%*	*11.8%*
Jin (晋)	*266-420AD*	*2*	*2*	*0*	*100%*	*0*
N & S dynasties (南北朝)	*420-589AD*	*23*	*18*	*3*	*85.7%*	*13.8%*
Sui (隋)	*581-619AD*	*2*	*0*	*0*	*NA*	*100%*
Tang (唐)	*618-907AD*	*32*	*13*	*5*	*72.2%*	*43.8%*
Song (宋)	*960-1279AD*	*179*	*37*	*2*	*94.9%*	*78.2%*
Jin (金)	*1115-1234AD*	*59*	*11*	*2*	*84.6%*	*78.0%*
Yuan (元)	*1271-1368AD*	*25*	*18*	*1*	*94.7%*	*24%*
Ming (明)	*1368-1644AD*	*54*	*11*	*5*	*68.8%*	*70.4%*
Qing (清)	*1636-1912AD*	*146*	*54*	*2*	*96.4%*	*61.6%*
Total		497	144	17	89.4%	65.1%

Table 1 summarizes the results. One clear trend here is that there are very few recorded failures. What is particularly conspicuous is that a substantial proportion of the rainmaking outcomes are not reported. While we do not necessarily need to know the details of every rainmaking attempt, we are interested in whether failures are more likely to go unreported than successes. There are a few reasons to think that this was the case. First, successful rainmaking was often viewed as a kind of achievement, and many rainmakers took pride in it (Snyder-Reinke, 2020). These rainmakers were thus more likely to advertise their own success. Second, a suspicious pattern can be observed when we consider the days it took for an outcome to occur: there are many more rainmaking successes that occur shortly after (0~1 days) the rainmaking ritual than those with a longer delay. The phrase 是日 (on this very day) is often used which gives an impression of immediate weather response. In the Qing dynasty where we have rather detailed records of the time for rainmaking efforts to take effect, 42.2% of the rainmaking successes occur on the same day the ritual is performed, and the distribution has a rather long tail, with the number of day before rain/snow/clear sky occurs ranging from 1 to 30 (Figure 2). This suggests that while cases of immediate success were unambiguously reported, the lack of immediate success was not interpreted and reported as failure; indeed, there is quite some room in attributing later rain to earlier rainmaking. On the extreme end we see a delay as much as 30 days could still be said to be due to previous rainmaking efforts.

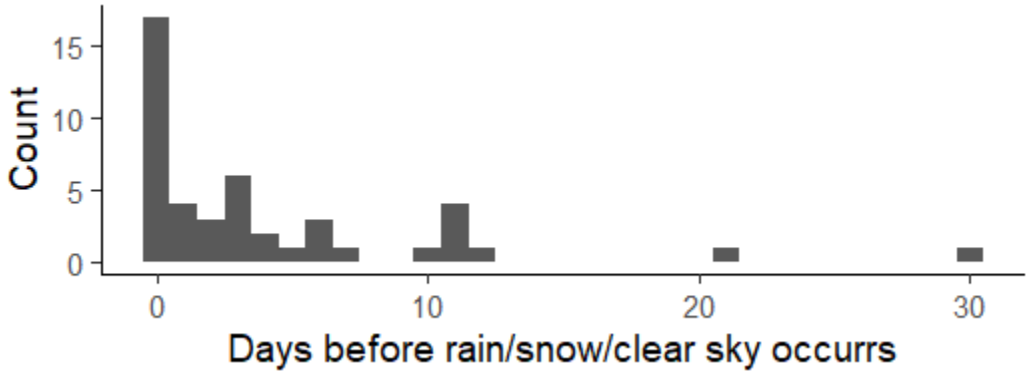

Figure 2. The number of days it took before the desired weather occurred, as recorded in the Draft History of Qing.

4.4. In the background: a supernatural worldview

We should keep in mind that despite the sporadic skeptics (whose views were never very popular), most ordinary people in pre-modern China held a worldview in which spiritual agencies can respond to human requests and objects may stimulate each other based on sympathetic principles. This meta-understanding of the world created strong content bias (Henrich and McElreath 2003) regarding the *a priori* plausibility of various kinds of rainmaking protocols. With the theoretical commitment of the existence of human-like agencies, failures to bring about rain are more likely to be attributed to unpersuasive effort or praying to the wrong deity.

A large literature in evolutionary psychology and anthropology have treated the content-specific biases as largely a result of genetically evolved causal intuitions (Boyer, 2020; Miton et al., 2015; Singh, 2017), although such a supernatural worldview can certainly be supported by innate intuitions, it is also subject to change due to systematic cultural input. As we will show, this was exactly what happened during the turn of the 20th century: the replacement of the supernatural worldview with the scientific-mechanistic finally led to the full rejection of ineffective rainmaking rituals. It was not the case that the Chinese suddenly had good data to distinguish ineffective from effective rainmaking methods; rather, a mechanistic understanding of the world categorically denies their plausibility.

5. The disappearance of rainmaking: a rejection based on theory

The persistence of various ineffective rainmaking methods throughout Chinese history and across the world is remarkable and have been extensively studied. Yet, their relatively sudden disappearance has received much less scholarly attention. This is rather unfortunate since the conditions under which people came to no longer believe in these objectively ineffective methods provide crucial insights into the psychological and sociological mechanisms that had sustained them for millennia. On the surface, the disappearance of ancient rainmaking and other magical practices took place in the late nineteenth and early twentieth century as China gradually modernized under Western cultural influences. Rainmaking, along with many other ancient

practices was deemed "superstitious" and was replaced with modern technologies that, unlike magic and divination, are truly capable of achieving what they claim to achieve.

This account is largely accurate, but it misses some key information regarding the social dynamics during this cultural transition. How did China modernize and what exactly happened to the ancient beliefs and practices? We suggest that the disappearance of rainmaking was ultimately due to the rejection of traditional theories of rain at the elite level, who then disseminated modern scientific theories of weather phenomena through institutional channels such as mass education. In other words, it was not case that people somehow realized that various traditional rainmaking efforts did not perform any better than chance based on *data*, but rather the imposition of a different worldview made the traditional theories behind these rainmaking efforts seem implausible.

From the late Qing to the early Nationalist era western scientific ideas had been spreading quite rapidly, as people were impressed by the superiority of Western technological and scientific achievements (Cheng & Waley, 1960). During the same time students were sent to the US and Europe to study science and applied technology (Deng, 1995; Xiu-li, 2008); most of them returned to China and many held important positions in the subsequent Nationalist government (Wei, 2008). Regarding rainmaking, many Western-educated Chinese scholars either publicly or anonymously voiced their criticism from theoretical perspectives by emphasizing the implausibility of weather being controlled by gods and deities, and often offered alternative, more naturalistic theories of rain. For example, in 1908, the influential early modern intellectual Hu Shi made the following comment on traditional rainmaking methods:

> When there is a drought, people want to pray for rain; but who do they pray to? Maybe praying to Heaven and Earth 天地? Yet heaven is but a puff of air, and earth is but a globe. Maybe to the Jade Emperor? To the Dragon King? Yet, the Jade Emperor and Dragon King are made of wood and mud and they know nothing [about weather]. (Six pieces of bad tradition, *Dian Huabao, Issue 5, 1908)*

Others explicitly articulated alternative, scientific theories of rain. In 1926, Harvard educated geologist and meteorologist Zhu Kezhen published an article repudiating the traditional rainmaking practices and explaining the natural causes of rain:

> Rain comes from the water vapor in the air. All air that is close to the Earth contains water vapor; not only air above the sea, but also air above the desert. Whether it rains or not depends on the condensation of water vapor into water. The lower the temperature of the air is, the less it contains water vapor… Therefore low air temperature is the necessary condition for rain. (On the prohibition of butchering for rainmaking and drought, *Dongfang Zazhi, issue 13*)

A particularly telling example occurred during a severe drought in southeastern China in 1934. The long lasting drought caused much desperation, and many traditional rainmaking practices were conducted at various localities (Ai, 2010). In Shanghai, philanthropists, entrepreneurs, and some local activists organized a fundraising event and invited the "Heaven's

Master Zhang" 张天师 to perform a rainmaking ritual. The ritual was in fact a "success"; rain indeed came afterwards (Hu, 2017a). In the old times this would no doubt be touted as proof of the rainmaker's capacity to induce rain and/or the effectiveness of the rainmaking method; the reaction from many Western educated intellectuals at the time, however, were full of criticism, ridicule, and sarcasm (Hu, 2017b). The following derisive comment in the leading newspaper at the time, *Shun Pao*, exemplified a common attitude:

> During the drought this year, the Soviet Union spent such time and money to invent artificial rainmaking; our 63rd generation Heaven's Master just needed to step onto the podium and exercise his magical power, didn't heavy rain fall as well? But it is told that Heaven's Master Zhang for some reason has attempted suicide five times; I hope that he passes all his magical apparatus to the 64th generation before he dies. (East, West, South, and North*, Shun Pao, issue 21, 1934*)

By this time, although uneducated lay people still maintained some of the traditional beliefs, the educated elites had rejected them on theoretical grounds. Therefore, any observed success could only be incidental and not due to the causal influence of rainmakers. A keyword search of "praying for rain" (求雨) in the Shanghai Library Chinese Periodical Full-text Database shows that in the year 1934, 44% of the articles expressed obvious negative attitude towards traditional rainmaking activities out of a total of 66 occurrences, and among the disapproving articles the vast majority (90%) did not mention any actual rainmaking failures. Rather, many of the articles explicitly label traditional rainmaking as "superstition" (迷信), and those peasants who believe in it "stupid people" (愚民). How was the elite-level skepticism during this time different from the sporadic skeptics for earlier eras? We suggest two key differences. First, the shock of Western superiority that hit China was so profound that it fundamentally shook many people's faith in traditional Chinese culture in general. Thus many intellectual elites adopted entire sets of cultural beliefs and value systems from the West, which led to a total rejection of the theoretical core of traditional Chinese divination, rainmaking and other magical practices (Spence, 1982) — a case of prestige-biased transmission (Henrich and Gil-White 2001), Second, these elites—given the power of the Chinese state — were in a position of power to quickly and efficiently spread new worldview thorough institutions such as modern schools, universities and government agencies.

The elimination of ineffective rainmaking methods and the realization of the superiority of the "do-nothing" strategy, therefore, should be viewed as the result of a group level process; that is, the spread of the materialistic and scientific worldview from Western Europe to other parts of the world. Within-group cultural evolutionary forces such as payoff biased transmission often fail to pick up the "do-nothing" among many "do-something" strategies, as the "do-nothing" strategy does not benefit from the under-reporting of disconfirmatory evidence (in fact, in this case *positive* instances are likely to go under-reported as they are less likely to be noticed), and as a single strategy with low salience it is unlikely to appear "efficacious" by chance. Again, people cared about outcomes, but the empiricism in traditional societies work better when the optimal variant is of a "do-something" nature. One of the prominent features of modern science,

we argue, is that it denies the causal relevance of magical action and alleged outcome, thus making the "do-nothing" strategy the only scientifically-defensible alternative.

6. Conclusion

In this paper, we focus on the nature of rainmaking rituals in traditional China and argued that they have always been instrumental activities to induce rain, as strongly supported by the extensive historical records and the extant studies on Chinese rainmaking. We further argue that despite the existence of payoff biased transmission which usually produce adaptive cultural practices, certain psychological and social factors nonetheless maintain such ineffective technologies as people fail to realize the superiority of the "do-nothing" strategy under a supernatural worldview. Thus, the disappearance of ineffective rainmaking requires a rejection of the underlying theories of rain. In China, such theoretical rejection was a result of contact with the West which led to the introduction and diffusion of a mechanistic worldview and scientific understandings of natural phenomena.

Although we have exclusively focused on rainmaking in pre-modern China, our proposed cultural evolutionary explanations for the persistence of rainmaking rituals hold for ineffective technologies in general. Whenever there is a need to achieve some desired outcome or to avoid an undesirable one, there will be an incentive to perform some (costly) technology, and potentially many technologies deemed plausible under some larger worldview; when the outcome is probabilistic, people may over-estimate the efficacy of these technology because many of the disconformatory instances were omitted and lost during cultural transmission. Gender selection[23], traditional healing (appeasing ghosts/spirits to cure illness), and many other forms of magic prevail largely for these reasons. A complete understanding of ineffective technologies, past and present, would require an understanding of the evolved intuitions, the population dynamics of information transmission, and the larger social context in which such transmission occurs.

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[23] Gender-related divination was also common in China (Jian Li, 2015); once the gender of the baby is believed to be revealed, one can decide whether to keep it (in the case of boy) or to abort to (in the case of girl).

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