Magic and empiricism in early Chinese rainmaking

A cultural evolutionary analysis

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Abstract

Ritual protocols aimed at rainmaking have been a recurrent sociocultural phenomenon across societies and throughout history. Given the fact that such protocols were likely entirely ineffective, why did such they 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 employ them in order to bring about rain. 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 the 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 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). The inclination to "do something" when a drought hits versus "do nothing" likely also plays a role and persists in the world today.

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* (1890), James Frazer devotes an

entire chapter to the magical control of the weather: the rain-making activities of the peasants in Russia, tribal farmers in New Guinea, the Omaha in North America, and many other traditional societies are all described in vivid detail. More recent ethnographic work further suggests the widespread nature of such 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 traditional[1] 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 (1952) and Max Gluckman (1944) who suggest that the two categories require 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. Malinowski, similarly, thinks that the indigenous people themselves recognize a distinction between the supernatural and rational (Malinowski, 1922/2002), and the great sociologist Talcott Parsons (1937) expanded this account by suggesting that there are certain actions that are "non-rational," that is, they have no pragmatic end other than the performance of the acts themselves. In short, the reaction against the 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 are driven by emotion, respect for tradition, power dynamics in the community, or other non-instrumental factors. Many anthropologists today still follow the reaction against Tylor and Frazer.

Let us step back and place rainmaking into this larger context. The 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

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

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 intended to be 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 advent of digitized databases of Chinese texts has enabled more quantitative assessment of elite history and culture (e.g., Sturgeon, 2006). Here we take advantage of such resources and offer a detailed analysis of rainmaking in China.

Our paper is organized as follows: In part one (section 2 and 3), we summarize major theories of rain in early China and the corresponding rain-inducing activities, arguing that the majority of rainmaking activities are best understood as instrumental efforts. In part two (section 4), 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. In the final section (section 5) we offer an account of the disappearance of traditional rainmaking in China by attributing it to a shift in people's background worldview.

2. Folk theories of rain and rainmaking in early China

Like many traditional societies, pre-modern China had elaborate theories about meteorological 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 capacity to make rain. In traditional China, these agents could be deceased ancestors, local deities (deceased famous individuals who serve as "protectors" of a geographic region), or supernatural beings such as dragons (detailed descriptions 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

Alongside many beliefs about rain that involved 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 -- tended to prefer 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 get murky, though this is common with regard to cosmic forces (Willard et al. 2020).

Broadly, these rainmaking theories involving impersonal forces 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 people, 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

[2] 明外史.

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

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

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 quotation 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) towns should close their southern gates[8] and open those on the north[9], or 3) the lighting of fires should be prohibited. As Bodde (1964) points out, the rainmaking efforts documented in *Chunqiu Fanlu* is more likely to be Dong's own scholastic formulation than an account of 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).

Interestingly, the concept of "sincerity" 诚 often played an important role in rainmaking: in order for Heaven to grant rain, political leaders needed to be completely sincere when performing these rituals (Snyder-Reinke, 2020). Consequently, rainmaking failures might be attributed to the insincerity of rainmakers. We suggest that this is an illustrative case of a more general phenomenon of "invoking auxiliary hypothesis to protect to core theories," in the language of the philosophy of science. It is common for people to invent reasons to explain (away) technological failures *post hoc* to prevent their theories from being falsified. However, there is ample historical and ethnographic evidence showing that people's subjective understanding of technological efficacy is probabilistic (Anonymized, in press; Anonymized, unpublished). That is to say, while people (under a particular worldview, see later sections) always believe that rainmaking can work *when properly conducted*, their estimation of the probability that the desired outcome (rain) would follow the technological action (rainmaking) will decrease in the face of empirical failures regardless of the excuses invoked. In other words, while the lack of sincerity may be used as an auxiliary hypothesis to protect confidence in

[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*

supernatural rain-making techniques, people's confidence in any particular rainmaking protocol (all factors considered, including sincerity) is likely to be affected by observed failures. This is especially true when multiple methods are available, as in the case, for instance, where multiple deities were believed to be able to exert control over weather.

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 bolster 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 officials pray for abundant harvest and good weather, rainmaking was also performed when there was a drought. This has resulted in a large corpus of transmitted "how-to" texts on rainmaking. These texts often have a distinctive problem-solving flavor: If it does not rain, do A; If it still does not rain; do B… 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 reducing taxation)…make the local officials bathe 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). The stepwise style of these instructions is reminiscent of how modern mechanics or IT technicians fix a car or a computer. Like traditional rainmakers, these specialists have certain causal theories of how things normally work, and adopt a strategy of trying a series of potential solutions until the problem is fixed.

3.2. Willingness to try alternative methods

In traditional China, both government officials and commoners were willing to try a variety of methods in hopes of bringing rain, and their attitude towards various methods of rainmaking was anything but dogmatic. If rain did not arrive after praying to deity A they often switched to a different deity without hesitation (Hansen, 2014). Such attitude is exemplified by the phrase in

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

Classic of Poetry (诗经), complied over two thousand years ago, that "there are no deities not honored, no sacrifices withheld" in the context of dealing with a lasting drought.

Although state Confucianism provided more abstract, moralistic theories about the causes of natural calamities (that drought and other disasters are intimately linked with the ruler's politics), government officials were 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 CE[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 comment: "although [the method] is unconventional, yet for saving people from drought, it is not to be avoided."[12] Although classically educated and presumably sharing the philosophical views of most Confucian scholars, the Emperor had an eminently practical view of rainmaking and was willing to try seemingly odd methods to obtain rain.

Lower officials were similarly likely to utilize a succession of 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 one perceives to be the most effective methods first and then attempt alternative methods down the effectiveness scale while also taking costs into consideration. If a particular method repeatedly fails to bring rain then skepticism naturally arises. 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

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

[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.

incompetent or insincere 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, but for the sake of illustration let us note the views of the most famous early Chinese skeptic of religious rituals, the Confucian scholar Xunzi (310-235 BCE). In a broader essay exploring the proper attitude to have toward "Heaven" or "Nature" (*tian*), Xunzi notes:

> 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 [perform a ritual to] 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 – all of these practices are performed for their cultural (*wen* 文) value. Therefore, the gentlemen sees these rituals as cultural practices, even as the common people take them as having supernatural (*shen* 神) causality. To see them as cultural is auspicious; to see them as supernatural is inauspicious[14].

This is part of a larger argument that Xunzi makes for understanding religious ritual in a symbolic and functional sense, rather than literally efficacious techniques for bringing about desired outcomes in the world (Campany, 1992). For Xunzi, sacrifice and other divinatory rituals are best seen as serving a social function: they bring people together, create a sense of community, and allow individuals to better understand where they fit into the social hierarchy. The scholar or intellectual, Xunzi's intended reader, should understand that we perform rituals for this social reason, not because there is any causal connection between human action and natural phenomena[15].

Xunzi's supernatural skepticism, however, is best seen as the exception that proves the rule. His agnostic or atheistic view of "Heaven" as simply an impersonal, blind process independent of human control (Machle, 1976) remained a minority position, even among the elite, and—as the evidence cited above indicates—appeared to have little or no effect on very much practical and literal views of the efficacy of rain rituals. The fact that, even armed with a theoretical argument against rain-making magic, the Chinese, from elite down to the general populace, continued to enthusiastically embrace such rituals makes their continued appeal even more puzzling.

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[14] *Xunzi*, Chapter *Tianlun*.

[15] Xunzi's larger point that rainmaking rituals may have political and social efficacy has been extensively addressed in the literature. Our main focus in this paper, however, is the *explicit* instrumental nature of rainmaking: i.e., rainmaking to induce rain. As we have previously argued (Anonymized (forthcoming)), a ritual's social, religious, political functions depend on the public's belief that the ritual can indeed achieve its explicit purposes (bringing about rain, generating accurate information, etc.), which means that we still need to answer the question of why people believe in the explicit efficacy of rainmaking in the first place.

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

Like most other culturally transmitted practices, 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. Often, the focus of this literature is identifying recurrent features of ineffective instrumental practices that contribute to their plausibility. For example, repetition and the presence of religious icons are shown to increase perceived efficacy of rituals (Legare & Souza, 2012); the form of bloodletting (co-location of cure and symptom and the act of removing blood from body) fit our folk physical and folk biological intuitions (Miton et al., 2015). More recently, Singh (2017) suggests that features like inhumanness – the physical appearance or behavioral habits that differ from normal humans -- contribute to the cultural success of many shamanistic practices. In sum, this line of research argues that certain practices are 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 empirically ineffective technologies such as magic and divination. Indeed, one proposed defining feature of magic[16] is that it is "non-empirical" (Levy, 1966) or seriously empirically inadequate (Nadel, 1954), with the implication that people supposedly do not care much about whether the means employed really produced the desired ends. 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? Research in cognitive psychology

[16] Note that "magic" is a anthropologically problematic term that resists clear definition (Styers, 2005). Here we are using it as a convenience shorthand to refer to cultural practices sustained by non-empirical components (primarily innate, evolved intuitions) as summarized in the previous paragraph. Below we use "magic/magical practices" to collectively refer to Frazerian sympathetic magic and practices that involve interacting with human-like entities.

has proposed several accounts based on faulty information processing, and we shall discuss two main ones that are most relevant for the present study. First, classic studies have demonstrated the phenomenon of "illusion of control" where people erroneously attribute some observed outcome to their own actions (Langer, 1975; Rudski, 2004). Second, certain heuristics such as the availability heuristic (Schwarz et al., 1991; Tversky & Kahneman, 1973, 2013) and the representativeness heuristic (Kahneman & Frederick, 2012; Kahneman & Tversky, 1972) may affect how we perceive frequency and probability. In the context of rainmaking, these biases mean that 1) we often subjectively feel that we have control over rainfall, especially when rain occasionally does occur after a ritual is performed; and 2) when we think about the frequency of rainmaking success, we tend to selectively recall cases where rain indeed fell after ritual being performed – arguably, these cases are more cognitively salient than rainmaking failures.

We think these accounts do fit the evidence, and they offer important explanatory insights on the persistence of rainmaking. However, these psychological accounts exclusively focus on individual cognition and largely ignores population-level processes in which beliefs are updated and transmitted over many generations. Previously, we have formally modeled how individuals' subjective perception[17] (from the perspective of the individuals themselves) of technological efficacy may be influenced by various factors, where objective efficacy (from the perspective of modern science) is an important input source (Anonymized, in press). Here we offer two additional factors that contributes to the perceived efficacy of rainmaking from the empirical front by considering both how individuals form and update beliefs regarding the efficacy of rainmaking techniques and how these beliefs transmit in the population. Briefly, the efficacy of certain rainmaking methods may be overestimated due to 1) statistical artefacts (i.e., multiple culturally transmitted rainmaking methods being evaluated simultaneously causes some to appear efficacious by chance) and 2) underreporting of failed rainmaking attempts. Finally, we discuss the role of the background supernatural worldview which sustains the fundamental validity of traditional rainmaking, and the eventual decline of rainmaking in China as a result of a shift in worldview.

4.1. Payoff biased cultural transmission in rainmaking

The focus on the outcome of rainmaking, both at the individual level and 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 termed "payoff biased cultural transmission," and it 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 CE) 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

[17] Hereafter by "perceived efficacy", "beliefs about the efficacy…" and "estimation of the efficacy of…" we mean individuals' emic understandings (i.e., their subjective perceptions, beliefs and estimates).

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 a 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[18] 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 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 immediately after the ritual. Sometimes explicit time limits were placed on specialists who claim to have to power of inducing rain. 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*[19]) 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 CE) that she had been informed by 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[20].

Third, in some historical periods the state was directly involved in spreading rainmaking methods that were seen as having been 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 also grant titles to these deities, which then accorded them legitimate status (正祀), allowing them to receive official endorsement and sometimes funding (for repairing temples, 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

[18] *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.

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

[20] Jin shi, chapter 101.

in the year 1074 CE 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."[21] 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 involved a lengthy verification process. Local people would request a particular deity to be officially recognized by making a request to the county magistrate who checked the power of the deity by sending local leaders and their deputies who would verify 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 even 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 their physical resemblance to the mythological 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[22]. 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 a typical example: Snyder-Reinke (2020) records 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 reviews 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, why did people, including highly educated elite, mistakenly perceive efficacy in certain rain rituals, and continue to pour significant material and temporal resources into pursuing such rituals? Why did individuals not adopt the obvious strategy of "doing nothing", which would have—as Xunzi pointed out in the 3rd century BCE—provided the same results without the effort or expense? Granted, while doing nothing in the face of drought is not as cognitively salient as the elaborative rainmaking rituals

[21] *Song Huiyao, Li, chapter 20.*

[22] *Xu Zizhitongjian Changbian, chapter 281*

that are often performed and public, we have seen that scholars such as Xunzi did question 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: some methods may appear effective purely by chance, and many rainmaking failures may have been under-reported.

4.2. Empirically successful rainmaking methods arising 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 challenge which requires carefully controlled experimentation and analyses. Our scientific understanding of the world tells us that none of the ancient rainmaking methods work; people without such theoretical commitments, however, were 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. This fact, combined with individuals' idiosyncratic local environments, creates a large number of available methods.

A little formalization may be useful 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 (as we would expect from a modern perspective when it comes to rain-making rituals), 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 merely because of chance. Of course, keep in mind that if a method with a solid track record suddenly fails, there are many potential explanations such as the incompetence or insincerity of a particular rainmaker.

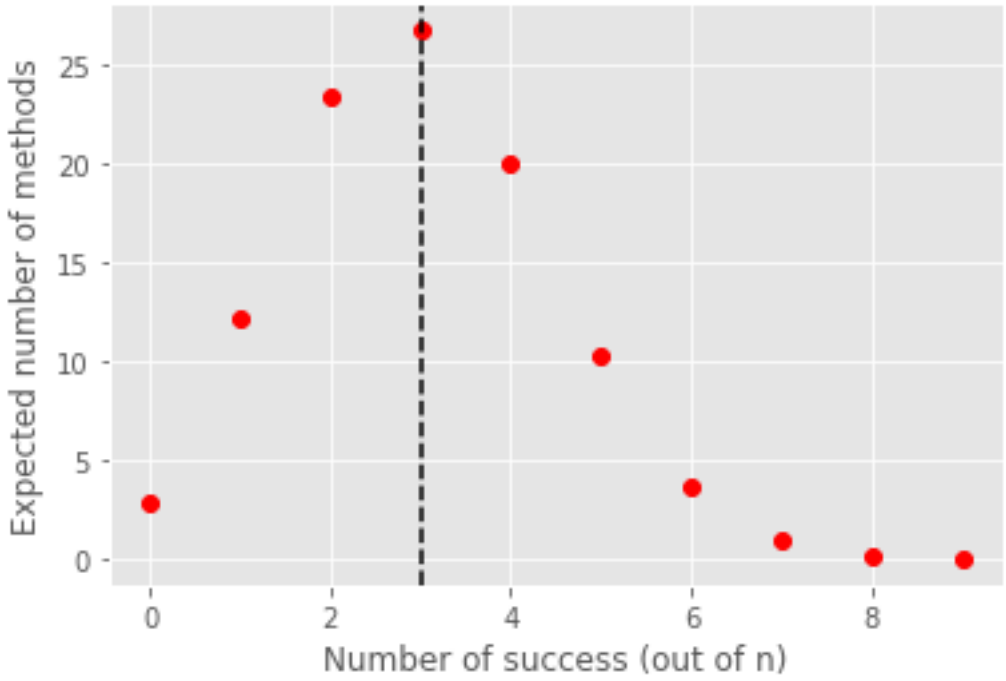

Figure 1. The graphical representation of equation (1) with illustrative parameter values: n = 10, p = 0.3, N = 100. The expected number of successes purely by chance (x = 3) is denoted by the dashed line.

4.3. Under-reporting of disconfirmatory instances

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 CE) 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 would 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*[23])

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

[23] 东莱左氏博议.

> 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*[24])

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 official Chinese dynastic records[25] (Twenty-Four Histories plus Draft History of Qing)[26] which are systematic records of important people and events of the previous dynasty written by professional historians of the later dynasty (Wilkinson, 2012) 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).

[24] 葬地论.

[25] Note that these recorded rainmaking instances are quite special in that they come from the official dynastic records which carry a certain authority. We suggest, however, that this sense of authority carried by transmitted texts are not unique to China: The authority of Aristotle in west, for example, has shaped our understanding of the causal structures of the world for thousands of years, and it was only rather recently (the scientific revolution in the 17th century) that we observe a profound shift in epistemology in Europe (Wootton, 2016). Galenic medical theory similarly shaped subsequent medical practices in Europe well until early modern times (Hankinson, 2009; Nutton, 1972).

[26] Books used for keyword search: Shiji (史记), Han shu(汉书), Houhan shu (后汉书), Sanguozhi (三国志), 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), Jiu Wudaishi (旧五代史), Xin Wudaishi (新五代史) Song shi (宋史), Jin shi (金史), Yuan shi (元史), Ming shi (明史), Qing shigao (清史稿).

Table 1: Rainmaking data from Chinese dynastic records

		Outcome & Accuracy				
Dynasty	*Date*	*Total ritual attempts*	*Rain ritual success*	*Rain ritual failure*	*Success rate*	*% outcome unreported*
Han (汉) and Pre-Han	*Before 220CE*	*17*	*15*	*0*	*88.2%*	*11.8%*
Jin (晋)	*266-420CE*	*2*	*2*	*0*	*100%*	*0*
N & S dynasties (南北朝)	*420-589CE*	*23*	*18*	*3*	*85.7%*	*13.8%*
Sui (隋)	*581-619CE*	*2*	*0*	*0*	*NA*	*100%*
Tang (唐)	*618-907CE*	*32*	*13*	*5*	*72.2%*	*43.8%*
Five Dynasties (五代)	*907-960CE*	*38*	*8*	*2*	*80.0%*	*73.7%*
Liao (辽)	*907-1125CE*	*10*	*3*	*0*	*100%*	*70%*
Song (宋)	*960-1279CE*	*179*	*37*	*2*	*94.9%*	*78.2%*
Jin (金)	*1115-1234CE*	*59*	*11*	*2*	*84.6%*	*78.0%*
Yuan (元)	*1271-1368CE*	*25*	*18*	*1*	*94.7%*	*24%*
Ming (明)	*1368-1644CE*	*54*	*11*	*5*	*68.8%*	*70.4%*
Qing (清)	*1636-1912CE*	*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 and as a result many more successes, relatively speaking. 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, and 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 that a delay as much as 30 days could still be said to be due to previous rainmaking efforts.

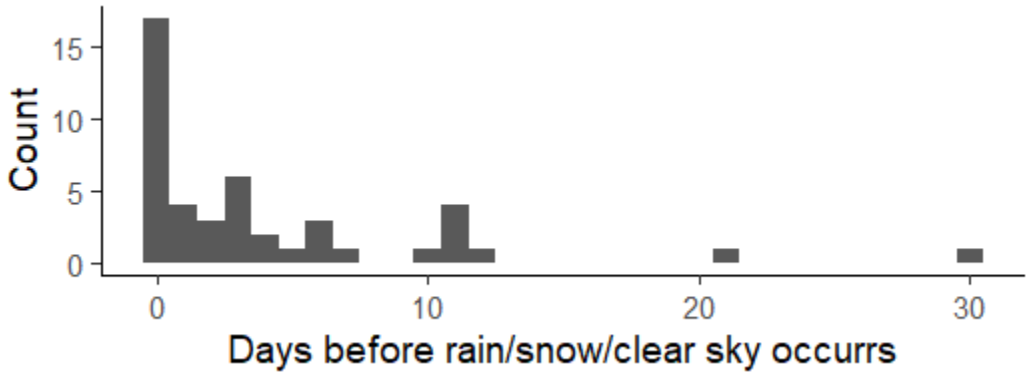

Figure 2. The number of days it took before the desired weather occurred, as recorded in the Draft History of Qing.

Such under-reporting may arise for a number of reasons, including confirmation bias (Johnson, 2017; Nickerson, 1998) and the aforementioned availability and representativeness heuristics. Regardless of the initial cause, the consequence of under-reporting is that naïve individuals (readers of the dynastic histories) may erroneously conclude that rainmaking is highly effective even if they do not possess the cognitive biases. In other words, the tendency to under-report disconfirmatory instances creates a feedback loop in which the belief in the perceived efficacy of rainmaking (or any other technology) may be recursively boosted.

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 negotiations with the divine or too much attention to the wrong deity.

This supernatural worldview is closely related to the literature that focuses on the intrinsic plausibility of cultural practices discussed in the beginning of section 4. To reiterate, this literature within evolutionary psychology and anthropology have treated the content-specific biases regarding why we find particular cultural practices plausible as largely a result of genetically evolved causal intuitions (Boyer, 2020; Miton et al., 2015; Singh, 2017). We would like to point out that although such a supernatural worldview is certainly supported by innate intuitions, it is also subject to systematic cultural input, and may change as a result of cultural influence. As we will show, this was exactly what happened during the turn of the twentieth 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 that categorically denied their plausibility increasingly supplanted earlier worldviews.

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

The persistence of various rainmaking methods throughout Chinese history and across the world is remarkable and has been extensively studied. Yet, their relatively sudden decline has received much less scholarly attention[27]. This is unfortunate since the conditions under which many 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 (e.g., Table 1). 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 replaced with modern technologies that, unlike magic and divination, often had both materialist theoretical explanations and systematic empirical grounding.

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 traditional 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 the case that people somehow realized that various traditional rainmaking efforts did not perform any better than chance based on *data*, but rather that 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 era 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

[27] Note that strictly speaking, traditional rainmaking still *exists* in both China and elsewhere in the world, just as astrology and other "superstitious" practices still have their market. In any society with sufficiently large population and complex social structures, there are going to be people who commit to different epistemologies and practice non-mainstream practices. In the US, for example, a small yet often vocal minority hold beliefs to the contrary of scientific consensus (e.g., anti-vaccination beliefs) despite the spectacular scientific and technological advances the US has experienced during the past few centuries. However, if we look at the larger picture, there is a genuine, qualitative difference between the public understanding and practice of rainmaking in traditional China and modern China precisely because of a worldview shift. Even in the case of Taiwan, where traditional rainmaking (praying to deities) is more frequent and sometimes attended by public officials, surveys show that the only a minority expect the rainmaking ritual to be "efficacious," and there is often public pressure from intellectuals that discourage high level government officials to attend these "superstitious" rituals (Wu, 2021).

either publicly or anonymously voiced their criticism 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 – that is the current scientific take on 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 in 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 traditional China, this would no doubt be touted as proof of the rainmaker's capacity to induce rain and the effectiveness of the rainmaking method. The reaction from many Western educated intellectuals at the time, however, was one 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 of earlier eras? We suggest two key differences. First, the shock of Western superiority that hit China was so profound that it fundamentally rattled 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 to quickly and efficiently spread new worldviews 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, it was caused by 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. This is because 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 do care 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. However, it is worth noting that the "do-something" bias is so powerful that we can still see it skewing behavior in modern societies: as a recent newspaper article notes, the modern version of rainmaking, seeding clouds with chemicals to induce precipitation,[28] is practiced quite widely across modern China. This is despite evidence that it is only efficacious in, at best, very specific circumstances, and that overall the costs of the practice appear to greatly outweigh the benefits. (*Cloud-Seeding Will Not Solve China's Water Shortages*, 2021). If an ineffective "do-something" strategy can prevail in modern China, even with the benefit of detailed data gathering and modern scientific models, the longevity of traditional rain making practices is not at all surprising.

In fact, rejection of a set of previously accepted practices due to a shift in worldview was likely a general feature in the evolution of ineffective instrumental practices. In his most

[28] In contrast with traditional rainmaking that involves praying to deities and/or sympathetic magic, cloud seeding, whatever its actual efficacy, is distinctive from them in being theoretically plausible within the modern scientific, mechanistic worldview.

celebrated book *Religion and the Decline of Magic*, Keith Thomas (1971/2003) penetratingly concludes that

> …once their initial premises are accepted, no subsequent discovery will shake the believer's faith, for he can explain it away in terms of the existing system. Neither will his convictions be weakened by the failure of some accepted ritual to accomplish its desired end, for this too can be accounted for…The reaction against magic could thus never come from the cumulative resentment of disappointed clients. It had to arise from outside of the system altogether. (Keith Thomas, *Religion and the Decline of Magic*)

Subsequent work in history of science largely corroborates this claim. Astrology in the 17th century England, for example, was suggested to be rejected on non-empirical grounds, as what it would take to test the core tenets of astrology was simply unavailable at the time (Kemp, 2003). Similarly, the decline of alchemy was attributed to change in the larger socio-cultural context rather than its empirical inadequacies (Clements, 2017). As in the case of rainmaking, a mechanistic worldview renders such traditional practices implausible.

6. Conclusion

In this paper, we focus on the nature of rainmaking rituals in traditional China and argued that they have always been understood as 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 produces adaptive cultural practices, certain psychological and social factors nonetheless can maintain such ineffective technologies as people fail to realize the superiority of the "do-nothing" strategy while under a supernatural worldview. Thus, the disappearance of ineffective rainmaking requires a rejection of the underlying theories of rain. In China, although anti-supernatural, mechanistic theories of the world were available to elites as early as the third century BCE, widespread theoretical rejection had to wait over two millennia until contact with the West. It is worth exploring in more detail the economic, political and cultural factors that finally allowed the successful diffusion of a mechanistic/materialistic worldview of natural phenomena at this point in Chinese history, but our view is that prestige-biased transmission played an important role.

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. Shang oracle bones, for example, contain many rain-related predictions (whether it will rain on a certain day) and sometimes have "verifications" (whether it indeed rained on that day), and the vast majority of the recorded outcomes are confirmatory (Keightley, 1985). More generally, whenever there is a need to achieve some desirable outcome or to avoid an undesirable one, there will be an incentive to perform some (costly) technology or practice, and potentially many technologies or practices deemed plausible under some larger worldview. Furthermore, when the outcome is probabilistic, people may over-estimate the efficacy of these technology either due to chance or because many of the disconformatory instances were omitted

and lost during cultural transmission. Fetal sex prognostication[29], traditional healing (appeasing ghosts/spirits to cure illness), and many other forms of magic prevail largely for these reasons. Note that the two proposed factors that bias efficacy perception -- statistical artefacts and under-reporting of failures -- are but two features (among many others) of the underlying cultural evolutionary processes (Anonymized, forthcoming), and 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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