Reputation Collectives: How International Industry Associations Influence China's Safety Standards in High-Risk Technologies

Jeffrey Ding and Dennis Yuen Li

Abstract

Emerging economies face challenges in managing safety risks from powerful technologies. Indeed, some analysts identify China as the most likely source of an accident linked to emerging technologies. Yet, China has achieved a remarkable safety record in certain technological domains, such as civil aviation and nuclear power. How? We theorize that, for industries in which one firm's accident damages the reputation of all others, international industry associations can contribute to improved safety standards in emerging economies. These associations subsidize laggards' efforts to raise their safety standards and exert peer pressure through internal benchmarking efforts. This departs from existing theories on certification clubs that set standards to deny association benefits to non-members. To demonstrate these different pathways of international private regulation, we study interactions between international industry associations and Chinese firms in three domains: nuclear power, civil aviation, and chemicals. The evidence supports a novel mechanism based on reputation collectives.

KEYWORDS

International private regulation; emerging technology; China, technology, global governance

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I. Introduction

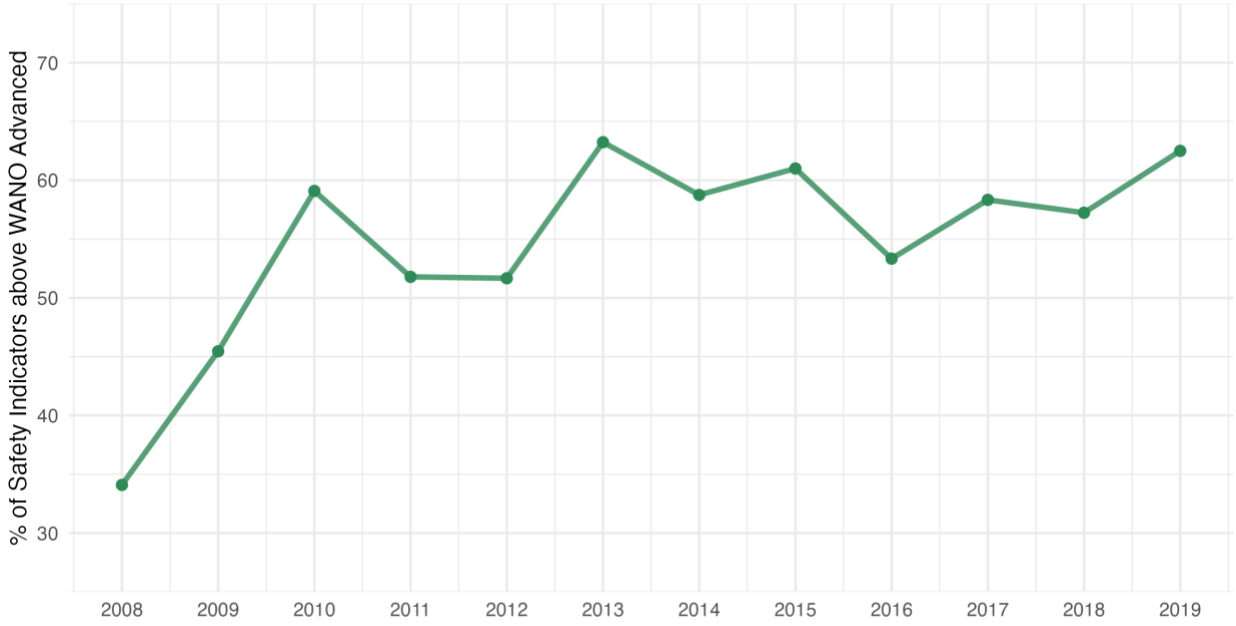
Technological advances promise to improve the world, but they may also sow the seeds of its destruction. Following Charles Perrow's seminal text *Normal Accidents*, social scientists have warned that highly complex, tightly coupled technological systems will inevitably fail due to unpredictable interactions that cascade, making them catastrophes waiting to happen.[1] The worst nuclear disaster of the Cold War was not caused by deliberate escalation of the nuclear arms race, miscalculation, or a rogue commander launching a nuclear strike without authorization; rather, it was precipitated by an accident at the Chernobyl nuclear power station, which released more than 400 times as much radioactive material as the U.S. nuclear bomb dropped on Hiroshima.[2]

In recent years, China's approach to managing safety risks in chemicals, civil aviation, and other high-risk sectors has drawn increasing scrutiny.[3] Existing literature expects technological accident risks to be particularly high in China due to the tendency of authoritarian regimes to suppress information and limit transparency, as well as low levels of regulatory quality and independence.[4] This extends to discussions of China's governance of emerging technologies like artificial intelligence (AI). One recent *Foreign Affairs* essay declares, "Due to Beijing's lax approach toward technological hazards and its chronic mismanagement of crises, the danger of AI accidents is most severe in China."[5]

Yet, contrary to these expectations, China has achieved a remarkable safety record in certain technological domains, such as aviation, space launches, and nuclear power.[6] China's aviation safety record leads the world by some metrics, and the U.S. Federal Aviation Administration even used the Chinese model to help India improve its aviation safety.[7] Likewise, China has registered impressive nuclear safety improvements. The World Association of Nuclear Operators (WANO, pronunciation rhymes with Bono) collects nuclear safety indicators from plants around the globe. Since 2008, the percentage of safety indicators in China's nuclear power plants that exceed the WANO Advanced standard (75th percentile) has nearly doubled (Figure 1).[8] How has China exceeded expectations in these domains?

[1] Perrow 1984.
[2] IAEA 1997.
[3] Suttmeier 2008.
[4] McLean and Whang 2020.
[5] Drexel and Kelley 2023.
[6] Erickson 2014.
[7] Pasztor 2007.
[8] See also Appendix Figure A1.

Figure 1: Nuclear Safety Performance in China (2008 Reference)



Note: Y-axis indicates the percentage of WANO performance indicators in China exceeding WANO Advanced (75th percentile), a global benchmark based on all WANO members. To maintain temporal consistency, the 2008 WANO Advanced values serve as a fixed reference for all years shown. Source: China Nuclear Energy Yearbook 2009-2020.

In this article, we develop a theory of how international industry associations like WANO can contribute to improved technological safety in emerging economies. For industries with a collective safety reputation, such that an accident in one firm damages the image of all others, firms are driven to organize global industry associations dedicated to improve industry-wide safety performance. To achieve this goal, these organizations (which we call "reputation collectives") institutionalize key activities: sharing of best practices, tracking safety indicators that allow firms to compare their performance against others, and conducting peer reviews of safety operations. In short, they exert positive peer pressure. Despite the constraints of global private governance, reputation collectives can play a valuable role in raising safety standards in emerging economies, which often lack strong domestic and international public regulators.

Crucially, this process differs from some existing theories of international private regulation, which highlight certification clubs that establish strict quality, safety, or environmental standards and deny membership benefits to firms that fall short of those standards. In contrast, under our "reputation collective" mechanism, international industry associations endeavor to admit all firms as members, as the weakest safety performers threaten the reputation of all. Specifically, we theorize that reputation collectives differ from certification clubs by treating industry reputation as a communal and non-exclusive good, safeguarding information shared among members from external stakeholders, and subsidizing weak links to keep them integrated in the group.

To demonstrate differences between the certification club and reputation collective mechanisms, we examine interactions between international industry associations and Chinese firms in three high-risk technological domains: nuclear power (1987-2016), civil aviation (1990-2008), and

chemicals (2002-2021). In all three sectors, background conditions suggest that an international industry association positively influenced China's safety advances, which means they are fertile ground for differentiating between the particular mechanisms at work. China represents a hard test for our arguments about how international private regulation influences safety standards in emerging economies. Taking the form of expert interviews, Chinese-language resources, and new data, evidence from these cases substantiate the validity of the reputation collective mechanism in high-risk industries with shared safety reputations.

This article makes two main contributions. First, it demonstrates how international industry associations can effectively raise safety standards, even in countries without the domestic institutions traditionally associated with protecting against technological accidents and contexts where international agreements are weakly enforced. This bears directly on debates over how to manage the safety risks of emerging technologies. Improved understanding of how international industry associations influenced China's safety improvements in other high-risk technologies could shed light on how it will govern powerful AI systems in the future, especially since industry actors lead development in many emerging technologies.

First, this article contributes to the growing body of scholarship on international private regulation as an essential part of the global governance toolkit.[9] Some of this literature has focused on analyzing the effectiveness of international certification standards at raising quality control, environmental, and safety standards in various domains.[10] While certification clubs illuminate how global governance operates through private organizations in many sectors, this article demonstrates that, in certain industries bound to a shared reputation, the reputation collectives mechanism serves as a more appropriate explanation for how international private regulation raises safety standards in emerging economies.[11] Speaking to broader debates about the effectiveness of transnational business governance initiatives, our findings highlight the significance of an oft-neglected variable: the *fit* between a particular technology domain and the corresponding governance regime.[12]

Second, it demonstrates how international industry associations can effectively raise safety standards, even in countries without the domestic institutions traditionally associated with protecting against technological accidents and contexts where international agreements are weakly enforced. This bears directly on debates over how to manage the safety risks of emerging technologies.[13] Improved understanding of how international industry associations influenced China's safety improvements in other high-risk technologies could shed light on how it will govern powerful AI systems in the future, especially since industry actors lead development in many emerging technologies.

[9] Abbott and Snidal 2013; Prakash and Potoski 2006.
[10] Potoski and Prakash 2006; Prakash and Potoski 2006.
[11] In doing so, it builds on the burgeoning literature on private-public governance interactions in China. Schleifer and Sun 2018; Wang and Yu 2022.
[12] Eberlein et al. 2014; Andonva et al. 2017; Abbott and Snidal 2013.
[13] Ding 2024; Ding 2025.

II. Theory

How can emerging economies achieve higher safety standards in hazardous technologies?[14] There are two sets of standard explanations. First, domestic politics play a clear role. Democratic political institutions foster decentralized mechanisms for risk management that hold the state accountable for accidents, such as independent regulatory authorities. Under the modernization mechanism, as a state gets wealthier, an expanded middle class compels the government to address safety risks by establishing stronger regulatory regimes. This process is captured by the slogan: "first rich, then green and safe."[15]

Another literature base, centered on regulatory development in authoritarian regimes, calls attention to the influence of international actors on elevating safety standards in emerging economies, even those with limited regulatory independence and democratic accountability. According to this body of scholarship, some regulators in authoritarian states exploit pressure from international organizations to push reforms past domestic political opposition.[16] In accounts of China's impressive turnaround in civil aviation safety, the International Civil Aviation Organization, a specialized UN agency, provides this leverage — in the form of binding international standards — for Chinese regulators to push through stringent reforms.[17]

Puzzlingly, in some contexts in which these two factors are absent, states have still been able to achieve gains in technological safety. In civil nuclear power, for instance, China has achieved a stronger safety record without an independent regulator or a strong international regulatory regime.[18] Nuclear safety reviews conducted by the International Atomic Energy Agency (IAEA) are voluntary, and the recommendations that come out of these reviews are non-binding. As the Belfer Center's Matthew Bunn and Olli Heinonen state, "These institutions still leave primarily to each country the decisions about what nuclear safety and security measures to take, with only broad and largely voluntary international standards in place and weak authority for global institutions like the IAEA."[19]

In this article, we theorize that international industry associations present another mechanism whereby emerging market countries reduce the risks of hazardous technologies, which cannot be solely explained by robust democratic institutions or strong intergovernmental regulators. The basis of our argument is that, for industries in which firms share a collective reputation, associations of firms exert positive peer pressure. As they become embedded in social environments that prioritize safety, member firms mimic the best performers, absorb the surrounding norms and

[14] This paper defines emerging economies as middle-income countries characterized by sustained economic growth, rapid industrialization, and growing integration with global trade and investment flows. The IMF identifies 40 emerging economies, including China, Hungary, India, Saudi Arabia, South Africa, etc. Duttagupta and Pazarbasioglu 2021.
[15] Suttmeier 2008.
[16] Eichengreen and Xia 2019; Yasuda 2021.
[17] Yasuda 2021, 133. See also Andrews-Speed 2020; Wright 2022.
[18] Xu 2014.
[19] Bunn and Heinonen 2011.

standards, and respond to scrutiny and criticism for nonconformance.[20] These associations institutionalize peer pressure in a variety of ways, including: exchanges of best practices and lessons learned, performance indicators that incentivize members to benchmark their safety performance against their competitors, and peer review activities in which members assess each other's safety measures.

Departing from the focus on *public* international regulation through intergovernmental organizations and transgovernmental networks, our argument builds on a growing body of literature that highlights the significance of international *private* regulation.[21] To be sure, industry self-regulation can often be ineffective, fragmented, and substitute public relations window-dressing for genuine betterment.[22] However, studies of international private regimes have found that they can play a valuable regulatory role in some settings, such as when backed by the threat of public regulations and in developing countries that lack capacity for traditional regulation.[23]

One important thread of scholarship has shown that international certification standards have helped improve environmental, quality control, and safety standards across various industries such as apparel, coffee, and food.[24] These transnational private regulations work under a "certification club" model. Using language that differentiates club goods from other types of goods, Matthew Potoski and Aseem Prakash posit that certification standards "provide nonrival but potentially *excludable* benefits to members."[25] Crucially, by establishing high barriers to entry (firms must pay tangible costs to join the club and adhere to its standards), these certification clubs deny benefits (positive brand reputation) to non-members.

The International Organization for Standardization (ISO) 14001 certification exemplifies the certification club approach to international private regulation. As the gold standard for environmental management systems, an ISO 14001 certificate provides a seal of approval for a particular firm's environmental practices, incentivizing reluctant firms to join the club.[26] These firms are willing to pay the costs of joining the ISO 14001 club — members open themselves to third-party audits and moderately sized facilities can spend $1 million to comply with the standard — to access positive branding benefits and relieve pressure from civil society groups directed at non-certified firms.[27]

Clearly, the club framework provides a useful explanation for industry-sponsored voluntary programs across a variety of fields; however, is this the only way through which global private regulation produces improved safety regimes in developing countries? This article proposes another

[20] Johnston 2008; King and Lenox 2000.
[21] Büthe and Mattli 2011; Berliner and Prakash 2014.
[22] Abbott and Snidal 2013.
[23] Braithwaite 2006; Büthe 2010.
[24] Büthe and Mattli 2011; Chu 2020; Drezner and Lu 2009.
[25] Potoski and Prakash 2005. Emphasis ours. See also Tsingou 2015.
[26] Prakash and Potoski 2006.
[27] Potoski and Prakash 2005.

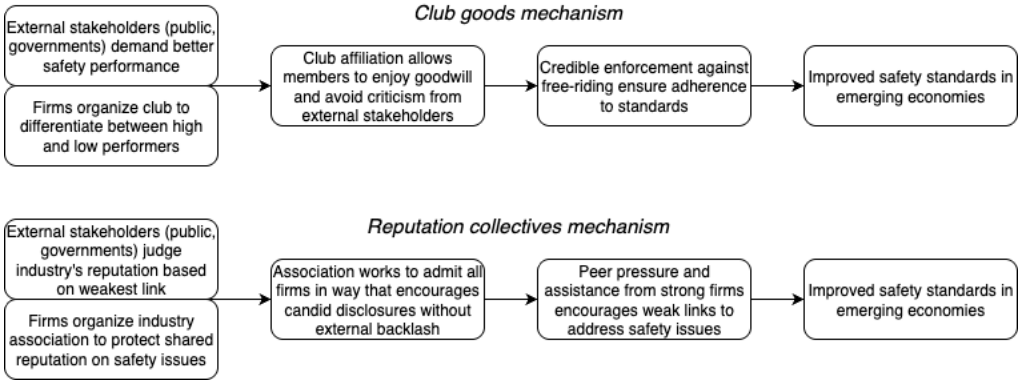
causal mechanism centered on "reputation collectives." For industries in which an accident in one company damages the reputation of all others, industry reputation functions as a common-pool resource that motivates firms to collectively monitor its consumption and discourage misuse (i.e., track and deter any reputation-depleting actions).[28] For example, after the Three Mile Island accident, Bill Lee, president of a major U.S. utility company, spearheaded the creation of the Institute of Nuclear Power Operations (INPO), which is often held up as an exemplary model for industry self-regulation. In a speech after the accident, Lee aptly captured the notion of an industry's collective reputation when he stated that all nuclear power plants were "*hostages of each other*."[29]

Driven to safeguard this shared reputation, different actors and circumstances can influence the mobilization of a reputation collective. Regrettably, as was the case with INPO, some safety-dedicated industry associations emerge in the wake of an accident. A key juncture is when a particular sector's firms understand that external stakeholders such as the public and regulators will not differentiate between the high and low performers when it comes to safety: they face the same sanctions as the weakest link. It is important to note that companies and governments in emerging markets can also play an important role in initiating interactions with international associations. For instance, in the late 1990s, the Chinese aviation authority threatened to prevent all Chinese airlines from purchasing new planes until airline officials adopted more comprehensive safety practices.[30]

Under the reputation collectives model, industry associations advance global safety standards through a process that diverges from certification clubs (Figure 2). First, we theorize that these associations treat industry reputation as a *public good*, not a club good. The key difference is that, for associations managing the "hostages of each other" effect, industry reputation is ***nonexcludable***. Unlike with certification standards, the benefits attached to WANO's efforts to improve the nuclear industry's image cannot be excluded from nonmembers. In the same way, members of WANO are not protected from mishaps involving nonmembers, as all firms in this industry are painted with the same brush. Like WANO, which includes every company that operates a nuclear power plant as a member, reputation collectives aim for universal membership.[31]

[28] Barnett and King 2008, 1152; Ostrom 1990.
[29] Emphasis mine. Cantelon 2016, viii.
[30] Pasztor 2007.
[31] This departs from the club approach: "If membership is universal, the club does little to distinguish environmentally progressive members" (Potoski and Prakash 2005, 236).

Figure 2: Two Mechanisms for International Private Regulation



Second, while the club goods mechanism enables non-governmental organizations, regulators, and customers to differentiate between in-club and out-club firms ("regulation from the outside"), reputation collectives refrain from public naming and shaming ("regulation from the inside").[32] In their study of voluntary environmental programs, Prakash and Potoksi write, "Clubs provide stakeholders with a low-cost tool to differentiate environmentally progressive firms from laggards so that they can shower goodwill on the leaders, and heap scorn and punishment on the laggards."[33] This approach is less effective for reputation collectives because publicized scorn on laggards rebounds to everyone. Instead, industry associations seek to admit laggards and exert peer pressure in a way that protects them from external backlash. For example, in its engagement with Chinese chemical companies, the International Council of Chemical Associations only reports industry-wide averages on safety indicators, instead of firm-specific data.

To flesh out this second set of differences, consider INTERTANKO, an association of independent tankers which formed after the *Torrey Canyon* oil spill in 1967, caused by a supertanker wreck on the coast of the United Kingdom. Facing shared pressures from governments and environmental groups — as exemplified by strict global regulations imposed on all ship owners after the spill — INTERTANKO does not establish strong divisions between in-club and out-club firms.[34] The association monitors and benchmarks the safety performance of the tanker industry, but this information is only available to members — not the public, NGOs, or government actors.[35]

Third, in reputation collectives, weak links heavily shape the industry's shared image, regardless of whether these poor performers are members of the self-regulatory association. Thus, in these settings, firms with leading safety performance should subsidize efforts to raise the standards of lagging firms.[36] This crystallizes another distinction between clubs and reputation collectives.

[32] Gunningham and Sinclair 2017, 142.
[33] Prakash and Potoski 2006, 18.
[34] Swift 2008.
[35] Email communication with Phil Blanshard, external relations manager at INTERTANKO.
[36] Fauchart and Cowan 2013.

Clubs are highly concerned with free-riding; they restrict access to membership benefits unless firms meet particular safety standards. In reputation collectives, however, free riding is self-defeating, as the weak link's poor performance is as damaging to its own reputation as it is to those of other firms.

Euro Chlor, the association of European chlorine producers that aims to limit accidental releases of chlorine, illustrates the differences between clubs and reputation collectives on dealing with free-riders. In 2007, the more active Euro Chlor members sought to prevent less engaged firms (that did not participate in safety meetings or report their incidents) from accessing certain group benefits such as best practices manuals. As two management scholars write, this action to remove free riders meant that "information needed to enhance private reputations was made a *club good*, and this move could have created, in effect, two groups in the eyes of the stakeholders."[37] In short order, however, chlorine producers realized that "the biggest threat to their assets was not that the smaller firms could access their collective efforts to produce codes of conduct and guidelines 'for free,' but rather that the weakest firms were not making progress."[38] In other words, Euro Chlor recognized that it was a reputation collective. Reversing course, Euro Chlor turned its efforts toward helping weak links address their safety issues by facilitating plant visits from high-performing firms.

This article focuses on reputation collectives and certification clubs, but it should be made clear that there is a broader universe of transnational private governance mechanisms beyond the two discussed in this paper. Transnational public-private governance initiatives, such as the Roundtable on Sustainable Palm Oil or the Alliance for Responsible Mining, involve agenda-setting, capacity-building, and policy implementation functions that do not fit neatly into this article's two mechanisms.[39] Furthermore, in many contexts, the distinction between reputation collectives and certification clubs is not as crisp as the examples above. The same initiative or organization may adopt a mix of governance functions linked to both mechanisms.[40] As the case evidence details, the International Air Transport Association mostly operates as a reputation collective; however, it did restrict membership benefits to some airlines that did not complete safety audits, which is in line with the expected behavior of certification clubs.[41]

Our theory's scope is limited to associations that govern industries with shared safety reputations. Among the 458 international industry associations in operation, many do not take on regulatory functions, concentrating their efforts instead on lobbying for particular policies (e.g., the Computer & Communications Industry Association's advocacy on copyright and content moderation issues).[42] Other associations do set quality and safety standards, such as the Global

[37] Fauchart and Cowan 2014, 535. Emphasis ours.
[38] Fauchart and Cowan 2014, 535.
[39] Eberlein et al. 2014; Westerwinter 2021.
[40] We are grateful to an anonymous reviewer for insights on this point.
[41] Still, as Table 2 emphasizes, the two mechanisms produce competing observable implications, which are traced in the empirical analysis. In the case of the International Air Transport Association, while it excluded some free riders, it ultimately invested helped laggards regain their membership.
[42] Ronit 2022, 64.

Cashew Council, but these operate more like certification clubs. To better specify the range of industries to which our argument applies, we tabulated ten high-risk technological domains in which an accident at one firm damages the overall industry's safety reputation. For each of these industries, we then identified a candidate reputation collective (Table 1).[43]

The industries that fall within our argument's scope meet two conditions. First, they are high-risk: the catastrophic effects of accidents mean that firms must fiercely guard their perceived safety reputations. Second, a firm's safety reputation is interdependent with other firms in the same industry. On the first condition, we cross-referenced Perrow's *Normal Accidents*, which studied high-risk technologies across a diverse set of industries, with a UN working group report that identified technological hazards that posed global risks. As for the second condition, in some of these domains, such as aviation, chemical, and nuclear power, there is empirical consensus that a serious accident affects all firms in the industry.[44] In other domains, the presence of spillover effects is disputed. For instance, researchers have found that the Deepwater Horizon accident's negative impact on BP's stock market performance did not spill over to other oil and gas firms.[45] We still included offshore oil drilling in our list because there is substantial evidence that oil and gas firms perceive accidents like Deepwater Horizon as an industry-wide threat.[46]

[43] To be clear, as demonstrated by studies of private rule-making activities in international regime complexes, it is possible that some sectors will have many complementary or competing private initiatives. Green and Auld 2017; Eberlein et al. 2014. For one analysis of around 40 transnational governance initiatives in the mining sector, see Auld, Betsill, and VanDeveer 2018.
[44] Barnett 2007.
[45] McGuire et al. 2022.
[46] For details on how we picked out these ten industries, see Supplementary Appendix B. We are grateful to Aseem Prakash for feedback on this section.

Table 1: Scope Conditions (Technological Domains)	
Domains	**Reputation collective candidate**
Chemical plants	International Council of Chemical Associations (Responsible Care initiative)
Many chemical sub-industries	World Chlorine Council
Maritime transport systems	INTERTANKO
Space ventures (launch service suppliers, spaceflight companies, satellite operators, etc.)	The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)
Nuclear power plants	World Association of Nuclear Operators
Biotechnology labs	Biotechnology Innovation Organization
Aviation systems	International Air Transport Association
Underground mining	International Council of Mining and Metals
Offshore oil drilling	American Petroleum Institute's Center for Offshore Safety
Artificial intelligence models (potential)	Frontier Model Forum

III. Research Method

To evaluate our explanation for how international industry associations help advance safety improvements in emerging economies, we investigate developments in China's nuclear, aviation, and chemical industries. In all three cases, a global industry association incorporated Chinese firms into voluntary safety programs, and China experienced a significant reduction in the rate of dangerous incidents. The starting year of each case corresponds to the initial engagement between the relevant international industry association and Chinese firms. The ending year aligns with the substantiation of significant safety gains. These cases provide fertile ground for differentiating between the certification club and reputation collective mechanisms, as the *cause* (the emergence of a global private regime that regulates safety) and *outcome* (improvement in technological safety) are both present, which is in line with guidance on process-tracing.[47] While other high-risk technological domains also warrant in-depth analysis, there is empirical consensus that, in these three industries, one firm's accident damages the safety reputation of all other firms.[48]

[47] Beach and Pederson 2013.
[48] Barnett 2007.

Moreover, our focus on China allows for a difficult and useful test for the reputation collective mechanism. Mobilization to protect shared industry reputations is more challenging when firms face significant differences in geography, interests, and culture[49]; all selected cases involve engagements between Chinese firms under party-state capitalism and three international industry associations based in Western democracies with free market economies. Regarding the generalizability of our findings, it is important to not overstate the difficulty of these cases. Based on the transnational environmental governance literature, some conditions might lead Chinese companies to be more receptive to these initiatives than firms in other emerging economies. These factors include pressure from foreign multinationals and the Chinese government's commitment to sustainable development.[50] All things considered, the key test is less about receptiveness to international private regulation in general and more about the differences between two mechanisms of international private regulation.[51]

In each case, we evaluate whether the evidence matches three observable implications predicted by each of the two mechanisms (Table 2). If the reputation collective mechanism is active, in each association's interaction with Chinese firms, it should manage industry reputation as a public good, recognizing that benefits and harms are not excludable to nonmembers. In addition, the association should engage Chinese firms with internal benchmarking, as opposed to a public name-and-shame approach that clearly differentiates between members and non-members. Lastly, if the impact of international private regulation on Chinese firms' safety practices materializes through the certification club pathway, associations should address free-riding by restricting benefits when firms do not meet requirements. By comparison, reputation collectives keep laggard firms in the fold, with high-performers supporting weak links.

Table 2: Two Mechanisms of Global Private Regulation

Mechanisms	*Excludability of reputation*	*Form of peer pressure*	*Approach to weak links and free-riders*
Certification Club	Treats industry reputation as club good	External naming-and-shaming	Restricts access to membership benefits
Reputation Collective	Treats industry reputation as public good	Internal benchmarking	Help laggard firms improve performance

[49] Barnett 2007.
[50] Andonova, Hale, and Roger 2017; Schleifer and Sun 2018.
[51] The programs highlighted in the relevant literature — most notably, China's adoption of ISO 14001 — largely operate in the certification club mold, not as reputation collectives.

The following cases draw on a diverse range of materials, including expert interviews, Chinese-language sources, and quantitative data. We interviewed experts and former officials knowledgeable about the efforts to integrate Chinese firms into industry-led safety initiatives in the nuclear, aviation, and chemical domains.[52] Unfortunately, we were unable to speak with Chinese practitioners based in these industries, which weakens our ability to trace changes in firm leaders' beliefs. In the case studies, we acknowledge this limitation and detail our efforts to overcome it.

To reconstruct interactions between global industry associations and Chinese firms, we also relied on underutilized Chinese sources, including annual reports from domestic industry associations such as the China Petroleum and Chemical Industry Federation, trade journals such as *China Civil Aviation Report*, and leading safety science publications such as the *China Safety Science Journal*. In the nuclear case, we analyzed 263 international engagements between 2008 and 2022, as recorded in the China Nuclear Energy Yearbook. This was supplemented by 157 reports on WANO's engagements in China from a Chinese Atomic Energy Authority database of more than 7,000 news articles published between 2001 and 2024.

IV. Empirics

Nuclear Case (1987-2016)

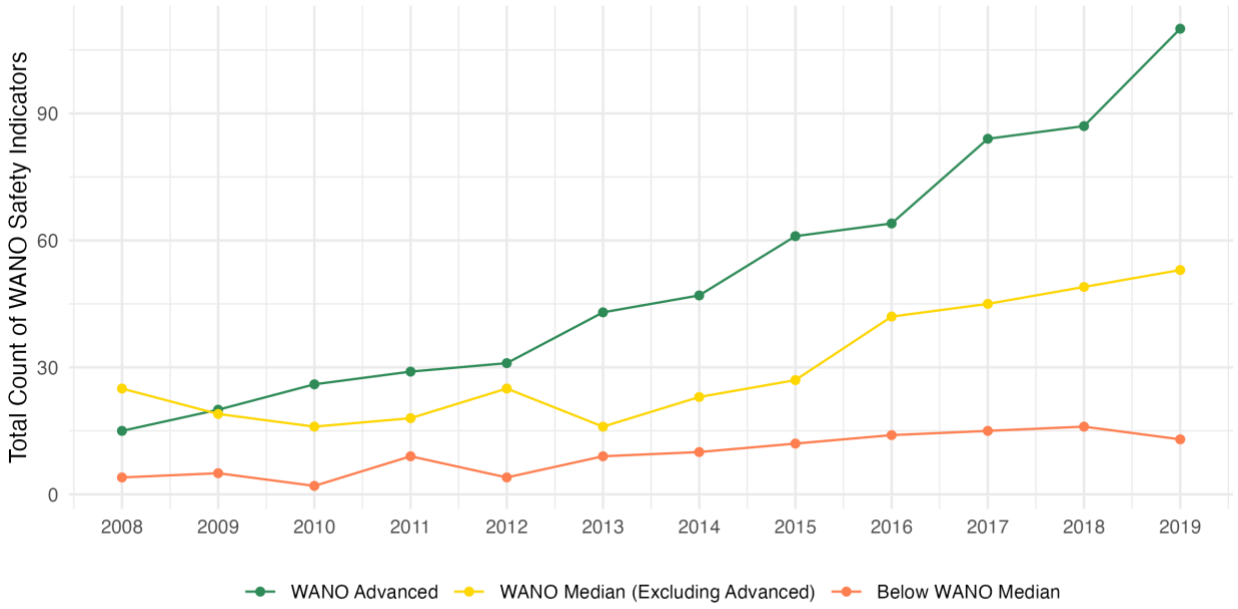
Since construction began on its first nuclear reactor in 1985, China has achieved impressive results in nuclear safety. As of the end of 2020, Chinese nuclear power plants have operated safely and stably for a total of 407 reactor-years, without experiencing any nuclear accidents that exceeded Level 2 on the globally accepted International Nuclear Event Scale (INES).[53] In a comprehensive review of China's regulatory framework for nuclear safety in 2016, the IAEA concluded, "[T]he Chinese government has brought its nuclear and radiation safety regulation up to a new level."[54] Andrew Kadak, a MIT Professor of Practice in Nuclear Engineering who has served on safety oversight boards at Chinese nuclear power plants, states, "The safety performance of the Chinese reactors has been quite good, with no known abnormal releases of radioactivity or events that have threatened the safety of the reactor core."[55]

This is not to say that China's nuclear safety record is spotless. One issue is the extent to which Chinese government reports on nuclear incidents can be trusted.[56] The largest database on nuclear incidents and accidents does not cover Chinese operators because Chinese authorities limit

[52] This study was declared exempt by the George Washington University Institutional Review Board, under IRB# NCR245704.
[53] Countries that have experienced more than two accidents above INES 2 include France, Japan, and the United States. Chong 2013.
[54] IAEA 2016.
[55] Kadak 2006.
[56] Meralli 2009.

public disclosure of operational mishaps.[57] Additionally, corruption cases have called into question the extent to which nuclear executives prioritize safety. Going forward, informed observers, including the former director of the National Nuclear Safety Administration, have expressed serious concerns about China's ability to maintain operational safety amidst its aggressive expansion of nuclear power plant construction.[58]

Figure 3: WANO Safety Indicators in China (2008 Reference)



Note: Y-axis indicates the count of WANO indicators in China above WANO Advanced (75th percentile), above WANO Median (50th percentile), or below WANO Median. To maintain temporal consistency, the 2008 WANO Advanved and Median values serve as a fixed reference for all years shown. Source: China Nuclear Energy Yearbook 2009-2020.

Nevertheless, WANO performance indicators bear out China's significant improvements in nuclear safety over time. Regarded by experts as carefully chosen and reliable, these metrics track unplanned scrams, leaks and radiation exposures, incident rates, and other factors that correlate with nuclear safety.[59] As relayed in the introduction, of the safety performance markers reported by Chinese nuclear power plants, the proportion that exceed the WANO Advanced standard (75th percentile) has nearly doubled since 2008.[60] As additional Chinese nuclear plant units became operational, the count of indicators that fall below the WANO Median (50th percentile) has slightly increased. Overall, as Figure 3 depicts, the large and growing majority of safety performance indicators land above either the median or advanced level, which shows that operators have made progress in nuclear safety relative to their international peers.

[57] Ayoub et al. 2021.
[58] Reuters 2009; Yi-chong 2010.
[59] Interview with nuclear energy historian Phil Cantelon, phone, 10/10/23; email communication with Ali Ayoub, 7/25/2024.
[60] WANO 2019. A floating standard version of Figure 3 is available in Appendix Figure A3 and yields similar results.

How did China realize these substantial nuclear safety gains? We argue that international private regulation, facilitated through WANO as a reputation collective, played a critical role in aiding Chinese nuclear operators achieve higher safety standards. Jolted into action after the Chernobyl tragedy, 144 nuclear operators established WANO in 1989 to prevent future accidents. Since its founding, WANO has enjoyed universal membership, which means that every nuclear power plant operator participates in the international industry association. To raise the bar on nuclear safety, WANO supports information exchanges on best practices and incident notifications, safety indicators, and peer review plant evaluations.[61]

Since its inception, WANO has worked with Chinese operators to improve nuclear safety. In 1987, two years after China started building its first nuclear power plant, Chinese operators were invited to the initial WANO meeting that led to the formation of the organization.[62] Both of China's major state-owned nuclear operators, the China National Nuclear Corporation (CNNC) and the China General Nuclear Power Corporation (CGN) became WANO members before the start of their commercial operations in 1994.[63]

WANO's outreach and engagement with Chinese operators ingrained its model of peer pressure and industry self-regulation within the Chinese nuclear industry. The heads of Chinese nuclear operators have repeatedly emphasized their prioritization of WANO standards.[64] Although the IAEA and Chinese state regulators also assess Chinese operators , WANO's reviews are deeper and more extensive. To begin, WANO facilitates the vast majority of reviews. From 2016 to 2018, Chinese nuclear power plants received 29 WANO peer review activities, compared to 3 IAEA review missions.[65] WANO peer reviews also probe technical details that IAEA-facilitated peer reviews do not cover. Trevor Findlay, an expert on nuclear governance in the Asia-Pacific region who regularly participates in global exchanges on nuclear safety, comments on the IAEA's process, "These peer reviews don't get anywhere close to the technology."[66]

Non-excludable vs. excludable reputation

In its engagement with Chinese firms, did WANO treat industry reputation as a non-excludable or excludable good? WANO was founded on the principle that all nuclear firms were hostages of each other. At a speech in Beijing in 2015, Joel Bohlmann, Deputy Director of WANO London Center, reiterated the industry's shared safety reputation, "When a nuclear accident occurs, the public tends to perceive it as a failure of nuclear technology rather than a failure of a specific operator or country."[67]

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[61] Cantelon 2016, p.185.
[62] Eckered 1987.
[63] IAEA 1997.
[64] Gu 2004; Tan 2005.
[65] Authors' analysis of China's National Reports for the Convention on Nuclear Safety.
[66] Interview with Trevor Findlay, Zoom, 12/25/23.
[67] CNEA 2016, 388.

In 2011, the Fukushima accident provided a grave reminder that one firm's reputation is coupled to the entire nuclear industry. WANO established a Post-Fukushima Commission of senior utility executives from 12 countries, including Ligang Gao from the China Guangdong Nuclear Power Group (CGNPG).[68] At the next biennial meeting general meeting in October 2011, held in Shenzhen, China, WANO members adopted the commission's recommendations to strengthen their safety commitments, including an increase in the frequencies of peer reviews and a requirement for pre-startup reviews at each new plant.[69]

Internal benchmarking vs. public naming and shaming

Besides the establishment of shared reputation, another key component of reputation collectives is the capacity of industry associations to internally generate peer pressure while safeguarding the industry from external backlash. Adopting the system developed by INPO, the U.S. domestic association, WANO grades each plant based on its safety performance, from category one (the best rating) to five (the worst).[70] At its Biennial General Meeting, WANO distributes the grades to all the CEOs in a closed session.[71] If this process resembles INPO's, it is a "remarkable ritual" of governance by embarrassment.[72] One CEO recalls:

> "All the CEOs are gathered in a big room with Zack Pate [INPO's then-President], and he flashes up the most recent evaluation numbers for each of the utilities by name. That's the only time we learn how our peers are ranked, and it kind of hits you right between the eyeballs. The first slide has all the number ones, the best-rated utilities. Then come the number twos…and then you get down to the fours and the fives. And after some pretty frank discussions of their problems, those guys are feeling rather uneasy to say the least."[73]

Notably, this candid feedback is kept in-house. Recounting her experience at INPO meetings, a former chair of the U.S. Nuclear Regulatory Commission said that she would attend the celebratory dinner to honor the best performers but was never invited to the next morning's "name-and-shame" breakfast.[74]

Discretion, not complete transparency, is critical to WANO's governance regime. Each member of WANO signs a formal confidentiality agreement, which safeguards information shared among members and describes protections for peer review results, assessment ratings, and other documents.[75] As one Union of Concerned Scientist report states, "WANO is not accountable to

[68] Felgate 2012.
[69] Cantelon 2016, 199-202.
[70] Prozesky 2020.
[71] Cantelon 2016, One WANO chapter.
[72] Rees 1994, 104.
[73] Quoted in Rees 1994, 104-105.
[74] Interview with Allison Macfarlane, Zoom, 4/5/24.
[75] WANO 2024.

governments or the public, and it performs the bulk of its work out of public view."[76] After the Fukushima accident, WANO governing boards contemplated shifting toward the IAEA's approach of making peer review reports open to the public. Ultimately, WANO decided that "it could be transparent about why and how it works, but not about what it finds."[77] It appears that China's nuclear industry association has also grappled with this balance between transparency and confidentiality. In 2012, the China Nuclear Energy Association (CNEA) published a global ranking of Chinese plants in terms of WANO indicators; the following year, it removed the rankings and has not disclosed them since.

To be fair to the certification club framework, some of the Chinese nuclear industry's reports that contain WANO benchmarks could be used to expose industry laggards to public scrutiny. Compared to their counterparts in most countries, CNEA provides slightly more transparency on safety performance through its China Nuclear Energy Yearbook. In addition to the actual scores, the yearbook also publishes the number of indicators for each plant that sit above or below the WANO median level.[78] Two caveats apply. First, as the above sections demonstrate, the yearbook figures provide a broad sense of where Chinese companies stand but they do not give specific rankings. Second, it is likely that CNEA feels more comfortable sharing these safety indicators because Chinese nongovernmental organizations have limited capacity to name and shame companies in strategic sectors.[79]

Assistance to weak links vs. exclusion of free riders

WANO committed to assisting Chinese safety laggards, including firms that hesitated to embrace its practices. For instance, CNNC's Qinshan plant, which did not adhere to WANO standards, experienced a safety incident in 1998, in which plant engineers discovered extensive wear on the reactor vessel's internal surface and damage to several fuel rods.[80] Instead of shunning Qinshan, WANO worked with management to develop a Five-Year Plan for the plant to reach safety indicators at the WANO Median level by the end of 2005.[81]

The pre-startup review process supplies additional evidence of how WANO enabled leading firms to provide safety assistance to firms that did not have any operational experience. Todd Brumfield was part of the WANO team that established a Hong Kong office to manage pre-startup reviews of new nuclear plants in China. On one visit to a plant in Ningde, which was preparing to begin commercial operation, he brought an international team of experienced managers from Britain and South Africa. When he asked for the plant's backup plan in case the computer monitors malfunctioned, the Chinese team pointed to a remote shutdown panel. After Brumfield inquired about the procedures to manage the panel, he recalls that it took the operators 30 minutes to find

[76] Gronlund et al. 2007.
[77] WNN 2017.
[78] See Appendix Table A3 in supplementary appendix.
[79] Utting 2003.
[80] NRC 2001, p. 4-5.
[81] CAEA 2006.

the relevant materials ("and wipe the dust off").[82] These types of engagements in the pre-startup review process helped inexperienced Chinese firms develop better safety culture and practices.

This commitment to assisting weak links was tested after the Fukushima accident, which placed pressure on WANO to ostracize problematic plants that did not comply fully with WANO standards. In essence, if it followed this route, WANO would have converted into a certification club. Instead, in an interview with *Nature* later that year, WANO Managing Director George Felgate reiterated the organization's reluctance to abandon safety laggards. "I cannot imagine it ever coming to the point where we would expel a member from WANO. Peer pressure is a very powerful tool in our industry," he stated.[83]

Alternative factors

It is worth reiterating that China's nuclear safety progress occurred in the absence of a powerful intergovernmental organization that imposed binding standards or publicly named and shamed weak performers. The IAEA's Convention on Nuclear Safety, the closest instrument to a legally binding treaty in this domain, does not mandate compliance with IAEA safety standards. According to one expert, "in an ideal and logical world" of nuclear governance in the Asia-Pacific region, a single body would "issue binding nuclear safety and security standards" and "work to increase transparency and public awareness."[84] Indeed, the developments described in this case diverge from the expectations of scholars about how international institutions could raise safety standards in nuclear power producing countries.

China's improvements in nuclear safety cannot be solely attributed to domestic institutions or top-down directives. In many instances, intensive collaboration between WANO and Chinese firms preceded and informed the development of domestic institutions and policies on nuclear safety. For instance, in 2002, China's Commission for Science, Technology and Industry for National Defense established an Operational Assessment Committee (OAC) for nuclear power plants,[85] which mandated that each nuclear plant should undergo an external peer review every 2 to 3 years through either the OAC, WANO, or the IAEA.[86] Shortly after Qinshan Phase II entered into commercial operation in 2002, the OAC conducted its first peer review at the plant, which was followed by a WANO peer review in 2003 and a WANO follow-up visit two years later.[87] At other times, Chinese regulators have struggled to develop comprehensive nuclear safety rules. Beijing did not issue the country's Nuclear Safety Law until 2017, when 37 nuclear power units were already in operation and seven years after the IAEA identified it as a top priority.[88]

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[82] Interview with Todd Brumfield, Zoom, 7/31/24.
[83] Butler 2011.
[84] Findlay 2010.
[85] NNSA 2004.
[86] Ding 2005.
[87] Gu 2005.
[88] CNEA 2018, 104; IAEA 2010, 8.

In sum, the development of self-regulation through the promotion of industry-led safety standards and peer reviews has been a key factor in China's nuclear safety progress. Crucially, however, engagements with WANO did not enhance the safety performance of Chinese operators through the certification club mechanism, which provides *excludable* benefits by differentiating the performance of members from non-members. Instead, WANO exposed Chinese operators to the type of peer pressure that forms in industries in which safety reputation is *non-excludable* from weak performers. This influence channel is characterized by three distinctive features of WANO's engagements: shared reputation, backlash protection, and laggard assistance.

Civil Aviation Case (1990-2008)

Over the past fifteen years, by some metrics, it has been safer to fly on Chinese planes than aircraft in some of the safest aviation systems in the world, including that of the United States. From 2008 to 2021, China's accident rate (per million departures) of large commercial aircraft was lower than the U.S.'s rate. Before the crash of a China Eastern Airlines flight in 2022, Chinese carriers had avoided a major incident for 100 million consecutive flight hours, a stretch of twelve years.[89]

China's current air safety record represents a substantial improvement from the 1990s and early 2000s when fatal disasters were an all-too-common occurrence. Using data on over 6,000 incidents in China's civil aviation industry, two researchers at the Civil Aviation University of China found that the incident rate declined from 183.3 incidents per million flight hours in 1994 to 28.4 incidents per million flight hours in 2008 — a mark that has held relatively steady since.[90] Over the 2008-2017 period, China's safety performance placed it among the lowest-risk group of aviation nations alongside the U.S. and Western European countries, based on probabilistic models of air traveler mortality risk developed by MIT Professor of Statistics Arnold Barnett.[91]

Founded in 1945, the International Air Transport Association (IATA) is the primary industry association for the world's airlines. In addition to advocacy on behalf of the industry, IATA also promotes global safety standards and recommended practices by managing operational audits, sharing data on incidents and risks, and conducting safety management training. Since it was founded with 57 member airlines from 31 countries, IATA has expanded to 320 member airlines from 120 countries around the world.

Broadly speaking, the history of IATA-China engagement tracks well with the expected operations of a reputation collective. China's shaky air safety record in the early 1990s prompted the IATA to work with the Civil Aviation Administration of China (CAAC) and provide technical assistance to China's aviation industry.[92] China's famed "Big Three" airlines — Air China, China

[89] Lau 2022.
[90] He and Sun 2023.
[91] Barnett 2020. See Appendix Figure A3 for more data on China's declining aviation accident rate.
[92] Shughuart 1998, 13.

Eastern, and China Southern — became IATA members in 1993, with three regional airlines joining shortly after.[93]

In the late 1990s and early 2000s, faced with a climbing global accident rate and the September 11th attacks, IATA took aggressive steps to combat the public perception that flying was unsafe.[94] To safeguard the entire industry's reputation, in 2001, IATA initiated the Internal Operational Safety Audit (IOSA) program, which aimed to establish a globally accepted safety evaluation system for airlines. Later that year, it also established a safety trend evaluation and data exchange system (STEADES), a voluntary initiative to share safety incident data. In the following years, IATA presented the IOSA program at a "Regulatory Authority awareness session" with CAAC; in 2005, eight Chinese airlines underwent IOSA audits, and four more Chinese airlines had contracts in place to complete IOSA audits in the following year.[95] IATA also sought to expand the global coverage of STEADES. By 2011, six Chinese airlines had joined the information exchange.[96]

These IATA initiatives encouraged Chinese airlines to adopt safety requirements that were more stringent than those set by the International Civil Aviation Organization (ICAO), the United Nations agency that manages civil aviation safety. According to *The Wall Street Journal*, after a crash in 2004, CAAC and IATA "worked out a separate cooperation pact." The report relates, "China became a pioneer in allowing IATA specialists to audit all airlines and in due course release their findings."[97] This embrace of IOSA audits indicates that Chinese airlines had adopted recommended practices that exceeded the baseline set by ICAO standards.[98] William Voss, who was the director of ICAO's Air Navigation Bureau at the time, recalls:

> "China became an early adopter of IOSA... It made a very significant effect because it was in some ways a more robust protocol than regulators could use. It's difficult to pass detailed regulations, and the protocols they could use in IOSA were derived from ICAO international standards but they could get far more granular in operational implementation."[99]

Shared reputation: Reputation collectives vs certification clubs

Evidence from this case also illuminates finer-grained distinctions between reputation collectives and certification clubs. First, IATA's outreach to Chinese firms demonstrated its recognition that the global aviation industry's reputation was non-excludable. Andy Pasztor, who reported on all major commercial aircraft crashes around the world for over two decades, detailed the CAAC-IATA cooperation agreement. On the motivating factors, Pasztor comments:

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[93] Reynolds 1995.
[94] Mills 2016, 52.
[95] IATA 2006; O'Brien 2004.
[96] Authors' data on STEADES members list (as of 2011) available upon request.
[97] Pasztor 2007.
[98] Mills 2016; Sabec 2004.
[99] Interview with William Voss, Washington DC, 5/21/24.

> "The notion of a shared reputation was the genesis of the whole effort. Boeing and Airbus were not just looking at crashes in the U.S., they were looking at countries in the developing world — China, most obviously. They realized that a crash anywhere would result in a tremendous reputational fallout, from the perspective of the general public everywhere, regardless of what the airline was where the crash took place."[100]

The IATA's management of the IOSA program provides additional evidence of the non-excludability of this industry association's safety benefits. In 2005, IATA made the audit program's standards and recommended practices freely available to non-members.[101] At an ICAO conference in March 2006, reporting on how the IOSA could contribute to a global strategy for aviation safety, IATA highlighted that the program was open to everyone, "It is important to note also that over 20 per cent of the IOSA audits being conducted are done on non-Members of IATA. This clearly demonstrates that IOSA is a programme for all airlines."[102] The proportion of non-IATA members that take advantage of the IOSA continues to be significant. In 2014, about 35 percent of airlines that had recently completed this audit were non-members.[103]

Internal benchmarking vs. public naming and shaming

If the certification club mechanism was operative in this case, IATA membership should function as a tool for the general public and community organizations to applaud leaders and condemn laggards. There is some evidence of public name-and-shame tactics. For instance, the website airlineratings.com incorporates whether airlines have passed the IOSA audit into its airline safety rankings. However, these ratings have limited influence and have been criticized for making "empirically dubious assumptions."[104] On the whole, IATA members do not advertise that they are safer than non-members. In fact, one report found that safety has "all but disappeared" from modern airline advertisements, in part because the "S-word" causes passengers to worry about the unpredictability of the overall commercial aviation industry.[105]

The development of STEADES provides further evidence of a reputation collective that seeks to protect laggards from external backlash. After the launch of STEADES in 2001, the CAAC and the Civil Aviation University in Tianjin worked closely with IATA to share incident reports that allow air carriers to benchmark their performance against their peers.[106] Contrary to the expectations of the certification clubs mechanism, IATA restricts access to STEADES data to safety regulators and air carriers out of "fear of misinterpretation by the media and the public."[107] Moreover, to

[100] Interview with Andy Pasztor, phone, 4/16/24.
[101] Mills 2016.
[102] IATA 2006.
[103] IATA 2015.
[104] Barnett 2020.
[105] Linshi 2015.
[106] vsundhara 2009.
[107] Mills 2010.

ensure confidentiality, STEADES data is de-identified to foster a candid reporting culture.[108] Likewise, IATA does not make IOSA audit reports available to the general public, as contents are only released to airlines or regulators with the audited airline's agreement.[109]

Assistance to weak links vs. exclusion of free riders

Did IATA approach weak links like a certification club or a reputation collective? IATA's decision to make IOSA a requirement for membership serves as a good test for these mechanisms. In 2006, IATA demanded that all members conduct an IOSA audit by the end of 2007, which ultimately resulted in 21 firms leaving the association between 2006 and 2008. On the one hand, this development appears to substantiate a certification club's expected behavior toward weak links: restrict access to membership benefits when safety laggards do not meet requirements. IATA expelled airlines that did not begin the IOSA process (such as Albanian Airways) or failed to resolve audit findings (Rwandair Express).[110]

On the other hand, even as it enforced this membership requirement, IATA proactively assisted airlines with limited resources to meet IOSA standards. Supported by matching funds from industry leaders Boeing and Pratt & Whitney, IATA's Partnership for Safety initiative distributed $3 million between 2005 and 2007 toward awareness seminars on operational safety best practices as well as trial audits to pinpoint areas of improvement for individual airlines.[111] One of these week-long seminars was held in Beijing in 2007; IATA's North Asia regional team also organized many seminars and trainings to help Chinese airlines and the CAAC address gaps in their safety management systems.[112] All Chinese airlines completed IOSA audits and retained their IATA membership.

In fact, as further evidence of a reputation collective dedicated to helping weak links, a substantial number of the ousted firms eventually regained their IATA membership. We traced developments in all 21 firms after they lost IATA membership.[113] Nine airlines ceased operations around this time due to financial difficulties that were unrelated to IOSA issues. Of the 12 that continued to operate, seven airlines rejoined IATA (the remaining five without an IOSA audit own very small fleets).

Alternative factors

This case study's main objective is to uncover the particular pathways by which international private regulation contributed to China's progress in aviation safety, not to provide an all-encompassing account of the outcome. Tracing these mechanisms helps uncover the influence of

[108] Mills 2010.
[109] IATA 2006.
[110] Schofield 2009.
[111] Hounsell 2008.
[112] China Civil Aviation Report 2012; IATA 2006).
[113] For a table that specifies outcomes for all 21 firms, see supplementary appendix.

international aviation standards developed by private organizations and technical assistance from international industry associations.[114] It is also important to acknowledge that China's advances in aviation safety were a product of many other interrelated drivers, including reforms that strengthened CAAC's regulatory authority over aviation safety, binding international agreements, the technical upgrading of China's aircraft fleet, and the leadership of Yang Yuanyuan as CAAC director from 2002 to 2007.[115]

Still, in many of these alternative explanations, international private regulation plays an essential role, which makes it important to differentiate between the specific mechanisms at work. In John Yasuda's account of how strengthened regulatory control reduced China's aviation accident rate, key CAAC interventions relied on the assistance of international airlines and organizations.[116] To be sure, the main public regulatory agency in this space (ICAO) encouraged safety regulators to adopt IATA programs such as IOSA.[117] Nonetheless, it was IATA that established and implemented these audit and reporting programs, as ICAO lacked the capacity to do so on its own.[118]

Chemical Case (2002-2021)

Over the past two decades, China has made modest progress in reducing the number of accidents in its chemical sector. Analyzing chemical accident data for the 2004-2019 period, researchers at TU Delft's safety and security science group found a consistent decrease in the number of accidents in China's chemical industry.[119] According to another study, hazardous chemical accidents in China declined by over 50 percent from 2015 to 2019.[120] In a 2019 feature, *Chemistry World,* the flagship magazine of the Royal Society of Chemistry*,* aptly captured the trend with the headline: "China makes slow progress on safety."[121]

It is important to not overstate these safety improvements in China's chemical industry. In December 2014, working with the United Nations Institute for Training and Research, Chinese experts based at Peking University and other institutions published a national profile of China's chemicals management system. Citing frequent occurrences of incidents, they assessed China's level of safety capacity with hazardous chemicals as "low."[122] Even as the frequency of accidents has declined, fatalities have only slightly declined from 2011 to 2018. China has seen two major chemical accidents in the past decade: a warehouse explosion in Tianjin in 2015, which killed over 170 people; and a 2019 accident at the Tianjiayi plant in Xiangshui county, which resulted in at least 78 deaths.[123]

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[114] Keck 2000; Yasuda 2021.
[115] Yasuda 2024; Suttmeier 2008; Pasztor 2007.
[116] Yasuda 2024.
[117] Ronit 2018, 78.
[118] Mills 2016; Eilstrup-Sangiovanni 2022.
[119] Chen and Reniers 2020.
[120] Zhou et al. 2022.
[121] Naidu 2019.
[122] Liu 2014.
[123] Kan 2019.

In 1989, chemical industry leaders formed the International Council of Chemical Associations (ICCA) to steward the Responsible Care (RC) program, a voluntary initiative that encourages chemical companies to revamp safety and sustainability practices, at the global level. At a UN international conference on chemicals management in 2006, ICCA launched a RC Global Charter, which committed signatories to share best practices and report safety performance measures. As of October 2021, this charter has been signed by more than 580 chemical firms, which comprise 96 percent of the world's largest chemical companies.[124]

The diffusion of RC practices to Chinese companies was gradual. In the early years, ICCA primarily relied on the Association of International Chemical Manufacturers (AICM), an industry group founded in Hong Kong in 1988 that represented Dow, Cabot, and other major multinational companies with facilities in China. However, the China Petroleum and Chemical Industry Federation (CPCIF) represented the overwhelming majority of Chinese companies. In April 2002, the two associations signed an agreement to cooperate on RC capacity-building and training programs.[125] After years of sparse activity, ICCA granted CPCIF observer status in 2011, and CPCIF eventually joined the RC leadership group in 2014.

Shared reputation: Reputation collectives vs certification clubs

ICCA's engagement with Chinese companies intensified alongside concerns that China's fast-growing chemical industry — which became the world's largest in 2011 — would outpace safety protections. ICCA confronted the necessity of "greater international acceptance of Responsible Care" because, as Professor Aseem Prakash articulates, "chemical accidents…outside the United States can strengthen public misgivings about the safety of industry's operations."[126] As one consultant for multinational firms operating in Asia stated, "For multinational companies such as Dow and DuPont, the ramifications of an accidental chemical spill because of poor handling or underdeveloped infrastructure can be disastrous. The negative publicity can negatively affect these companies' future plans *as well as other foreign companies looking to expand its* [sic] *business into China*."[127] In 2011, three of the 17 global capacity building projects funded by the RC leadership group were based in China and Hong Kong.[128] This reflected that China, alongside India, had become one of the "priority ICCA targets."[129]

Because it recognized that the entire industry shares reputational gains and losses, ICCA strove to incorporate all chemical firms in the RC program rather than maintain barriers around an exclusive group of high performers. When it comes to enforcing the excludability of RC membership benefits by clearly differentiating in-group firms from out-group firms, ICCA cannot

[124] RCLG 2021.
[125] RCLG 2012. CPCIF 2022.
[126] Prakash 2000, 202.
[127] Oey 1998. Emphasis ours.
[128] RCLG 2012.
[129] RCLG 2018.

operate like a certification club. In fact, the origins of the RC initiative, launched by the Canadian Chemical Producers' Association, date back to an accident that threatened the reputation of all chemical firms: the 1984 Bhopal disaster at the Union Carbide plant in India, which resulted in the deaths of thousands.[130]

Internal benchmarking vs. public naming and shaming

ICCA-China engagement also aligns with the expectations of the reputation collectives mechanism about name-and-shame tactics. In its annual RC status updates, CPCIF reports on industry averages of key performance indicators such as process safety event rates and injury rates per million man-hours, but it does not provide firm-specific data. Based on these reports, external stakeholders, such as the general public and advocacy organizations, cannot single out individual Chinese firms as poor performers.[131] This limited transparency is consistent with data sharing practices across the global RC regime, under which the ICCA collects data from national associations in aggregate form.[132]

There are some aspects of this case that point to the certification club mechanism at work. In November 2021, adhering to ICCA guidelines, CPCIF and AICM jointly registered a "China Responsible Care" trademark. To use this trademark in their brands, Chinese chemical firms must follow requirements on an annual basis, including performance indicator reporting as well as an annual assessment of their RC practices.[133] If this trademark becomes a tool for external stakeholders to praise in-club firms and criticize out-club firms, then this development would support the certification club mechanism. However, there is scant evidence that Chinese companies leverage this trademark in marketing and public relations. The CPCIF frames the trademark as a way to promote broader awareness about the program among firms, as opposed to a vehicle for firms to garner goodwill with consumers.[134] In sum, ICCA's RC promotion efforts in China aim to encourage laggard firms to share their shortcomings in an environment that protects them from negative outside publicity.

Assistance to weak links vs. exclusion of free riders

Another test of the reputation collective and certification club mechanisms is ICCA's approach to poor-performing Chinese firms that free-ride on RC's reputational benefits. Consider, for instance, the requirement that RC member firms report safety performance on indicators such as process safety incident rate. It is well-documented that, since CPCIF joined the RC leadership group in 2014, many of China's small and medium-sized chemical firms, which number around 30,000, have not met this requirement.[135] If ICCA denied membership benefits to disengaged Chinese firms,

[130] Barnett and King 2008.
[131] CPCIF 2022; CPCIF 2021.
[132] Conzelmann 2012.
[133] CPCIF 2022.
[134] PROCESS 2019.
[135] Naidu 2019.

just as Euro Chlor once attempted to prevent free-riding chlorine producers from accessing best practices manuals and other group goods, then this would partially validate the certification club mechanism.

On the contrary, ICCA assisted Chinese firms that had not met certain Responsible Care requirements. The group's 2018 Responsible Care Status Report acknowledged that the Chinese chemical industry faced "very particular challenges in performance reporting" and stated that it was "examining its options for a reporting approach that suits the reality of China's situation."[136] In 2018, ICCA and CPCIF published a three-year action plan to broaden RC adoption through piloting evaluation programs in chemical industry parks, popularizing knowledge of RC principles, and improving training and education for safety personnel. In a speech at the 2019 China RC Promotion Conference, CPCIF president Shousheng Li emphasized the importance of this plan to help small and medium-sized enterprises with RC implementation, explicitly labeling these firms as "weak links" [*boruo huanjie*].[137]

Alternative factors

Binding international agreements and top-down government directives cannot explain China's modest progress in chemical safety. In this domain, the global governance landscape is an "alphabet soup" of international agreements and initiatives, including three multilateral treaties that address trade in hazardous chemicals, the UN Environment Programme's Strategic Approach to International Chemicals Management policy framework, and the OECD's efforts to harmonize chemical standards.[138] In other words, intergovernmental instruments provide Chinese regulators limited leverage to push through chemical safety reforms.

During this period, China initiated and revised chemical safety regulations that pressured firms to raise their safety standards, but ICCA and other international actors helped fill in implementation gaps. The 2014 national profile of China's chemicals management system, co-authored by Peking University researchers, identified large gaps in the central government's policies and resources for chemical risk management. Specifically, the State Administration of Work Safety (SAWS), responsible for issuing licenses for hazardous chemical production, lacked institutional capacity and technical expertise.[139] According to a chemical regulation specialist from a Chinese consulting group, the dearth of qualified local staff has also hindered enforcement of the amended Production Safety Law (2019), leading companies to seek out international companies for help with production safety.[140]

[136] RCLG 2018.
[137] PROCESS 2019.
[138] Sheoin 2014; Selin 2010.
[139] Liu 2014.
[140] Naidu 2019.

V. Conclusion

In this paper, we put forward and evaluate a novel theory of global private regulation in high-risk technologies. We theorize that, in industries with a collective safety reputation, international industry associations regulate safety among member firms by treating industry reputation as a communal good, protecting information on member performance from external stakeholders, and subsidizing laggard firms to keep them connected to the group. These reputation collectives diverge from the most prevalent model of international private regulation: certification clubs that maintain strict quality, safety, or environmental standards and deny membership benefits to firms that do not meet such standards. Tracing interactions between international industry associations and Chinese firms in three high-risk technological domains, the article's findings support the validity of the reputation collective mechanism.

This article contributes to a growing literature on voluntary self-regulation, which has challenged the assumption that global private governance is either futile or insubstantial. Previous scholarship has focused on clubs that grant membership to firms that uphold certification standards in safety, sustainability, human rights, etc.[141] However, as this article demonstrates, governance regimes must fit the demands of particular technologies. In certain domains when an accident's reputational effects spill over to the entire industry, the reputation collective mechanism provides a better account of how international industry associations endeavor to improve safety standards in emerging economies. If the design criteria of certification clubs — e.g., stringent membership criteria and credible enforcement procedures — is used to assess the effectiveness of voluntary initiatives in these high-risk technologies, then the resulting analysis may mislead more than it informs.

Our study of reputation collectives provides a basis for further exploration of the interdependencies between public and private regulation. Some evidence from the cases suggests that the effectiveness of reputation collectives is partially dependent on their relationship with international public agencies. It would be fruitful to explore, for example, whether the threat of strong ICAO regulations functions as an invisible force that encourages IATA to take action, or the extent to which WANO shares safety performance information with the IAEA. Future work in this direction would build on the growing research into public-private governance initiatives, which investigate the agendas of civil society actors as well as the extent to which public actors legitimate private actors.[142]

Finally, our findings also have implications for those that research and shape the governance of emerging technologies. In 2024, influential AI companies from multiple countries agreed to a set of voluntary "Frontier AI Safety Commitments", which aim to reduce risks like powerful AI systems escaping human control. Our paper suggests that an important variable for the design of these

[141] Potoski and Prakash 2005; Prakash and Potoski 2006.
[142] Schleifer and Fransen 2024.

initiatives is whether the AI industry develops a collective safety reputation. If it does, then the effectiveness of global private governance will rest on the features of reputation collectives: low entry requirements in pursuit of universal membership, avoidance of public naming-and-shaming, and reliance on socialization and peer-to-peer learning to improve the safety performance of laggards.[143]

[143] Conzelmann 2012, 199-200.

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