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Comparing science communication ecosystems: towards a conceptual framework for cross-national research on science communication

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Abstract

This paper proposes a framework to guide cross-national, comparative research on science communication. Current research often relies on ad-hoc criteria for selecting countries (such as geographic proximity) or on pragmatic considerations (like data availability), which may limit the ability to capture broader contexts or identify the cases best suited for analysis. Drawing on the ecosystems concept, we integrate theoretical perspectives on political systems, academic systems, and media systems to identify a set of ideational and structural factors that are essential for understanding country variations in science communication: political system settings, the role of the state/market, political attention to science communication, and societal values and norms. Based on these, we suggest (and preliminarily illustrate) a typology of four ideal-types of science communication ecosystems — public-service-oriented, market-oriented, state-centred and fragmented — that could guide and should be tested in future research.

Keywords

Science communication: theory and models

Received: 8th January 2025

Accepted: 24th September 2025

Published: 20th October 2025

Many of humankind's current challenges, from climate change to public health and digital transformations and AI, are science-related. Accordingly, demands for science to be open and responsive to societal needs have risen and catapulted science communication to eminent importance [Davies, 2021]. Correspondingly, research on science communication has grown, institutionalised and diversified [Guenther & Joubert, 2017], and within the field, comparative and particularly cross-national studies have become increasingly important [Agin & Karlsson, 2021; Schäfer, 2012]. While science, science communication and the underlying communication ecosystems have become increasingly global [Davies & Hara, 2017], national contexts are still influential in shaping them. How, by whom and through which channels science communication is conducted is influenced by the specifics of national academic and higher education systems, the media system, national policies, funding structures, incentives, but also cultural values and beliefs [Gascoigne & Schiele, 2020].

However, the field still lacks conceptual frameworks that can systematically guide cross-national analyses. Country selection often depends on geographic proximity [Kessler et al., 2022], pragmatic considerations such as data availability [Pidgeon et al., 2017], or theories specific to the subject of study. To ensure meaningful results that contribute to theoretical development and allow for broader conclusions about science communication [Kim et al., 2020], it is important that the selection of countries is based on a conceptual framework. Without such a foundation, cross-national studies risk producing findings in which any observed similarities or differences are artifacts of arbitrary country choices [Hantrais, 1999; Norris, 2009]. This makes theoretical guidance particularly crucial for cross-national analyses, which often can only include a limited number of country cases [Esser & Vliegenthart, 2017].

Typologies that allow informed country selection, such as the media system's typology in communication science [Brüggemann et al., 2014; Hallin & Mancini, 2004], are important heuristics that can guide researchers in their country selection [see also Esser & Hanitzsch, 2012]. Building on these is vital to further develop and apply such frameworks in order to advance comparative research. Doing so can help generate findings that go beyond mere descriptive accounts [Esser & Vliegenthart, 2017].

We propose such guidance in the form of a typology of science communication ecosystems. Applying the concept of ecosystems to science communication, we integrate theoretical approaches to understanding socio-political contexts [e.g., Esping-Andersen, 1990], academic systems and science and technology cultures [e.g., Godin & Gingras, 2000; Slaughter & Rhoades, 2004], media systems [e.g., Hallin & Mancini, 2004] and science communication cultures [Mejlgaard et al., 2012]. On this basis, we distinguish two overarching dimensions that influence how science communication ecosystems unfold, combine these two dimensions to create a typology of science communication ecosystems, and suggest where individual countries could be situated in this typology. Even though we will provide an illustration of how such a typology could apply to different countries, we are not able to provide a fully-fledged empirical analysis here and must leave this to subsequent studies. Yet if validated, the proposed typology could inform cross-national research on science communication by offering a basis for country selection and enabling meaningful most-similar or most-different research designs [Esser & Hanitzsch, 2012].

1 - Conceptualising the science communication ecosystem

To develop a framework for cross-national research on science communication, we use the notion of science communication ecosystems. We understand science communication as any communication focusing mainly on science, scientific work and its results [Schäfer et al., 2020] that is at least partly directed to audiences outside of science [Davies & Horst, 2016].¹ The “ecosystem” term was developed in the bio- and environmental sciences [Tansley, 1935]. Although the use of the term differs slightly between fields and has changed over time, it generally proposes a holistic view of species living in a habitat and their relations to each other. It also emphasises the importance of their environment and of interactions between species and the environment [Chapin et al., 2011]. We adopt these basic elements and conceptualise science communication ecosystems as consisting of a) actors, b) the relations between the different actors within an ecosystem and c) their environment including the surrounding culture, infrastructure and institutions (see Figure 1).

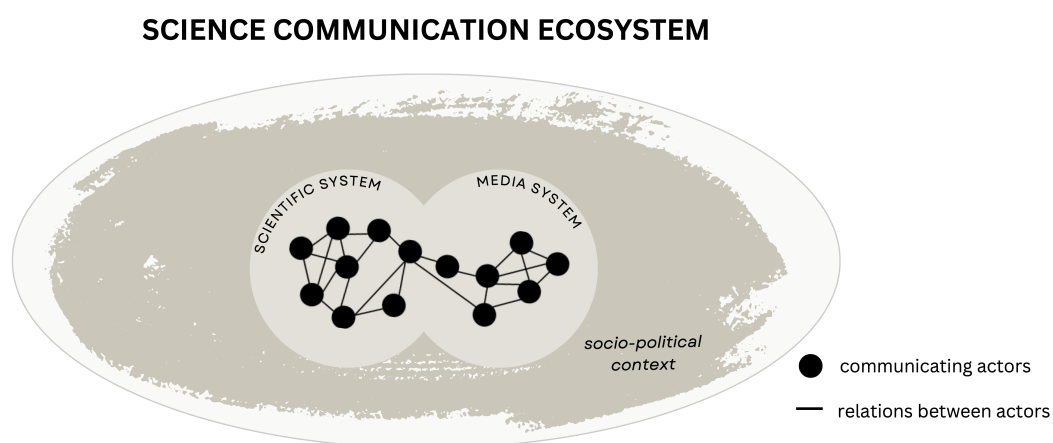


Figure 1. The science communication ecosystem (authors' own illustration).

1.1 - Actors of science communication

The first component of science communication ecosystems are its actors. We broadly differentiate actors who are themselves producers of scientific information, intermediaries and publics [Delicado et al., 2021]. Actors who produce scientific information are mainly scientists who communicate about science [Besley et al., 2018], higher education and scientific institutions as well as corporations [Thaker, 2020], civil society organisations such as NGOs [Fährich et al., 2020], or political institutions [Scheufele, 2014] who often have R&D or research divisions and experts.

In addition, there is a rich “ecology” of intermediaries with different competences, intentions and operational models [Kivimaa et al., 2019; Fischer & Schmid-Petri, 2023]. These are “traditional” intermediaries like science journalists [Guenther, 2019] as well as science communication professionals working in scientific or higher education institutions [Fürst et al., 2022]. These have been joined by other more unconventional intermediaries who use

1. We do not consider internal science communication, in the sense of scholarly communication, in this paper, as we are interested in the relations between different science communication actor groups as outlined below and scholarly communication by nature involves only the interaction within one group of actors (i.e., scientists).

the communication of scientific information for campaigns of different types [Kupper et al., 2021] like influencers [Chinn et al., 2024], bloggers [Brown Jarreau, 2015] and science podcasters [Yuan et al., 2022].

Citizens [Kupper et al., 2021; Yang, 2021] are actors of science communication as well when and if they communicate about science, scientific findings, methods, the scientific system or about scientific or science-related topics (e.g., vaccinations, climate change), and as audiences of science communication.

1.2 ■ *Actor relations in science communication*

The second component is concerned with the relations between the different actors within an ecosystem. These relations can be conceptualised along different, ideal-type models of science communication [Akin, 2017; Trench, 2008]. Models such as ‘Public Understanding of Science’ (PUS) depict science communication relations mainly as a hierarchical one-way process. Scientists produce information, traditional intermediaries such as PR professionals disseminate this information to journalists who “translate” it for the “general public” [Brossard & Lewenstein, 2009].

‘Public Engagement with Science’ (PES) describes relations of two-way engagement [Schmid-Petri & Bürger, 2020] that take a dialogic or participatory form [Palmer & Schibeci, 2014]. In this model, a broad range of actors, including researchers, stakeholders and citizens can take part in more egalitarian conversations around science and science-related topics. More recent approaches conceptualise science communication as a network of different actors embedded in the complex political contexts of today’s societies, therefore including scientific policy advice, activism and more [Akin, 2017; Schmid-Petri & Bürger, 2020].

Others speak about the social conversation around science, emphasising the complex interplays between different actors that converse with one another about science [Bucchi & Trench, 2021]. These models are not chronological or mutually exclusive. In contemporary societies, they, and the different relations between actor groups they describe, can co-exist. They comprise the complex structure of relationships that defines science communication ecosystems and can change over time [Kupper et al., 2021].

1.3 ■ *Environment: country-specific characteristics shaping science communication*

The actors of science communication and their relations are embedded in an environment – the third dimension of the ‘ecosystem’ which influences actors and their relations. It affords opportunities to certain actors, but also imposes restrictions, can provide resources and valorise certain activities structurally or symbolically, e.g., by providing funding for the communication of higher education institutions or by incentivising outreach activities.

We posit that such environmental influences on science communication can be conceptualised and assessed along two overarching dimensions. First, science communication is fundamentally influenced by existing structures, i.e., rules and regulations, institutions and related sanctions and incentives [Ojeda-Romano et al., 2022; Bucchi & Trench, 2016]. Second, ideas about science, its role in society and the desired interfaces between science and the public play an important role [Palmer & Schibeci, 2014; Mejlgaard

et al., 2012]. In line with prior comparative research on science communication [e.g., Mejlgaard et al., 2012] and science and technology cultures [e.g. Bauer & Suerdem, 2016; Claessens, 2021; Godin & Gingras, 2000], we propose to assess the environment along these two dimensions: (1) the structural and (2) the ideational one.

Within these two dimensions, we aim to identify the central factors shaping science communication. To do so, we merge factors that define the socio-political context of a country with typologies of media systems as well as academic and higher education systems, and with prior comparative studies on science communication.

First, the socio-political context of countries provides the basic structure influencing science communication (and other) activities, coupling science and the public in specific ways [Neuberger, 2023; Weingart, 2022]. The socio-political context also creates the framework (through regulations, funding and normative as well as value sets) for other societal systems such as the economy and influences science communication indirectly through these other systems as well. Accordingly, the socio-political context has been analysed by a rich tradition of scholarship distinguishing general system types and their focus, e.g., on the form and strength of government, different electoral systems and fundamental values [see Baker, 2024; Inglehart, 2013; Gregg & Banks, 1965; De Meur & Berg-Schlosser, 1994]. Furthermore, the role of the market and the state [Hall & Soskice, 2001], the openness and closedness of political systems [Lijphart, 1968] and the setup of welfare regimes [Esping-Andersen, 1990] are key aspects of the socio-political context of a given country.

Second, looking at media systems, the work of Hallin and Mancini [2004] is influential. They built on and extended previous media system's frameworks [Siebert et al., 1956; Martin & Chaudhary, 1983] and proposed four dimensions in their seminal conceptualisation of Western media systems: the media market, political parallelism, journalistic professionalism, and the role of the state [recently, the use of digital information technologies has been added as a distinguishing factor, Humprecht et al., 2022]. Hallin and Mancini's [2004] main contribution was to identify useful dimensions to distinguish media systems, and to propose a first typology of three basic media systems. Subsequent empirical tests then validated the dimensions and system types but also proposed adaptations. Whereas Brüggemann et al. [2014, pp. 1056–1057] identified an additional type of media system, Humprecht and colleagues [2022] only found evidence of three different types. They especially argue for a dissolution of the Nordic cluster and an integration of the Nordic countries with the Central European countries [Humprecht et al., 2022]. Despite these different results, however, the dimensions established by Hallin and Mancini [2004] and their fundamental assumption of media systems as distinctive contexts of public communication are still central to scholarship on communication, politics and other disciplines and have catalysed these fields in meaningful ways. This shows that a conceptual approach can make a substantial contribution to research even if it has to be empirically validated and corrected by further studies.

Third, higher education systems have been differentiated according to differences in market influences [Hölscher, 2016; Slaughter & Rhoades, 2004] and have been found to align partly with the underlying welfare regimes of the respective countries [Bégin-Caouette et al., 2016; Willemse & de Beer, 2012]. This approach has not been as influential as Hallin and Mancini's media systems model, but has still provided a basis for empirical analyses. The respective authors have proposed to distinguish higher education systems within liberal or coordinated market economies [Hölscher, 2016] or liberal market-oriented countries, conservative

self-governance and democratic state-centred systems [Schulze-Cleven & Olson, 2017]. Depending on the underlying economic theory, the distinction between higher education systems can therefore vary. Additionally, increased liberalisation is blurring the boundaries between different higher education systems, introducing market mechanisms across system types [Schulze-Cleven & Olson, 2017; Bégin-Caouette et al., 2016].

In scholarship on science communication, comparative studies have used a variety of factors to delineate country-specific forms of science communication. Mejlgaard and colleagues [2012] for example draw on six factors: the degree of institutionalisation (e.g., the presence of popular science magazines, the regularity of a science section in newspapers, dedicated science communication in TV etc.), political attention to the field, the scale and diversity of actor involvement, traditions for popularisation within academia, public interest in science and technology and finally, the training and organisational characteristics of science journalism in the country.

We integrate factors stemming from these scholarly traditions and frameworks into the structural and ideational dimension we propose. Looking first at the structural dimension, we draw on classical political science literature and consider the basic setting of a political system (authoritarian vs. democratic) as well as its openness to be key factors. We are conscious of the fact that political theory goes far beyond these two aspects, but we regard them as a sufficient basis for our argument. Based on theories of academic and media systems as well as science communication, we also believe that considering the roles of the state and the market are pivotal for understanding science communication. Political system settings influence the roles that the state and public institutions play in science communication, and conversely the degree of competition between institutions and the place of science communication in this competition.

Looking at the ideational dimensions, we argue that political attention to the field of science communication, as laid out by Mejlgaard and colleagues [2012], is central as it describes the political motivation and will to promote science communication. In addition to that, we assume that values concerning the role of science in society, as well as attitudes towards science, are key, as these determine the importance of science communication and the demand by citizens, which can be a powerful push factor incentivising more science communication.

In the following, we explore the two dimensions and the core factors in more detail and highlight how they influence science communication actors and their relations.

1.3.1 ■ *Structural dimension*

Basic settings of the political system

The fundamental distinction that can be made with regard to different political systems is that of the general system type, i.e., the form and strength of the government or administrative institutions; the stability of a political system, its degree of centralisation [Baker, 2024]; the existence and type of electoral system (proportional or majoritarian), or how authoritarian or hierarchical a system is; the social security system and the level of individual liberties. These features directly determine how liberal a country is and whether fundamental freedoms such as freedom of the media, freedom of information, or academic

freedom are ensured and guaranteed in the constitution [Gregg & Banks, 1965; De Meur & Berg-Schlosser, 1994].

Democratic systems can be further differentiated along two key dimensions: the role of the market (considered below) and the general openness or closedness of a system [Lijphart, 1968]. The openness or closedness of a political system captures how easy it is for different groups of actors to access institutions of a state, and if there are formal access points when it comes to the design of and debate about issues of collective relevance. We assume that more open political systems allow for more science communication activities overall. Opportunities for participation encourage societal actors to engage [Braun & Hutter, 2016]. In less centralised states (e.g., with a federal structure), there are many different access points, as well as in highly fragmented states and states with a strong separation of power [Kriesi, 1995]. These structures influence how easy it is for intermediary actors to participate in (political) debates. The organisation of these structures influences dominant patterns of decision-making and how conflicts are managed and resolved in a society [De Meur & Berg-Schlosser, 1994].

In authoritarian systems, the scientific system is strongly tied to state influence, and fundamental academic freedoms may not be granted. As a result, authoritarian regimes often instrumentalise science for political purposes [e.g., Burnay & Pils, 2022; Smagli, 2018]. In democratic countries, the academic sector is afforded more freedom and is often organised according to market mechanisms. The same applies to the function and position of the media within a society. Authoritarian regimes generally do not allow free media but try to steer media reporting in their favour [Stier, 2015]. Authoritarian regimes prioritise securing and maintaining power, and the dominance of state control in shaping scientific narratives can be expected to limit science communication efforts. Conversely, societies with greater media and academic freedom are expected to foster more diverse science communication, as individuals are freer in sharing their research [Valiveronen & Saikkonen, 2021].

In politically unstable systems, reliable science communication structures are often lacking, complicating long-term planning and project implementation. General economic conditions, thus, indirectly influence the development of science communication by determining its priority on a country's agenda.

Role of the state/market

The more regulated a state is, the more power remains with the state to control the development of different sectors, such as academia or the media, through laws, funding and policy programs. Deregulation, on the other hand, is also often described as liberalisation, which recounts the process by which market forces are introduced in different sectors. We assume that the more deregulated the media and scientific systems are, the more market forces will also influence the constitution of science communication and the predominant actor constellations.

Regarding the role of the market, the Varieties of Capitalism Approach (VoC) by Hall and Soskice [2001] has been influential. It relies on the development of two theoretical ideal-types: liberal and coordinated market economies — the former characterised by a strong reliance on market mechanisms (with the US as a key example), the latter with a restriction of market mechanisms (with Germany as an example [Hall & Soskice, 2001]). Related to the role of the market is the setup of the welfare regime, which regulates whether

this sector of society is subjected to market forces or influenced by the state to minimise inequalities or to maintain and emphasise status differentials [Esping-Andersen, 1990].

When we look at the scientific system, we see that in recent years, many countries have liberalised the academic sector, linked to New Public Management reforms, which subject the academic sector to market forces and introduce extensive competition into the scientific system [Schulze-Cleven & Olson, 2017]. Publicly and privately funded institutions now compete for students, funding [Slaughter & Rhoades, 2004] and also public visibility and reputation [Fürst et al., 2022]. Performance-based funding has been strengthened [Bégin-Caouette et al., 2016] vis-à-vis direct public funding through block grants not tied to output expectations [Baker, 2024]. This impacts science communication as it increases institutions' willingness to allocate resources to science communication [Fürst et al., 2022], and can lead to an expansion of communication departments and growth of the community of professional science communicators [Fürst et al., 2022], especially in the PR sector [Peters, 2022].

The same applies to the media system. It has been observed across Western countries how "paid printed newspaper circulation has declined, television audiences have fragmented as more and more channels compete for viewers, and the rise of the internet has confronted legacy media with new competitors for both attention and advertising" [Nielsen, 2014]. This is exacerbated in countries with a high degree of commercialisation of media with low or absent press subsidies, as well as low state involvement and weak public broadcasting [Hallin & Mancini, 2004]. This development is accompanied by an economic crisis in journalism, leading to a decline in science sections and in the number of science journalists [Delicado et al., 2021; Schäfer, 2017]. With the need and demand for public communication about science and research still high, other agents step in and fill the gap left by science journalism [Barel-Ben David et al., 2020]. PR professionals have become proficient in writing ready to print news stories, a general trend in PR [Jackson & Moloney, 2016] that has also been found in science-related PR [Heyl et al., 2020]. To counter this trend, institutions like Science Media Centres have been founded with the intention to support science journalists [Buschow et al., 2022]. Private industry actors are also incentivised to enter the field [Thaker, 2020].

1.3.2 ■ *Ideational dimension*

Political attention to science

A (political) focus on science communication [Mejlgaard et al., 2012] may manifest, for example, through funding programs for science communication and designated bodies that foster science communication or training programs for science communicators. Eventually, the importance that the scientific system itself assigns to communication is relevant. In recent years, higher education and scientific institutions, professional associations and scientific academies in many countries have more strongly emphasised science communication [Schäfer et al., 2021; ALLEA, 2021].

As outlined above, science communication is now often part of competitive project-based funding schemes [Arboledas-Lérida, 2023]. The evaluation of performance incentivises a communication which showcases and emphasises research outcomes [Bauer & Entradas, 2022; Ojeda-Romano et al., 2022] and thus the expansion of science PR. Project-based funding can also be used to incentivise communication by scientists themselves [Arboledas-Lérida, 2023], especially when it is combined with training to enable scientists

to engage in communication [Palmer & Schibeci, 2014]. Apart from the material support through funding or infrastructure, predominant ideas about science communication by those who support it have an influence on the communicative relations between its actors [Palmer & Schibeci, 2014].

Another instrument to foster science communication is to tie its funding to larger research grants and therefore largely science-centric ideas determine what is communicated and how [Halpern & O'Rourke, 2020]. In states with a high attention to the field, science communication is often enshrined in laws that create communicative obligations for public institutions [e.g., Hetland et al., 2020].

Overall, we assume that science communication expands with more (political) attention dedicated to it, however, which form of communication will be favoured will depend on (political) preferences and the distribution of (political) power.

Attitudes and values

Countries develop norms and values around science, (higher) education and their role in society. As welfare regimes build the ideological foundation for many public services in a given country, it has been argued that welfare regimes differ in how they understand the role of science (and scientists) in society [Schulze-Cleven & Olson, 2017]. This is linked to the question of whether there is a tradition of academia to open up to the public and how scientific matters are deliberated in society [Mejlgaard et al., 2012]. Countries with a stronger tradition of popularisation tend to have a stronger focus on science communication currently [Mejlgaard et al., 2012].

Public attitudes towards science, trust in science and scientific literacy/capital are tied to the importance of science in society, the interest in and need for scientific knowledge and how well societies deal with the implications of scientific information [Mejlgaard et al., 2012]. Coupled with trust in the media as well as media and digital literacy this determines not only journalism's status in society, but also how different media are used, and influence, for example, the ability to deal with the flood of information online and to recognise (scientific) misinformation [see for example Strömbäck et al., 2020]. When digital skills are integrated into school curricula and supported by digital capacity building, digital channels can effectively reach broad audiences [Deng, 2024].

Inclusiveness is another important societal characteristic. The more inclusive both the media and the academic and higher education system are, the more inclusive we can assume science communication to be. If journalistic media reaches different segments of society, it is likely that this also extends to the scientific content in the media. If the scientific system is inclusive, then more people will have an opportunity to acquire higher science capital, which will enable them to participate in science communication [DeWitt et al., 2016].

Journalistic professionalism [Hallin & Mancini, 2004] is another important feature, as a professionalised science journalism will set clear boundaries for other professions [Brüggemann et al., 2020] and encourage further professionalisation of the sector.

2 - Constructing science communication ecosystems: a tentative typology based on empirical impressions

In order to construct (tentative) ideal-types of science communication ecosystems, we combine the ideational and structural dimensions into a matrix. The high end of the structural dimension describes countries with high regulation, public funding and strong public institutions, the low end the reverse. The high end of the ideational dimension describes countries with strong traditions of popularisation in academia, high political attention to science communication and a strong integration of science in society; the low end describes the opposite. When combined, this 2x2 matrix yields four ideal-types of science communication ecosystems which we term the public-service-oriented, the market-oriented, the state-centred and the fragmented ecosystem.

We are aware of the pitfalls here, however. The first is the danger of oversimplification. However, we consider the reduction to four types justified by our aim to provide orientation for researchers and to enable them to use the typology to make meaningful choices in country selection. Still, we do not mean to suggest that there are no differences between countries in the same quadrant. On the contrary, comparisons between countries within the same quadrant may prove highly productive because they can uncover variation between countries that share basic characteristics [most-similar systems comparisons, see Ankar, 2008].

The second pitfall is that we are not able to provide a large-scale, robust empirical validation of the typology here. We can, however, illustrate the potential usefulness of the matrix by illustrating where specific countries might be situated, drawing on prior scholarship. To do so, we relied primarily on the book “Communicating Science. A Global Perspective” [Gascoigne et al., 2020], which compiles information on science communication in a diverse set of countries. In addition, we consulted scholarly literature on science communication cultures [Mejlgaard et al., 2012], comparative studies on science communication and included a range of macro-indicators characterising different countries such as PISA scores, academic and press freedom, government expenditures on research and development and further indicators.² Through thematic analysis and a qualitative coding into high, moderate and low of different indicators, country characteristics were extracted from these sources, coded into the analytical categories laid out above and, eventually, placed on the two-dimensional matrix (see Figure 2). The data we draw on is not complete and placement of the countries followed a largely heuristic process, informed by the data available but not fully empirically validated. Our approach is designed as a blueprint that future empirical studies could build on highlighting potential ways forward.

Below, we describe the four types further by drawing on empirical examples.

2.1 ■ *The public service-oriented ecosystem*

The public service-oriented ideal-type is characterised by a strong role of the state coupled with long traditions of academic popularisation and a strong role of science in society. In this type, the state safeguards these values, and there is high political attention to the field of science communication. Public institutions and funding dominate in both academia and the

2. See tables on OSF: https://osf.io/ekv5z/?view_only=34ed4901f4f147cdb4bd93798209ebb5.

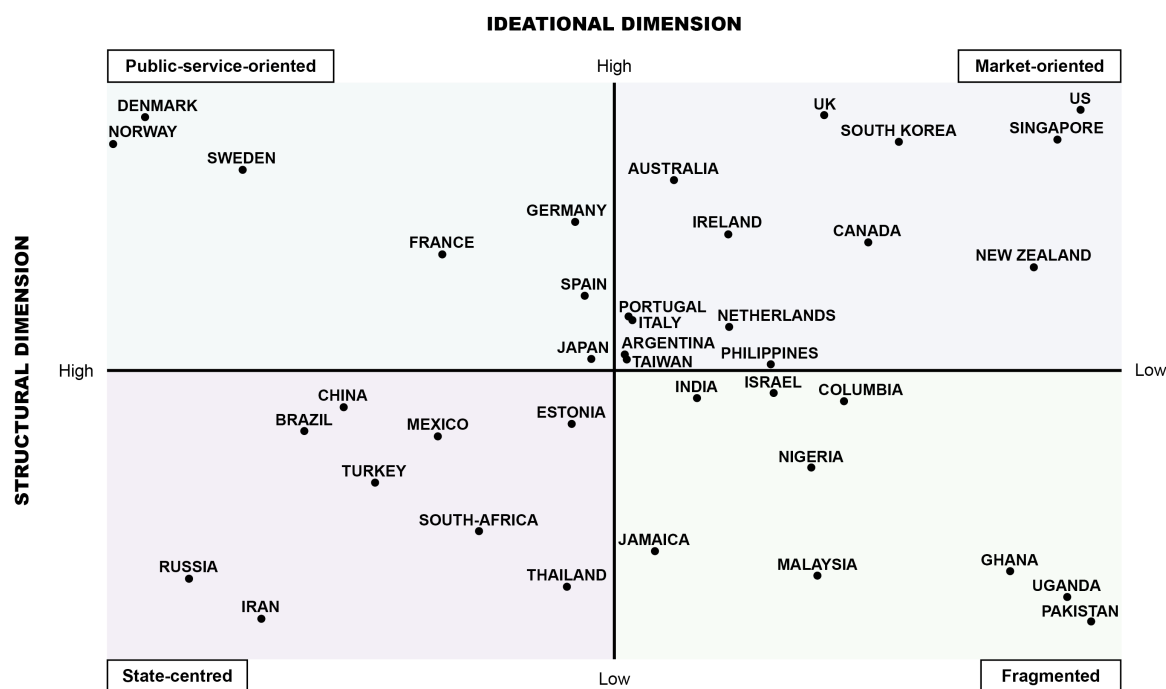


Figure 2. Country classifications into the four science communication ecosystems.

media. Among our 39 countries, we sorted seven into this type — among them the three Scandinavian countries, Germany and France.

In these countries, science communication is often enshrined in laws that create specific obligations for public sector institutions. In Scandinavia, for example, the “third mission” of universities plays an important role, illustrated by the Swedish Higher Education Law of 1977 which stated that university researchers now had a ‘third mission’ to fulfil, and it was their responsibility to inform and collaborate with society” [Hetland et al., 2020, p. 267]. It is also quite typical for these countries to have a strong connection to science communication, again the Nordic countries illustrate this well where “science communication played an important role in the formation of national identity” [Hetland et al., 2020, p. 255]. Furthermore, there tends to be a strong tradition of science that encompasses its connection to society, for example in Germany, where “the necessity of the society-orientation of science” [Peters et al., 2020, p. 319] is stressed. Even though governments and political power structures change, science communication tends to remain central in these countries, and science communication efforts tend to be concerted and connected to larger funding schemes.

2.2 ■ *The market-oriented ecosystem*

The market-oriented ideal-type is characterised by a weak role of the state and, consequently, high liberalisation and competition. At the same time, there is a strong tradition for academic popularisation and science plays an important role in society. The state funds academia and subsidises media, but private and commercial funders also play an important role.

We situated 13 countries in this type, including the US, the UK, Australia, the Netherlands and Singapore. In these countries, the state is “no longer the leader of the nation but just one

leading actor,” [Kim, 2020, p. 817]. This can give science communication a push, as in Singapore, where “[a] milestone in the development of science communication [...] since the 2010s is the entry it has now made into the commercial sector.” [De Souza et al., 2020, p. 762]. In many of the countries, such as in the UK this results in a multitude of communication efforts, so that the field is shaped by “many activities by individuals and individual groups and institutions” [Smallman et al., 2020, p. 948]. However, due to the many different sources of funding and motivation, science communication efforts are not necessarily coordinated. Along these lines, science communication in the US has been described as “a cacophony”, which as the authors say “can be positive, in that it promotes new thinking, innovation and creativity [...] but it can also lead to inefficiencies, misalignment and conflicting messages” [Bevan & Smith, 2020, p. 961]. In addition to that, in the case of New Zealand, it has been pointed out that the presence of commercial interests fosters science communication directed at creating publicity and visibility while science journalism often suffers from economic pressures on the media market [Fleming et al., 2020, p. 75].

2.3 ■ *The state-centred ecosystem*

The state-centred ideal-type builds on a strong role of the state, in the absence of a tradition of academic popularisation and in the face of a less prominent role of science in society. Both media and academia are largely state funded but driven by current political concerns and power relations, so that they can be subject to fluctuations due to changes in government or the political climate.

Nine of the countries we analysed fall into this type, including China, Russia and Turkey. In these countries, science communication can look very different depending on the prevailing political will. This has been diagnosed, for example, in Mexico, where science communication is “vulnerable to political and institutional changes” [Reynoso-Haynes et al., 2020, p. 586]. There is no established private sector, and science communication hinges not only upon political motivation but also upon the capacity to implement policies. Russia provides another example where “[t]he ousting of independent funders meant that the government was preparing to enter the market itself with significant resources and its own view of how things should be done.” [Borissova & Malkov, 2020, p. 728]. In Brazil “public policies are still vulnerable to change in political attitudes” [p. 169], exemplified by the massive cuts made to science spending by the government first by two thirds of its former size in 2013 and then by another 40% in 2019 [Massarani & Moreira, 2020].

2.4 ■ *The fragmented ecosystem*

The fragmented ideal-type is characterised by a weak role of the state, a weak tradition of academic popularisation and a weak role of science in society. There is little state funding for academia and media, combined with the presence of private and commercial actors with their own interests and agendas. In this ecosystem, science communication is not yet established as a fixed part of society. Science communication efforts and activities tend to be uncoordinated, executed by a diversity of often unconnected actors with very little access to systematic funding.

We assigned nine countries to this ecosystem type. Pakistan is an illustrative case where “a proposal for setting up four more science centres was put to the government for funding but

has not materialised yet” [Soomro & Raza, 2020, p. 653]. A similar situation is described in the example of Colombia where “public investment in [...] interactive museums and centres has been very variable, going from periods of great support to periods of almost none” [Daza-Caicedo et al., 2020, p. 245]. This makes it very hard for any permanent science communication (infra)structures to establish themselves. In the absence of coordinated either public or private support, it is often the work of a few dedicated individuals that keeps science communication alive and thriving, as described in Ghana where “many individuals have played leading roles in promoting science communication at both the local and national levels” [Tagoe & Tagoe, 2020, p. 364].

3 - Discussion and conclusion

This paper proposes a conceptual framework for science communication ecosystems designed to help comparative, cross-national research on science communication. We understand ecosystems as constituted by actors, the communicative relations between them and the environment surrounding them. We have conceptualised this environment to identify factors that influence how science communication develops, and organised those factors along two dimensions, the structural and ideational one. On this basis, we were able to propose four ideal-types of science communication ecosystems, and to tentatively illustrate those with country cases based on a secondary reading of prior scholarship enriched with quantitative indicators.

Future studies may use this typology to make more informed decisions for comparative studies in science communication. For some studies it might be of special interest to compare countries that differ most structurally, for others an ideational difference might be more interesting, and yet other studies may be interested in teasing out differences between countries that have very similar science communication ecosystems. The typology of science communication ecosystems proposed here offers a useful lens for interpreting insights across a broad range of science communication topics: from the roles and role perceptions of science communication actors to the interaction between publics and science communication actors or the prevalence of certain goals, motives and values of science communication across countries.

Our typology contributes to scholarship in several ways: First, it offers a conceptually grounded differentiation of science communication ecosystems and can help understand and explain country differences. Second, it provides a basis for selecting countries more systematically for cross-national studies. Third, it contributes to much-needed theory building in the field of (comparative) science communication research. It can, thereby, inform discussions about changes in science communication by highlighting historical, institutional and structural factors which can foster an understanding of requirements and conditions for change.

Despite these contributions, the paper also has its limitations. First, we were not able to conduct a robust empirical analysis of all data available here. We could only draw on secondary readings of prior analyses to characterise and place country cases and are fully aware that this would need more work — similar to Hallin and Mancini [2004] whose ideal-types of media systems were later partly corroborated, partly corrected by empirical work [Brüggemann et al., 2014; Humprecht et al., 2022].

Second, we are aware that our focus on the national level, which we believe is the most relevant level of analysis, omits other levels. While transnational efforts in science communication undoubtedly exist, e.g., in the European Union's funding programs, and within-country differences between regions and communities exist as well, especially in large and/or federal countries like the US or Germany, we focused on the national level as it is crucial for the organisation of the academic sector and media systems in most countries. In addition, studies in science communication and beyond, comparative or not, analyse national cases much more often than supranational, regional or local ones.

In any case, we hope and think that the proposed framework and typology inspire other researchers both conceptually and methodologically. We hope that future studies will put our framework to an empirical test and adapt it where necessary. We believe that science communication research needs common theoretical and conceptual grounding. Only based on a sure theoretical footing can we integrate the wealth of empirical evidence into comprehensive insights that enhance our overall understanding of science communication. We hope to have contributed to this and provided a starting point for theoretical and conceptual debates as well as an orientation for future empirical studies.

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How to cite

Fischer, L., Schäfer, M. S. and Schmid-Petri, H. (2025). 'Comparing science communication ecosystems: towards a conceptual framework for cross-national research on science communication'. *JCOM* 24(05), A02. <https://doi.org/10.22323/148320250924054927>.



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