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Received: 26 September 2023 | Revised: 3 May 2024 | Accepted: 30 June 2024

DOI: 10.1111/gove.12885

ORIGINAL ARTICLE

Governance WILEY

Network dynamics in public health advisory systems: A comparative analysis of scientific advice for COVID-19 in Belgium, Quebec, Sweden, and Switzerland

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Funding information
Social Sciences and Humanities Research Council of Canada, Grant/Award Number: 435 2021 0332; Fonds de recherche du Québec, Grant/Award Number: 203845; Canadian Institutes of Health Research; Canada Research Chairs; Riksbankens jubileumsfond, Grant/Award Number: P20-0463

Abstract

This study presents a dual-method approach to systematically analyze public health advisory networks during the COVID-19 pandemic across four jurisdictions: Belgium, Quebec, Sweden, and Switzerland. Using network analysis inspired by egocentric analysis and a subsystems approach adapted to public health, the research investigates network structures and their openness to new actors and ideas. The findings reveal significant variations in network configurations, with differences in density, centralization, and the role of central actors. The study also uncovers a relation between network openness and its structural attributes, highlighting the impact of network composition on the flow and control of expert advice. These insights into public health advisory networks contribute to understanding the interface between scientific advice and policymaking, emphasizing the importance of network characteristics in shaping the influence of expert

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advisors. The article underscores the relevance of systematic network descriptions in public policy, offering reflections on expert accountability, information diversity, and the broader implications for democratic governance.

1 | INTRODUCTION

The role of expert advisors is crucial when policymakers must make decisions in a context of uncertainty. Yet, these advisors do not merely compile and produce evidence and advice neutrally. Whether consciously or not, they frame issues, assisting policymakers in developing problem understandings—a critical step in navigating policy alternatives (Cairney, 2016; Cairney et al., 2016; Rochefort & Cobb, 1993). Consequently, the identity of expert advisors is of paramount importance (Doberstein, 2017). Their role was particularly critical during the COVID-19 pandemic and continues to be significant during normal times when policymakers routinely try to govern these expert groups, who themselves seek to be influential (Hesstvedt & Christensen, 2023; Marciano & Craft, 2023).

The influence of individual advisors largely depends on the networks in which they are embedded. The credibility of individual experts stems, at least in part, from their specific networks, which either reinforce or weaken their perspectives. These networks are inherently complex, sometimes limiting the range of expert opinions and strategically positioning certain advisors to confer privileges, particularly regarding their capacity to receive, interpret, and transmit information (Montpetit et al., 2006; O'Connor & Owen Weatherall, 2019). Within these network configurations, some advisors may find themselves distanced from policymakers, while others occupy more central positions, granting them authority in shaping and interpreting information before it reaches political decision-makers. These positions are instrumental in understanding the management and control of these networks and their impact on public policy.

Embedded within an expert network where his country's Public Health Agency (PHA) played a central role, the perspectives of Anders Tegnell, Sweden's Chief Epidemiologist, directly influenced Sweden's approach during the COVID-19 pandemic. His stance that school closures were ill-advised went unquestioned by the Swedish government, which kept schools open throughout the pandemic, unlike many countries (Lemor et al., 2022). However, Tegnell's advice might not have held such sway had the PHA employing him been less central to the network of advisors mobilized during the crisis.

Public policy literature primarily examines expert networks through the lens of Policy advisory systems (PAS). This article presents a novel dual-method approach for describing these networks, both in their configuration (e.g., centralization, density, central actor, structure) and their openness to new actors or ideas. This dual method encompasses a formal network analysis, inspired by egocentric network analysis, focusing on network structures. The second method, derived from the policy subsystems approach, measures the openness or closure of these networks. This dual method provides an in-depth examination, offering new insights into the interplay between network configuration, management, control, and policy change.

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The strength of this dual method lies in its dual validity: external, through the use of formal measures of egocentric networks, and internal through the adaptation of the subsystem approach to the specific domain studied, that of public health. We apply these two methods to describe the networks of public health expert advisors who effectively informed governments during the pandemic (2020–2023) in four jurisdictions: Belgium, Quebec, Sweden, and Switzerland. This dual method operationalizes the recent theoretical alliance between the literature on PAS and the more established literature on policy subsystems and networks (Craft & Wilder, 2017).

The primary contribution of this study is to provide a systematic method for describing the networks of experts advising policymakers. Our goal is not to causally link networks to government decisions or policy performances during the pandemic. However, we produce essential insights into the configuration of networks and their openness, enabling observations on their management, control, and implications on public policy. We believe systematic description has intrinsic value, not merely as a preliminary step toward explanation. Indeed, a valid and reliable description of an expert network provokes reflection on critical issues such as the diversity of information and advice provided to policymakers and the management of these networks, which inherently influence the range of available policy alternatives.

2 | THEORY

The literature on science and technology has focused on the boundary that separates actors considered experts from those who are non-experts, highlighting the mobile nature of this boundary over time, and across countries (Jasanoff, 2003, pp. 393–394). By indicating who counts—or does not count—as an expert, these boundaries highlight the groups that, by virtue of their specialized knowledge, are certified by policymakers and can enjoy privileged access to them. Experts' certification refers to the "extent to which a group of experts exists to advise policymakers on the issue at hand (...) and (...) [have] been validated by the state" (Dunlop, 2014, p. 212). Among the literature interested in this issue, the study of PAS holds an important place. Introduced by Seymour-Ure (1987) and further developed and expanded by Halligan (1995), the concept of PAS refers to the interlocking set of actors who produce knowledge and advice aimed at informing decision-makers and their public policies.

2.1 | Studying and conceptualizing advisory systems

The "first wave" of PAS studies focused on the boundaries that define groups involved in advising governments, using two key criteria: the location of experts, whether inside or outside the government, and the degree of political control exerted over them (Craft & Howlett, 2012; Craft & Wilder, 2017). This approach provided insights into PAS configurations, often highlighting the types of actors who generate knowledge, such as consultants or civil servants, and their relationships, particularly in terms of control and influence. These studies were interested in the unique organization of advice and expertise in different countries and their impact on policy (Campbell & Pedersen, 2014; Craft & Halligan, 2020; Peters and Barker, 1993). Recent trends in many countries' PAS involve outsourcing advice, which may restrict the diversity of perspectives and policy alternatives (Craft & Halligan, 2020; Craft & Howlett, 2013; Doberstein, 2017).

However, some scholars have critiqued the use of location (inside or outside government) as a criterion for analyzing the configuration and effects of PAS, especially given the diversity of

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advice sources. They have called for a "second wave" of studies focused on the actual content of advice and expert perspectives, rather than solely on their location (Craft & Howlett, 2012; Craft & Wilder, 2017). Craft and Howlett (2012) argue that in a context of diversification and outsourcing, location alone is insufficient for analyzing PAS, particularly concerning actor influence. They emphasize the importance of examining the content of PAS, identifying different actors (such as political staff, officials, in-house experts, and think tanks) and the policy advice they generate, hypothesizing that different types of expert groups have varying perspectives on problems and produce different types of advice.

To operationalize the study of content, these second-wave studies focus on specific domains, considering their institutional context, to analyze advisory systems (Craft & Wilder, 2017). This aligns with recent studies on PAS management related to government control, which lead to specific configurations like laissez-faire or dependence (Marciano & Craft, 2023). Some authors have suggested examining and mapping advisory systems in public health during the COVID-19 pandemic (Easton et al., 2022, 2024). This approach addresses key empirical questions about PAS configuration. While rooted in location-based logic, this mapping allows for an understanding of PAS by analyzing interactions and relationships between actors. Importantly, it facilitates analysis based on both the configuration of PAS and its content, addressing empirical questions about how PAS configuration impacts policy outcomes.

Network analysis is well-suited for studying advisory systems, as it emphasizes the ties connecting actors, which are key drivers of their actions (Perry et al., 2018). Understanding these actors and their relationships is crucial for examining the institutional context and configuration of PAS. Egocentric network research is particularly useful, as it focuses on the immediate environment, ties, and structure of an individual's social network, or ego (Godbeck, 2013; Perry et al., 2018). Comparative mapping of PAS, as done by Easton et al. (2024), aligns with egocentric network logic but doesn't fully leverage its potential, especially regarding centralization, density, and actor centrality measures. Using this method and its measures could reveal the internal logic of PAS configurations, particularly concerning management, control, structure, and the processing of information and advice.

2.2 | The policy subsystems approach

Parallel to PAS studies, other works have explored network configurations, including research on policy subsystems. Subsystems cover a broader set of actors than PAS, encompassing both experts and non-experts involved in a specific policy domain. Originating in the United States in the 1960s and 1970s, this literature emphasizes that some domains are dominated by closed networks, or "iron triangles," which confine policy to a narrow group of interests (Cater, 1964; Lowi, 1969). Later studies revealed more open networks characterized by participant mobility, known as issue networks, which are more receptive to policy change (Heclo, 1978). These studies highlight the importance of network membership, relationships, mobility, and actor preferences in shaping public policy (Coleman et al., 1996; Howlett, 2002; Sabatier, 1987).

This literature has refined and expanded tools for studying policy subsystems. Marsh and Rhodes (1992) proposed analyzing networks along a continuum between two ideal types: "policy communities" and "issue networks". A policy community is a closed, small, and stable network of actors with similar perspectives, while an issue network is more open, populous, diverse, and unstable (Marsh and Rhodes, 1992; Rhodes, 1997). This literature argues that different network types lead to different public policies. Openness to diverse actors and

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perspectives can provide policymakers with a broader range of alternatives but may affect their ability to anticipate problems (Atkinson & Coleman, 1989). These studies emphasize the importance of openness and closure to new ideas and actors in shaping policies (Howlett, 2002). Parallels have been drawn between this approach and the study of epistemic communities in international relations (Haas, 1992; Löblová, 2018).

Craft and Wilder (2017) pointed out many similarities between PAS and policy subsystems studies. Both use similar methods, highlighting the roles of actors and the influence of network structure. Craft and Wilder (2017) demonstrated that varying degrees of compatibility between advice and subsystems, and differing levels of openness and accessibility, can create distinct types of PAS. For example, a "collaborative PAS" features high accessibility, openness, and compatibility between advice and the subsystem (Craft & Wilder, 2017, p. 225). Subsystem openness to new perspectives often leads to more significant policy changes, as it fosters fluid membership open to new ideas (Craft & Wilder, 2017, p. 222; Howlett, 2002). Subsystem studies have focused on openness through the distribution of membership, integration, and power and resources within subsystems (Rhodes, 1997, p. 44).

2.3 | Empirical analysis of PAS in the context of public health and the COVID-19 pandemic

The call for a new wave of research aims to "better theorize and empirically examine why advisory system components combine in particular policy domains or at specific conjunctures, and with what effects" (Craft & Wilder, 2017, p. 216). One approach to contribute to this area is to focus on a specific policy domain and conjuncture to conduct a thorough empirical analysis of the interaction between the configuration of PAS in terms of structure (network organization, centralization, density, central actors) and their openness. However, operationalizing such research encounters challenges due to the specificity of each policy domain and its related advisory system. The methodological framework must account for this by adapting its criteria to the particularities of each domain and conjuncture. A viable method could involve using a dual approach that adapts criteria of openness and closure to the policy domain (enhancing internal validity) while also relying on formalized methods and measures of network analysis (improving external validity).

The domain of public health advice and the specific conjuncture of the COVID-19 pandemic are suitable for this objective. This article uses two complementary methods to analyze advisory systems, aiming to shed light on expertise organization during the pandemic. We focus on questions like: Were public health advisory systems structured differently across jurisdictions? How open, stable, and consensual were they? Which actors were isolated, and which held central positions? How connected were these actors to decision-making bodies? What perspectives did they represent in different positions? Our goal is empirical and descriptive, not causal, but we recognize that differences in public health advisory networks could be linked to different policies. Networks constrain but also provide opportunities for agents who may or may not leverage them (Marsh & Smith, 2000). Thus, a particular configuration doesn't always lead to similar policies, but a given opportunity structure might significantly enhance the likelihood that certain expertise will be used by policymakers.

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3 | METHOD

In this article, we undertake a comparative study of public health advisory networks activated during the COVID-19 pandemic by employing two complementary approaches: the subsystem approach and network analysis inspired by egocentric analysis. We refer to "public health advisory networks" as we perform a de facto rather than a de jure network analysis, targeting experts' groups that were effectively mandated and mobilized during the pandemic, as opposed to advisory systems established by law that were sometimes not activated (see Ingold et al., 2013). This approach is also the reason why our network analysis draws inspiration from the egocentric method, though it does not adhere strictly to it. In our methodology, we confine our analysis to groups that are de facto mobilized, beginning with a previously identified actor. However, we expand our scope to include only the network that has been certified.

Our research spans four jurisdictions: Belgium, Quebec, Sweden, and Switzerland. The similarities among these regions in population size, economic development, and political system provide a solid foundation for comparability, particularly in terms of pandemic risk and response. This is crucial for understanding how different public health advisory networks operated under similar baseline conditions. Secondly, the comparison of different countries with distinct degrees of governmental centralization offers valuable insights. This diversity allows us to explore how various levels of centralization in governmental structures influence the organizations of public health advisory networks. This comparative approach can reveal patterns and idiosyncrasies in how advisory systems contribute to policymaking.

Our empirical investigation is circumscribed to expert groups that were government-certified during the pandemic to provide advice on non-pharmaceutical interventions (NPIs) at the national level, or at the provincial level for Quebec. NPIs are population-based policies aimed at reducing virus transmission through social distancing measures such as lockdowns, school and workplace closures, or bans on public and private gatherings (Ferguson et al., 2020), excluding pharmaceutical interventions like vaccination. Though critical in combating a virus, vaccination requires distinct expertise and is thus handled by specific advisory networks separate from those dealing with NPIs. For instance, in Switzerland, a specific federal commission is tasked with vaccination advice (CFV), while in Quebec, it is an independent scientific committee (CIQ) (see INSPQ, 2023; OSFP, 2023). Vaccination policies, which also involve private pharmaceutical actors, are therefore the product of specific and distinct advisory groups from those related to NPIs. Lastly, all organizations at other orders of government (local, federal) are not investigated in the case of Quebec as they were not mobilized to inform NPIs.

We use two complementary methods (detailed in Appendices 1 and 2). The first method measures the openness of each policy advisory network using an "openness score." This goes beyond Craft and Wilder's (2017) concept of accessibility, incorporating subsystem openness factors into public health: openness to actors and ideas (Howlett, 2002, p. 247). We use Rhodes' (1997) subsystem approach and its categories (membership, integration, resources, and power) to develop criteria tailored to public health, summarized in Table 1. This approach focuses on the advisory part of the subsystem. Adapting these criteria is crucial for internal validity the institutional context of public health. For example, to analyze membership in public health advice for NPIs, we consider the presence of diverse expertise beyond natural sciences, indicating openness to multiple actors and perspectives. The openness score we use aligns with the premise of subsystem studies, which suggests that open subsystems are more conducive to policy change (Howlett, 2002).

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TABLE 1 Characteristics and objectives of the dual method in analyzing public health advisory networks.

Methods	Characteristics and measures	Objectives
The subsystems approach: Openness of the advisory System's network		
Openness score: Placing the advisory system on a continuum between two ideal-types of an open (issue network) and a closed network (policy community) to both actors and ideas.	• **Membership:** Refers to the range of actors included in the network, where a large membership indicates a wide diversity of expertise and representation from various sectors, potentially including certified expert groups outside of government. This composition can influence the network's approach to policy issues and the type of advice offered. **Criteria used:** narrow or large diversity of expertise; certified expert group inside or outside government. • **Integration**: Pertains to the stability of actor groups and the level of consensus within the network. A stable and integrated network with high agreement among actors may lead to cohesive policy recommendations, whereas instability and disagreement can reflect a dynamic network where policy outcomes are more contested and potentially more innovative. **Criteria used:** stability or instability of actors' groups; agreement or disagreement among actors. • **Resources and power:** Concerns the locus of authority and influence, such as whether a central or peripheral health agency is the primary source of recommendations. It also involves the transparency of the advisory process, including whether recommendations and policy deliberations are conducted and communicated openly to the public, which can affect the debate around policy options and the integration of	• **Analyzing the content of the advisory system**: Expertise (type and diversity), integration and internal relations (instability, disagreement), distribution of power and resources (public health agency, possibility of transparent communication from experts, transparency of decision-makers' deliberations). • **Measuring the openness of the advisory system's network:** Openness of the network to a diversity of actors, ideas, and perspectives.

(Continues)

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TABLE 1 (Continued)

Methods	Characteristics and measures	Objectives
	new perspectives. **Criteria used**: central or peripheral health agency; transparency or opacity in recommendations; opacity or transparency in public policy deliberations.	
Network analysis: Structure, management and control of the advisory system		
Network analysis inspired by egocentric analysis: Mapping, measuring, and analyzing the structure of the advisory system's network.	• **Density**: The degree to which nodes[a] (i.e., actors) within a network are interconnected. High density suggests that most actors are directly connected to one another. • **Centralization**: The extent to which edges[b] (i.e., connections) in a network are either concentrated around one or a few nodes or spread more evenly. High centralization indicates a network with a dominant central node. • **Central actor** (closeness centrality): The node that holds a position of importance within the network due to its shortest paths to all other nodes, facilitating efficient communication or influence. • **Overall structure:** The general configuration of the network, encompassing the arrangement and connection patterns between nodes, which can influence the flow and control of information.	• **Analysis of the advisory system's network in terms of:** - **structure and organization** (density, centralization), - **management and control** (central actor), - **content** through the processing and circulation of the advice produced (overall structure).

[a]Nodes: In network analysis, a node represents an individual actor or entity within the network.

[b]Edges: Edges are the connections or links between nodes in a network.

We develop an "openness score" for each advisory network, positioning them on a continuum from openness to closure to new actors and ideas. A score closer to 0 indicates a more closed network, while a higher score indicates greater openness. The subsystem approach suggests that more open networks are likelier to integrate new actors, offer diverse perspectives and expertise, but also experience actor disagreements. Appendix 1 outlines the rules and criteria for constructing the score. Each indicator adapts the original subsystem ideal types from Rhodes' (1997) categories. For example, integration is assessed through the stability of actor groups; intermittent presence indicates low integration and openness to new participants. Similarly, the distribution of

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power and resources is evaluated based on the presence of an autonomous PHA, which controls the inclusion of new actors and the diversity of perspectives and ideas.

Our second method incorporates network analysis, guided by principles of egocentric analysis, with key measures and concepts detailed in Table 1. The specific rules for constructing these measures are delineated in the first Appendix, while the calculations are documented in the second Appendix. Typically used to depict an actor's relationships within their environment, egocentric network analysis (Perry et al., 2018, p. 26) in our study is adapted to a broader scope. This adaptation extends beyond traditional single-node centered relationships and standard quantitative social network analysis to encompass an evaluation of public health advisory systems involving only certified actors. Our approach, while inspired by egocentric network analysis, focuses on the network emanating from a designated ego, identified as the primary organization certified to provide government advice during a public health crisis. This methodological adjustment is essential, as it allows for the quantification of network characteristics such as density but only within a network of certified actors, which would otherwise be challenging.

This method aims to achieve a higher level of external validity by using established measures. In analyzing advisory networks, this approach allows us to examine management and control by measuring the central actor—that is, the actor likely to be the most influential. For instance, if the central actor is a political figure, network management is likely to be more "authoritative" (see Marciano & Craft, 2023, p. 494). It also enables us to observe the structure and organization by measuring the density and centralization of the advisory networks, which may indicate a strengthened institutionalization. Finally, this method allows us to observe how the advice and information are processed and how they circulate within the network. It also allows specifying roles, which actors serve as brokers for example,

We employ three established measures used in network analyses (see Godlbeck, 2013) and presented in Table 1: (1) a measure of network density (the closer to 1, the denser the network); (2) a measure of centralization (the closer to 0, the less centralized the network); (3) the actor with the lowest closeness centrality measure, indicating the actor closest to other actors. We also produce a mapping that allows for the analysis of the processing and circulation of the advice in the network.

The collection of information was carried out in a systematic manner in each jurisdiction. After agreeing on the rules guiding the empirical work (see first Appendix), the co-authors were ultimately responsible to provide the necessary information to represent the networks for their respective country. Knowledgeable on public health actors and policy in their respective country, the co-authors were nonetheless invited to consult with practitioners to ascertain the information. A single person, the first author of this article, was made responsible for ensuring consistency in the interpretation of the rules guiding the collection of information, for archiving information from all four jurisdictions, and for the preparation of the network figures and comparative table.

4 | RESULTS

The results of the first part of the egocentric network analysis are presented in Figure 1, which maps the public health advisory networks. Notably, two advisory networks, Belgium, and Switzerland, underwent reorganization during the pandemic, necessitating the construction of two distinct networks. Table 2 presents the second part of the egocentric network analysis, including measures of network density, centralization, and the central actor. Table 2 also

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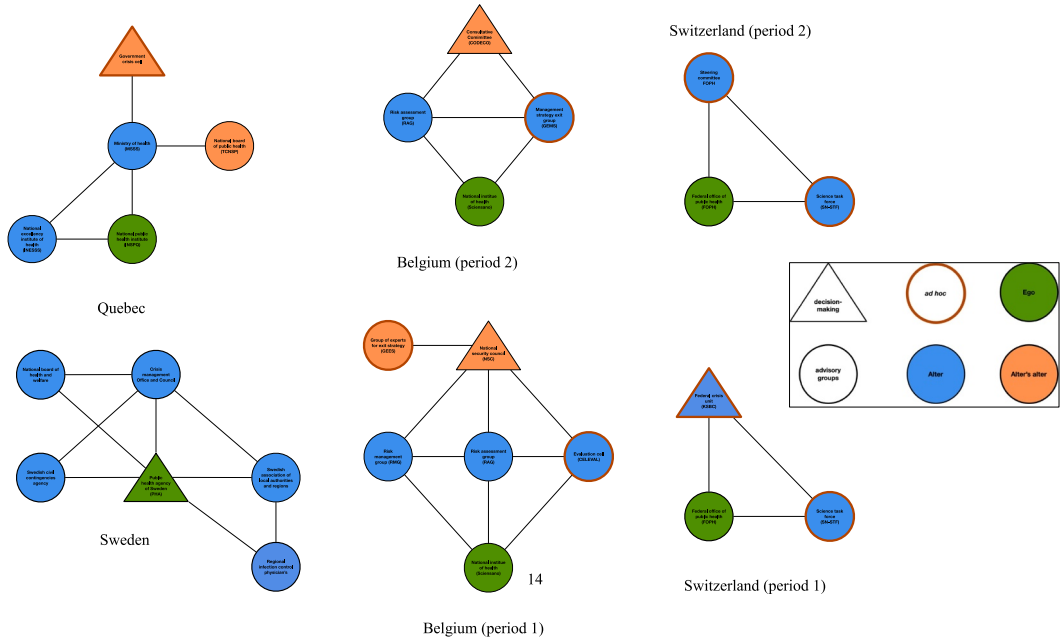


FIGURE 1 Public health advisory networks during the COVID-19 pandemic in Sweden, Switzerland, Belgium and Quebec.

incorporates the openness score, derived from adapting the subsystem approach. Results are discussed in the sections below.

4.1 | Mapping advisory networks in public health during the COVID-19 pandemic

The primary criterion for selecting the initial node for the network analysis is the organization formally certified as the primary source of advice on infectious disease control before the pandemic (marked in green in Figure 1). In three of the four jurisdictions—Quebec, Sweden, and Belgium—this organization is a legally established PHA. Hence, the analysis shows that internal provision of advice was often preferred. In Sweden, the PHA was formed in 2014 following the merger of two organizations (Olofsson et al., 2022). Similarly, in Belgium, Sciensano was established in 2018 as a result of a double merger (Fallon et al., 2020). In Quebec, the Institut national de santé publique du Québec (INSPQ) was created in 1998 as a new entity (INSPQ, 2023).

In three jurisdictions—Quebec, Belgium, and Switzerland—these organizations did not possess any capacity to set policy goals (indicated by triangles in Figure 1), which implies a model of subordination, where public health experts recommend, and the government decides. This subordination can lessen the use of expertise, allowing governments to draw information from non-expert sources. Indeed, studies in Belgium showed an instrumental use of science (Easton et al., 2022, ; Pattyn et al., 2021; Zaki et al., 2021; Zaki & Wayenberg, 2021). In Switzerland, experts were sidelined during the pandemic, at the benefit of groups at the forefront of the country's corporatist tradition (Armingeon & Sager, 2022; Eichenberger et al., 2023).

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TABLE 2 Results of the egocentric network analysis and openness score measurements.

		Belgium 1st period	Belgium 2nd period	Sweden	Switzerland 1st period	Switzerland 2nd period	Quebec
Egocentric network analysis	Density	0,6	0,83	0,6	**1**	**1**	**0,5**
	Centralization	0,11	0,11	0,06	**0**[b]	**0**	**0,125**[c]
	Central actor[a]	NSC + RAG (hybrid)	GEMS + RAG (hybrid)	PHA (public health agency)	None	None	MSSS (political)
Openness score		5		**1**	**7**		**1**

[a]The central actor indicated here corresponds to the node in the network with the minimum value of closeness centrality, that is, the node closest to all other nodes. In network analysis, a node represents an individual actor or entity within the network.

[b]The cells shaded in light gray represent the lowest values.

[c]The cells shaded in dark gray represent the highest values.

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In Quebec, the influence of expert advice diminished during the pandemic in favor of public opinion (Lemor et al., 2024).

In Switzerland, the initial organization is a federal office directly attached to the Department of the Interior, rather than a specialized PHA with autonomy (in green, Figure 1). The Swiss Department of the Interior usually tends to turn to external ad hoc organizations for expert advice rather than having its own resources (Hadorn et al., 2022; Hofmänner, 2021). Consequently, the network includes temporary ad hoc organizations, including the primary expert group mandated during the pandemic, the SN-STF. While infectious disease expertise is legally located within the Federal Commission for Pandemic Preparedness and Responses (FCP), in practice, the significance of these commissions has gradually declined (Hadorn et al., 2022, p. 364). In fact, the FCP was not convened during the pandemic.

Sweden is the only jurisdiction in which the PHA has some decision-making powers. Resulting from a desire to clarify the division of tasks, the 2014 merger that created the agency was aimed at fostering cohesion in pandemic response (Brusselaers, 2022; Olofsson et al., 2022, 2–3). This desire for cohesion is reflected in the requirement for other government agencies to adhere to the PHA's guidelines and strategy in the event of a pandemic. Of the four jurisdictions, Sweden is the only one whose advisory network does not correspond to a model of subordination to politics. Its advisory network is semi-autonomous, making the recommendations of the PHA difficult for the government to ignore. This context can explain the influence of the perspectives of the PHA's chief epidemiologist (Lemor et al., 2022).

Quebec and Sweden contrast with Belgium and Switzerland in terms of network stability (Figure 1). In Belgium, the network was modified in November 2020 amidst declining public adherence to NPIs (Easton et al., 2022; Zaki et al., 2021, p. 321). Similarly, in June 2020, Switzerland ended the extraordinary legal status granting the federal government sole responsibility for managing the pandemic (Armingeon & Sager, 2022). The network was then modified, and the main expert group, the SN-STF, lost its direct connection with policymakers (Eichenberger et al., 2023). This second period was marked by contentious relations between experts and policymakers. An expert resigned from the SN-STF, and a bill was introduced in the federal parliament to ban unauthorized public statements by the SN-STF whose influence declined (Armingeon & Sager, 2022; Eichenberger et al., 2023).

Interestingly, the instability of the Belgian and Swiss networks coincides with the presence of ad hoc expert groups specifically created to inform policymakers during the pandemic (red circles, Figure 1). The Belgian advisory network included several ad hoc groups which changed over the course of the pandemic to sometimes include new expertise, particularly in the social sciences. While the Swiss case reflects a usual practice of temporary mobilization of expertise (Hadorn et al., 2022; Hofmänner, 2021), the Belgian case is consistent with the complexity of its advisory network during the pandemic (Zaki & Wayenberg, 2021, p. 22). Indeed, during a health crisis, ad hoc groups are sometimes employed, beyond merely providing advice, as coordinating entities for various agencies and actors involved, aiming to enhance the efficacy of policies (Nair & Garg, 2024).

4.2 | Egocentric network analysis measures: Insight into control, management, and information processing of advisory networks

Three key finding emerge from egocentric network measurements (Table 2). Firstly, the jurisdiction with the highest network density (where a higher density indicates more

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interconnected actors) is Switzerland, followed by Belgium (1st period), then Sweden, and lastly Quebec. Conversely, the most centralized jurisdiction (where higher centralization indicates more actors being concentrated around a single node) is Quebec, followed by Belgium (2nd period), Sweden, and Switzerland. Finally, the central actor in Belgium consists of hybrid groups (experts and policymakers). In Sweden, it is the PHA. In Switzerland, no actor is central as the network displays an equal number of edges. In Quebec, it is a political and administrative actor, the Ministry of Health. These three elements provide insights into the control of advisory networks (particularly whether the central actor is political or rather a group of experts), their management (especially in terms of centralization and network density), and the processing of advice (by focusing on the structure and the relationships between actors).

The high density of the Swiss network highlights its horizontality, lack of centralization, and low institutionalization. During the pandemic, the Swiss advisory network relied on ad hoc groups providing knowledge on demand—a common practice in Switzerland—due to the absence of a formal PHA (Hadorn et al., 2022; Hofmänner, 2021). The main expert group, the SN-STF, is unique among the four jurisdictions in the sense that it was established on the initiative of, and by experts and academics themselves (Hofmänner, 2021). The SN-STF was then mandated by the government to produce advice in a broad range of areas from public health to economics (SN-STF, 2023). Poorly integrated into a weakly institutionalized network, the influence of the SN-STF rapidly declined during the pandemic (Eichenberger et al., 2023).

In contrast, Quebec's advisory network constitutes the least dense but most centralized network. The network is centered around actors of the central administration (the Ministry of Health, MSSS; Figure 1), maintaining close ties with two public health agencies, INSPQ and INESSS. The strong centralization of the network around the ministry, which constitutes the central actor of the network, reflects the government's preference for a strict control of information and advice during the pandemic. The political control of information in Quebec has indeed been underscored in evaluation reports (CSBE, 2022, p. 78). Compared to Switzerland, Quebec is thus more institutionalized and centralized but less dense.

In the case of Sweden, the network is less centralized than Quebec—and slightly denser, the difference being minimal—meaning that actors within the network tend to be more interconnected. The PHA is the central actor of the network, reflecting its status, autonomy, and power. The PHA is the formally designated organization for producing knowledge and controlling infectious diseases (Brusselaers, 2022; Olofsson et al., 2022). Like Quebec, the existence of this agency has discouraged resorts to ad hoc organizations to provide additional advice during the pandemic, as was the case in Belgium and Switzerland (Figure 1). The moderate density of the Swedish network indicates a network management based on collaboration among various groups around the PHA and a limited political control of the network.

Regarding the Belgian network, its density in period one is similar to that observed in Sweden, but it becomes higher in the second period. Moreover, it has the second-highest level of centralization, suggesting tightened political control and management of the network. This political control is also reflected in the nature of the central actors of the network, which comprise both policymakers and experts. Furthermore, the high density of the Belgian network is coupled with a large number of actors, further complicating its organization (Figure 1). The network's density in Belgium has been compared to a "labyrinth" during the pandemic (Zaki & Wayenberg, 2021, p. 22).

It should be noted that, except in the Swedish case, the central actors in the networks are not organization exclusively made of experts. This implies that the advice produced by advisory organizations were often not transmitted directly to policymakers but were mediated by a third,

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often political, organization. In Quebec, this role is played by the Ministry of Health and Social Services (MSSS). In Belgium, during the first period, it is primarily the Risk Management Group (RMG), composed of experts and political representatives, along with the Risk Assessment Group (RAG), made up of experts only. In the second period, the RMG was replaced by the Exit Strategy Management Group (GEMS), tasked with planning the end of the crisis.

In Switzerland, a group also acted as an intermediary, but only in the second period. In the first period of the pandemic, the Science Task Force (SN-STF) conveyed its advice directly to the federal crisis unit (KSBC). In the second period, the advice from the SN-STF was channeled through a Steering Committee within the Federal Office of Public Health, which had access to policymakers (not shown in Figure 1). The change observed in Switzerland between period 1 and period 2 aligns with the observed decline in the influence of experts over the course of the pandemic (Armingeon & Sager, 2022; Eichenberger et al., 2023).

These variations reflect differences in the political systems of each advisory network. The Belgian advisory network draws from a tradition of consensus-seeking and neo-corporatist practices (Pattyn et al., 2019), as does the Swiss network (Armingeon & Sager, 2022; Hadorn et al., 2022; Hofmänner, 2021). Quebec's network aligns with a state-centered tradition, centralizing expertise near the government. Indeed, the ad hoc crisis unit was tightly controlled by the province's premier (see CSBE, 2022). The absence of an intermediary body in Sweden aligns with a centuries-old principle of "executive dualism," prescribed by the constitution, which affords agencies a semi-autonomous position (Ahlbäck Öberg & Wockelberg, 2016).

4.3 | Evaluating network openness and its impact on public health advisory networks

The openness scores of networks are presented alongside egocentric network analysis measurements in Table 2. Drawing from the subsystem approach, these scores gauge the network's openness to actors and ideas, where a higher score indicates a greater openness. More open networks contain a diversity of actors and expertise, are more accessible in terms of information, ideas, and membership, but are also conducive to disagreements. Our results show that, from this perspective, the Swiss network is the most open, followed by the Belgian network, and then the Swedish and Quebec networks.

The high openness of the Swiss and Belgian networks aligns with the egocentric analysis. The openness to new actors and ideas resulted in more instability and ad hoc groups. This is particularly noticeable in Switzerland where the main expert group advising the government during the pandemic, the SN-STF, was established at the initiative of experts themselves. The process leading to certification and exchanges with government authorities were more transparent and received extensive media coverage (Hofmänner, 2021; Tinari & Riva, 2023). In Belgium, critiques from experts led to the inclusion of new disciplines, and the openness of the network was such that an expert was selected after being noticed on social media (Easton et al., 2024).

Conversely, in Sweden and Quebec, the advisory networks formed a closed community of experts who enjoyed privileged access to policymakers and were concentrated around central regulatory actors, either an agency or a ministry. Consequently, the range of expertise was more limited and controlled, leading to greater network stability (Figure 1). This significant closure of the network to new actors in Sweden resulted in the formation of an external group of experts that publicly contested the orientations of the certified experts, in addition to complaining about

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restricted access to decision-makers (Vogel, 2020; Vetenskapsforum COVID-19, 2023). In Quebec, the closure of the network limited discussions around a virus suppression strategy, limiting consideration for mitigating measures, resulting in a particularly severe policy approach to the pandemic amidst uncertainty (Lemor et al., 2024; Lemor & Montpetit, 2024).

The diversity within the Belgian and Swiss networks was much broader than in Quebec and Sweden. In Switzerland, the SN-STF included experts in social sciences and economics from the outset. In Belgium, the PHA, Sciensano, was relegated to the background, although it did provide public health experts to the ad hoc groups the government preferred for supplying advice. The expertise represented in these groups, especially in the latter half of the crisis, extended beyond public health to include specialists in psychological and social issues (Zaki et al., 2021). Perspectives were much more disputed internally in the Swiss and Belgian networks than they were in the Swedish and Quebec networks.

Finally, network openness is associated with higher density and lower centralization, as indicated in Table 2. These findings are consistent, especially as higher network density implies higher horizontality and less centralization around a dominant actor who could regulate the network in terms of composition or ideas. Conversely, a more centralized and less dense network implies lesser interconnections between actors, resulting in a less horizontal network. For instance, the most closed networks have a single central actor, whereas open networks either have multiple central actors (both policymakers and experts) or none. Therefore, network openness is associated with the absence of a central actor, as well as with greater instability of the network over time (Figure 1).

5 | DISCUSSION AND CONCLUSION

Employing two distinct methods, this article offers a systematic way to describe public health advisory networks during the COVID-19 pandemic. The strength of this dual-method approach is its ability to simultaneously address two critical dimensions: differences in network structure, such as density, centralization, and the role of the central actor, and variations in network openness and closure. These aspects are essential for understanding the networks' configuration and their internal characteristics in relation to policy change, and the question of management and control within the advisory networks. Two main observations emerge from these analyses.

Firstly, regarding policy change, while the relationship is undoubtedly complex, we argue that systematic descriptions of advisory networks are still valuable for explaining, to a certain degree, the stability or change in policy strategies. For example, we observed more closed and less dense networks in Quebec and Sweden. Notably, Quebec and Sweden did not undergo major changes in overall policies during the pandemic. Quebec's particularly stringent policies Sweden also demonstrated stability in its strategy over time (Olofsson et al., 2022). Despite were sustained from the onset of the pandemic until February 2022 (Lemor et al., 2024), and the possibility for a strategic shift provided by the exceptional legislation adopted in January 2021, the Swedish government opted to continue with its initial approach to the pandemic (Berger, 2021).

The configuration of the Swedish public health advisory network, characterized by the centrality of a single regulatory actor—the PHA—neutralized internal dissent and influenced the range of policy alternatives throughout the pandemic. The chief epidemiologist, A. Tegnell, who favored a voluntary approach, was able to significantly influence Sweden's strategy due to this configuration. Similarly, in Quebec, a comparable structure was centered around a single

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regulatory actor, in this case, a politico-administrative entity—the Ministry of Health. The centrality of the Ministry may explain that political considerations such as public opinion are part of the explanation for Quebec's severe policy throughout the pandemic (Lemor et al., 2024). Although not a determinant factor in policy change by itself, the configuration and openness of advisory networks enable the causal effect of individual variables, whether it be the preference of a chief epidemiologist or the political pressure of public opinion.

In contrast, the more open, denser, and less centralized Belgian and Swiss public health advisory networks facilitated policy change during the pandemic. For instance, Belgium, after incorporating new experts into its public health advisory network in the fall of 2020, adopted policies addressing the psychosocial impact of the pandemic (Zaki et al., 2021). Similarly, public disagreements within the Swiss public health advisory network enabled the government to become less responsive to expert advice in late 2020 (Armingeon & Sager, 2022; Eichenberger et al., 2023). The presence of ad hoc expert groups in these two networks indicates their greater openness in terms of membership and ideas. Indeed, ad hoc groups are less regulated and more diverse and can initiate reflexive learning by incorporating new perspectives (Nair & Garg, 2024, 13-4). However, instability seems to be a consequence of the openness of these networks, which reorganized during the pandemic. This openness also led to disagreements around differing perspectives among experts (Easton et al., 2024, p. 14).

These systematic descriptions are crucial for understanding advisory network management and control (Marciano & Craft, 2023). They show variations in control mechanisms between countries like Sweden and Quebec, where government or autonomous agencies tightly regulate networks, and Belgium and Switzerland, where control was looser and more fluid. These descriptions inform the recent theoretical debate on the management and control of advisory systems which posits the government as the primary actor in exerting control (Marciano & Craft, 2023). For instance, in Sweden, control lies with an autonomous agency rather than the government. This further justifies the empirical work carried out here by highlighting the importance of considering who controls advisory networks and to what extent, shifting focus from government control to broader network dynamics.

Three limitations of this study must be highlighted. The first relates to the unconventional use of egocentric network analysis. We explicitly state that our analysis employs these concepts in a contextually expanded form. This approach does not strictly adhere to the conventional quantitative social network analysis but is designed to provide a nuanced understanding of advisory networks' structure and function adapted to the institutional context and the objectives of the study, especially in terms of analyzing certified public health advisory networks. Second, we produce measures of density, centralization, or closeness centrality without directly resorting to the methods of generating quantitative social network analysis, which may raise some concerns. However, the selection of the ego, the determination of their characteristics and their links, and all the data collected followed a rigorous protocol respecting a set of pre-established rules that we reproduce in Appendix 1. These rules were precisely constructed to ensure a robust and comparative empirical analysis. Finally, this study paves the way for new empirical research and encourages, when possible, subsequent research to explore advisory network dynamics with traditional SNA methodologies.

ACKNOWLEDGMENTS

The work of Éric Montpetit and Antoine Lemor was supported by the Social Sciences and Humanities Research Council (SSHRC) of Canada [grant number 435 2021 0332] and the Fonds de recherche du Québec (FRQ) [grant number 203845]. The work of Jean-Louis Denis and

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Shoghig Téhinian was supported by a Canadian Institute of Health Research (CIHR) grant, "The prospect of wise governments: The Canadian experience of policy learning in and after COVID-19 pandemic (2022–2023)" and by the Canada Research Chair on Health System Design and Adaptation. The work of PerOla Öberg was supported by Riksbankens jubileumsfond, grant number P20-0463.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to report.

DATA AVAILABILITY STATEMENT

Data derived from sources in the public domain.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Lemor, A., Montpetit, É., Téhinian, S., Belleghem, C. V., Eichenberger, S., Öberg, P., Varone, F., Aubin, D., & Denis, J.-L. (2024). Network dynamics in public health advisory systems: A comparative analysis of scientific advice for COVID-19 in Belgium, Quebec, Sweden, and Switzerland. *Governance*, 1–20. https://doi.org/10.1111/gove.12885

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