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Public orchestration, social networks, and transnational environmental governance: Lessons from the aviation industry

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Abstract
This article contributes to current debates on the potential and limitations of transnational environmental governance, addressing in particular the issue of how private and public regulation compete and/or reinforce each other – and with what results. One of the most influential approaches to emerge in recent years has been that of "orchestration." But while recent discussions have focused on a narrow interpretation of orchestration as intermediation, we argue that there is analytical traction in studying orchestration as a *combination* of directive and facilitative tools. We also argue that a social network analytical perspective on orchestration can improve our understanding of how governments and international organizations can shape transnational environmental governance. Through a case study of aviation, we provide two contributions to these debates: first, we propose four analytical factors that facilitate the possible emergence of orchestration (issue visibility, interest alignment, issue scope, and regulatory fragmentation and uncertainty); and second, we argue that orchestrators are more likely to succeed when they employ two strategies: (i) they use a combination of directive and facilitative instruments, including the provision of feasible incentives for industry actors to change their behavior, backed up by regulation or a credible regulatory threat; and (ii) they are robustly embedded in, and involved in the formation of, the relevant transnational networks of actors and institutions that provide the infrastructure of governance. © 2017 JohnWiley & Sons Australia, Ltd

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Introduction

The challenges involved in tackling global environmental problems, such as increasing greenhouse gas (GHG) emissions, are enormous. Regulation by nation states is only effective globally if all major polluting countries apply similar measures. International agreements that can provide common regulatory platforms have been difficult and slow to negotiate. Even when successfully concluded, key polluting industries may remain out of their remit – international shipping and aviation, for example, are not covered by the Paris Agreement, thus limiting its effectiveness. In parallel to these processes, a wide range of voluntary, experimental, and innovative governance initiatives have emerged at various geographic scales to tackle environmental challenges, from networks of cities to multi-stakeholder initiatives on sustainability – often driven by, or operated in cooperation with, business, industry associations, and civil society groups. The existing fragmentation of governance fields limits the aggregate effects of these initiatives, because of possible duplication or conflict between them. How can governments and international organizations (IOs) avoid hampering innovation and variety at the same time as ensuring that these initiatives pull in the same direction? In this article, we provide a contribution to answering this question through a theoretical engagement with the nascent field of "public orchestration" and an empirical case study of the aviation industry.

Aviation is one of the main global GHG-emitting industries, and one in which change is hampered by low operating margins and made slow by the dominance of capital intensive and mobile assets (Gössling & Upham 2009). Its main international regulatory body, the International Commercial Aviation Organization (ICAO) has been ineffective at

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providing global regulation on the environmental impacts of the industry. At the same time, a variety of voluntary initiatives have emerged, but with important orchestration functions carried out by the United States (US) and the European Union (EU), including key roles in the construction of a globally connected network on aviation biofuels. This case study provides an opportunity to learn important lessons on how national and (in the case of the EU) regional governments can exercise orchestration in the absence of an effective global regulator – a condition that is common in many industries and regulatory fields.

Our contribution speaks directly to current debates on the potential and limitations of transnational environmental governance (TEG), but is framed within a broader debate (to which *Regulation & Governance* has provided key contributions) on how private and public regulation compete and/or reinforce each other. Part of the existing literature suggests that private regulation started strengthening from the 1980s onwards as a result of the failure of (or retreat from) public authority in regulating pressing social and environmental challenges – especially those with a transnational or global character – eventually leading to a crowding out of public regulatory instruments by private regulation (Cutler *et al.* 1999; Bartley 2007; Vogel 2008). An alternative argument is that public authorities remain key not only in providing legitimacy to private regulation, but also in facilitating its compliance (Black 2003; Gale & Haward 2011; Foley 2013; Verbruggen 2013; Gulbrandsen 2014; Mills 2016). A main focus in existing work has been the interplay of government, civil society, and business (Avant *et al.* 2010) to understand how they compete and/or cooperate to shape rule systems and achieve legitimacy (Bernstein & Cashore 2007; Black 2008; Fransen 2012; Eberlein *et al.* 2014), with particular attention paid to the effects of alignment and misalignment of interests between industry and the state (Verbruggen 2013; Auld 2014; Gulbrandsen 2014; Mills 2016).

This vast body of literature has provided important insights in unpacking the complexity of transnational governance fields variously conceptualized as "hybrid governance" (Ponte & Daugbjerg 2015), "ensemble regulation" (Perez 2011), "partnered governance" (Hale & Roger 2014), "regulatory ecosystems" (Meidinger 2009), "co-regulation" (Sinclair 1997; Gunningham & Sinclair 2002; Gunningham 2009) and "responsive regulation" (Ayres & Braithwaite 1992; Abbott & Snidal 2013). There has also been growing attention paid to understanding how interests can be (and have been) *made* to align – in other words, whether and how public authority can (or should) work to bridge possible gaps between different groups of public, private, and civil society actors and/or work to shape established positions to new realities. This literature examines how public authorities can "steer" an existing variety of private and hybrid governance instruments to promote desired outcomes. Examples are Braithwaite and Drahos (2000) and Black (2003), who have variously employed the concept of "enrolment" for this purpose; Hale and Roger (2014), who have used the concept of "steering"; and Overdevest and Zeitlin (2014), who have applied the lenses of experimental governance to examine processes such as benchmarking.

One of the most influential approaches to emerge in recent years, however, has been that of "orchestration." While not diverging substantially from the concerns of experimentalist governance and from the concept of "steering," orchestration has provided an intuitive heuristic device that reflects the current complexities of governing: as the conductor of an orchestra needs to make all her musicians work together, public authority needs to align different kinds of instruments – some of which it has some degree of control and influence over, and some of which it can only indirectly shape or facilitate (Abbott & Snidal 2009a, 2009b, 2010, 2013; Schleifer 2013; Hale & Roger 2014; Abbott *et al.* 2015).

We use a slightly different term, "public orchestration," to even more explicitly signal a concern with tools and a combination of instruments that *public* regulatory bodies can use to shape TEG. These can involve indirect tools and soft power in view of steering industries and citizens toward addressing global problems, but also more direct regulatory tools, regulatory threats, and/or incentives – thus including instruments that nudge actors toward self-regulation and those seek public and private sector co-regulation (as in Gunningham & Sinclair 2002; Albareda 2008; Héritier & Eckert 2008; Gunningham 2009). Although more recent literature has focused on IOs as possible orchestrators, our main proposition is that in regulatory fields or industries lacking an effective IO that handles environmental concerns, key national/regional governments can play key roles as orchestrators of TEG (Abbott *et al.* 2015).

In this article, we engage in theory building and descriptive inference to provide two sets of arguments. First, we propose four *analytical factors* that facilitate the possible emergence of orchestration: issue visibility, interest alignment, issue scope, and regulatory fragmentation and uncertainty. Second, we argue that orchestrators are more likely to succeed when they employ two *strategies*: (i) they use a combination of directive *and* facilitative instruments, including the provision of feasible incentives for industry actors to change their behavior, backed up by regulation or a credible regulatory threat; and (ii) they are "robustly" embedded in, and involved in the formation of, the relevant transnational networks of actors and institutions that provide the infrastructure of governance.

We specifically stress the importance for public orchestrators to embed themselves within networks of experts and other stakeholders, an aspect that has rarely been explored in the literature so far (among recent exceptions, see Fransen 2015; Henriksen 2015; Fransen *et al.* 2016; Henriksen & Seabrooke 2016; Seabrooke & Henriksen 2017). These networks can be used to stay informed on what industry is doing and to communicate signals to industry about where policies are headed. The use of social networks to orchestrate the interplay of various governance instruments is an important yet understudied aspect of orchestration – especially in the context of transnational governance processes. Through our analysis of the position of public organization within the issue-specific social network of aviation biofuel – alongside in-depth qualitative analysis of the institutional features and trajectories of governance initiatives – we are able to assess the relative prominence of different public organizations and provide insights about how this might reflect on their ability to orchestrate. Our combination of interpretive analysis and social network analysis (SNA) helps us provide insights on orchestration that are at the center of current theoretical debates, but that need further empirical exploration – including what role (national and regional) public organizations play in transnational governance interactions (Eberlein *et al.* 2014). Using a novel network data set on aviation biofuels (developed by the authors), we apply exponential random graph models (ERGM) to model the relational configuration of public orchestrators, including what mix of actors they interact with in learning and information-sharing networks.

Transnational environmental governance and orchestration

What we call TEG consists of "transnational actors operating in a political sphere in which public and private actors interact across borders and political jurisdictions" to address environmental concerns (Andonova *et al.* 2009, p. 69). TEG is fragmented, multi-layered, characterized by a hybrid of private and public authority, and takes place through different kinds of partnerships – frequently involving the steering of networks to achieve public policy goals (Haas 2004; Bäckstrand 2008; Andonova *et al.* 2009; Andonova 2010). Yet we still know too little about the characteristics of these networks, who steers them, and to what degree they are steered.

A major area of interest in the TEG literature has been establishing the extent to which private authority has led to a wholesale retreat of the state or to new overlaps between public and private spheres (Cashore *et al,* 2004; Bartley 2007; Bernstein & Cashore 2007; Pattberg 2007; Gulbrandsen 2010; Büthe & Mattli 2011). A now extensive literature has usefully shown that state capacity still has a crucial role in facilitating the emergence, implementation, and enforcement of private regulation, and that successful public support is more likely to happen when norms, objectives, and interests overlap between the public and private spheres (Gale & Haward 2011; Foley 2013; Verbruggen 2013; Auld 2014; Bartley 2014; Gulbrandsen 2014). Other work has focused on understanding the numerous transnational experiments and entrepreneurial governance initiatives that are being carried out by cities and their networks, industry associations and individual corporations, international and local non-governmental organizations (NGOs), and other non-state actors (Andonova *et al.* 2009; Dingwerth & Pattberg 2009; Overdevest 2010; Hoffmann 2011; Bulkeley *et al,* 2012; Green 2013, 2014; Ponte 2014a, Overdevest & Zeitlin 2014).

For the purpose of this article, we engage specifically in TEG debates that are concerned with the possible mechanisms and strategies that nation states and IOs can use to shape environmental outcomes (Keohane & Victor 2011; Hale & Roger 2014; Abbott *et al.* 2015; Graham & Thompson 2015). A major source of concern in this realm remains the "fragmentation" of governance architectures in the environmental field and the resultant "governance deficit" (Haas 2004; Biermann *et al.* 2009; Zelli & van Asselt 2013). Although new experimentation and innovation in TEG was ushered in by the 1992 Earth Summit in Rio, nation states and IOs are only slowly coming to terms with the complexity of emerging multi-level and decentralized governance initiatives, and are starting to act as "entrepreneurs to facilitate collaboration with non-state actors within their spheres of expertise" (Andonova 2010, p. 26; see also Andonova & Hoffmann 2012).

The concept of orchestration provides an explicit analytical and normative tool to address the current TEG deficit. Orchestration entails paying critical attention "not only to who is involved in transnational governance, but also to the ways in which transnational networks deploy different sources of authority and mechanisms of steering in order to govern" (Andonova *et al.* 2009, p. 57). It goes beyond the established distinctions between self-regulation, co-regulation, and hierarchy to highlight the combinations that may be successful to push forward an environmental agenda in transnational governance (Sinclair 1997).

Abbott and Snidal (2009b) distinguish two broad sets of mechanisms under the concept of "orchestration," some of which are defined "directive" and others "facilitative" (see also Schleifer 2013). On the one hand, they see directive orchestration as relying on the authority of the state and seeking to incorporate private initiatives into its regulatory framework (through mandating principles, transparency, codes of conduct). On the other hand, they conceive facilitative orchestration as relying on softer instruments, such as the provision of material and ideational support (financial support, technical support, endorsement), in order to kick-start new initiatives and/or to further shape and support them. Similarly, Hale and Roger see orchestration as "a process whereby states or inter-governmental organizations initiate, guide, broaden, and strengthen transnational governance by non-state and/or sub-state actors" (2014, pp. 60–61), and distinguish between "initiating" orchestration, where states or IOs are active in forging a new initiative, and "shaping" orchestration, where they lend support to already existing initiatives.

More recently, Abbott *et al.* have taken a narrower view of orchestration as occurring when an IO "enlists and supports intermediary actors to address target actors in pursuit of… governance goals" (2015, p. 4). Orchestration, from their current perspective, is a specific form of governance characterized by *soft* instruments and *indirect* influence on target actors, in what they call the "O-I-T model" (orchestrator-intermediary-target). In this interpretation, intermediation and orchestration are used synonymously to identify a specific form of governance that is distinguished from the other three forms: (i) hierarchy, the more traditional form where a governor applies *hard* regulatory tools *directly* to its targets; (ii) delegation, where the governor uses *hard* regulatory tools but delegates the regulatory function to another party, thus has *indirect* influence (Green 2013, 2014); and (iii) collaboration, where the governor utilizes *soft* tools, such as ideational or material incentives, and collaborates *directly* with the targets of regulation (Cutler 1999).

In Abbott *et al.*'s (2015) model, intermediation is indirect because orchestrators enlist an intermediary institution between them and the targets of regulation, and is soft because it uses facilitative instruments. Abbott *et al.* also propose a series of hypotheses to explore when intermediation is more likely to work. These are: (i) low orchestrator capabilities in focal domain, (ii) intermediary availability, (iii) low orchestrator focality (other actors are also operating in the governance domain), and (iv) an organizational structure that facilitates entrepreneurship. To these, they add two hypotheses that apply specifically to IOs: (v) there is divergence of goals among member states, and (vi) there is weak oversight of member states in the focal domain (Abbott *et al,* 2015, pp. 20–30). These conditions, with the exception of "organizational culture," are based on rational choice and institutionalist considerations. As we will discuss, some of these factors explain why the relevant IO (ICAO) did *not* use intermediation in the TEG of aviation. However, they do not explain why and how, in the absence of ICAO action, other public authorities (in the US and the EU) were actually successful in orchestrating transnational (not only domestic) environmental governance.

We take three points of departure from Abbott *et al.*'s (2015) approach: (i) we re-focus on the role that national and regional regulators can play in orchestrating TEG, a key feature, especially in regulatory fields or industries lacking an effective IO; (ii) we return to the broader conceptualization of orchestration as a tool used by public orchestrators to steer TEG through *a combination of different instruments* – direct and indirect, soft and hard; and (iii) we identify key factors of orchestration through a mixture of institutionalist, evolutionary, and sociological approaches, including an examination of how these instruments can be woven together through network formation and maintenance.

We do so in recognition that public governors often use a combination of mechanisms, including network formation, in attempting to achieve policy goals, and that outcome effectiveness is linked to different combinations of these mechanisms in the context of industry or issue specificity, rather than the superiority of one governance form over another. In our approach, intermediation is indeed an important governance tool to be examined, but does not equate with orchestration. In other words, orchestrators may combine hard regulatory tools with softer instruments, such as mandates or subsidies, sometimes with the threat of future/stronger regulation, an aspect not captured by either hard or soft instrument classification. Orchestrators, when using soft instruments, may also operate *both* directly *and* through intermediaries. Furthermore, they can combine hierarchy, collaboration, delegation, and intermediation with other *hybrid* mechanisms, such as placing their representatives in regulatory intermediaries – an approach that is neither pure intermediation (the orchestrator populates the "intermediary") nor collaboration (the orchestrator does not regulate directly). Orchestrators can also employ different tools at different times in their historical trajectories, thus calling for an evolutionary perspective.

Clearly, Abbott *et al.*'s (2015) classification is a useful heuristic device that can help to disentangle some of the complexity of transnational governance, and clarifies the role of intermediation – a governance instrument that has attracted less attention form researchers so far. However, we argue that what distinguishes "orchestration" in the broader sense of the term we employ here is a focus on what combinations of regulatory tools governments and IOs can and do use.

In our framework, we take two steps. First, we go back to the descriptive classification of orchestration instruments originally developed in Abbott and Snidal's (2009b) earlier work, which distinguishes: (i) *directive* orchestration instruments, which for us include international and national regulation, the "threat of regulation," also known in the literature as the "gorilla in the closet" or "shadow of hierarchy" factor (Bäckstrand 2008; Verbruggen 2013), the incorporation of private standards, codes of conduct or transparency measures in public regulation, the provision of direct subsidies and the setting of mandates, and public procurement and other direct forms of direct financial support and investment; and (ii) *facilitative* orchestration instruments, where public authorities either facilitate, indirectly influence, network, and/or participate with other stakeholders in key initiatives or groups – such as industry associations, multi-stakeholder initiatives, and industry conferences.

Thus, we propose that successful orchestration *trajectories* entail the use of plural governance tools and a combination of direct and indirect instruments – together with active participation of the orchestrators themselves in the relevant regulatory networks. The latter aspect remains underexplored in the literature, and current research tells us little about what the social networks of public orchestrators look like and what types of actors they interact with in learning and information-sharing networks. Given that not only facilitative, but also directive orchestration tools hinge on effective social coordination with regulatory targets (as well as with intermediaries), building relations of learning, information-sharing, and trust within the broader regulatory environment is an important factor to be examined. The coordination of different instruments within specific jurisdictions in itself can be enabled through social networks, but when this needs to take place across jurisdictions, acting through social networks can become even more important for national and regional public authorities.

Second, we propose four *analytical factors* that can help explain (and potentially predict) the conditions that facilitate orchestration (rather than intermediation per se): issue visibility, interest alignment, issue scope, and regulatory fragmentation and uncertainty. These four factors were co-developed by one of the authors elsewhere by drawing on some of the key insights of the literature on TEG (Lister *et al.* 2015). On *issue visibility*, we can expect more potential for orchestration if the industry involved, and the related set of environmental issues are clearly visible to the general public, and particularly to consumers (Dauvergne & Lister 2012). On *interest alignment*, we can expect better orchestration possibilities if there is substantial overlap between public and private interests, and relative cohesion internally within each sphere (Schleifer 2013; Verbruggen 2013). On *issue scope*, we can expect orchestration to be more likely to succeed when addressing a narrower and more specialized set of issues, rather than a more comprehensive set (Auld 2014). On *regulatory fragmentation and uncertainty*, we can expect more difficult conditions for orchestration in situations when public regulation of environmental concerns is fragmented and uncertain, and when relevant private or hybrid initiatives are multiple and diverse (Haas 2004; Alter & Meunier 2009; Biermann *et al.* 2009; Fransen 2012; Zelli & van Asselt 2013).

Case selection and methodology

To test these propositions empirically, we selected the aviation sector as a case study of orchestration. The aviation industry provides a critical case study for two reasons. First, within the transport sector, it has the highest CO_2 emissions per unit transported, and is projected to have a faster growth rate than other modes of transport. It has experienced constant growth over the last three decades, and continues to do so, spurred by low-cost airlines and growth in emerging markets (Gössling & Upham 2009). Air travel emits 650 million tons of CO_2 a year and is responsible for approximately two percent of annual anthropogenic CO_2 emissions or 10 percent of total emissions from transport, with estimates suggesting that it could rise to three percent of global emissions by 2030 and to five percent by 2050 (IATA 2013; Lane 2014). Longer flights and more passengers have entailed the rapid growth of total passenger kilometers (pKm) traveled, from 28 billion pKm in 1950 to 5.4 trillion pKm in 2012 (European Environment Agency website). In 2012, aviation moved almost three billion people, a growth rate of almost five percent over the previous year and up from 960 million passengers in 1986 and 31 million in 1950. Improved aircraft and engine design and materials, as well as improved air control and airport operations, have decreased the unit rate of emissions, but these factors alone are not enough to curb the predicted future increase of emissions.

In other words, the aviation industry is under normative pressure to address the growth of GHG emissions, but needs to do so in a global, comprehensive manner – given that it operates at extremely low margins (Doganis 2001, pp. 2–4). Despite this pressure, the IO that regulates the industry (ICAO) has historically failed to seriously tackle the environmental impacts of its operators. The other international agreement that could have regulated at least GHG emissions (the Paris Agreement) failed to include aviation in its remit. Therefore, a combination of normative pressure and regulatory failure at the global level entails that national and regional governments have taken (and kept) the mantle of orchestrators. As a result, the industry is now focused on regulating and supporting the development of renewable jetfuels (hereafter "aviation biofuels"). We focus on this particular aspect of the aviation industry in this article.

Second, the emergence of aviation biofuels as the principal response to the normative pressures on the aviation industry makes it a critical case for exploring the role of networks in the orchestration of TEG. The aviation biofuels industry springs out of production networks in the broader biofuel industry and has strong ties and affinities with the biotech industry. These industries are largely based on *network forms of governance* (Powell & Brantley 1992; Powell *et al.* 1996, Ponte 2014b), with "coordination characterized by informal social systems rather than by bureaucratic structures within firms and formal contractual relationships between them" (Jones *et al.* 1997, p. 911; see also Powell 1990; Ring & van de Ven 1992; Snow *et al.* 1992). At the same time, the aviation industry is characterized by the heavy involvement of governments in the coordination of complex products and services in what is an uncertain and competitive environment (Upham *et al.* 2009). This structure makes it crucial to understand and analyze the overall network structure of actors within the industry – as well as the particular embedding of public actors – in order to understand overall governance dynamics. Network governance literature has firmly established the importance of network structure for intra-firm and inter-firm governance but rarely theorizes the role of public actors in the coordination and collaboration of industries (Jones *et al.* 1997).

To examine the development of orchestration in the aviation industry, and in relation to aviation biofuels more specifically, we followed a two-step methodological approach. First, we applied a qualitative interpretative approach to primary and secondary material, mainly drawn from semi-structured interviews with industry stakeholders and attendance at seven biofuel and bioenergy conferences from September 2011 to April 2013.[1] These conferences had either special panels or specific presentations on biofuel use in the aviation sector (civil or military). During these biofuel-focused conferences, one or the other author attended over 175 presentations on biofuels and established contacts that led to over 100 interviews (face-to-face and/or via email or phone). Out of these, 35 of the attended presentations (in addition to another 21 for which overhead slides were made available to the authors) and 15 interviews dealt mainly with aviation biofuels – although many other interviews and presentations also touched upon this sector. Interviewees were offered full confidentiality. This first step was used to systemically identify the institutional features and trajectories of TEG in aviation biofuels.

Second, we mapped the transnational network of industry actors and experts involved in aviation biofuel. Using a snowball sampling method, we identified the social ties between actors who are transnationally recognized for their aviation biofuel expertise. We applied SNA to map the presence of public sector actors in the network and to locate who they forge ties with.

The transnational network was located through a social network snowball e-survey. The survey was initially sent to 160 aviation biofuel experts who were identified from *objective criteria*, such as event attendance and formal group membership, including: fieldwork-based interviews with experts and presenters at selected biofuel conferences, desk research identifying presenters at key conferences (from published programs), and the distribution email lists of two sustainable aviation initiatives for which we obtained permission. The criterion of *inclusion* in the network was that an individual had to be nominated by a survey respondent as a "key member" of his/her "professional network" in the aviation biofuel sector. One individual enumerating another as *a key industry or expert peer* is thus our measure of a directed social tie. Our total list of survey respondents evolved dynamically through six survey waves. The experts who were nominated by peers in the first wave of the survey, and who had not been included in the first list, received the same survey – thus creating a second wave. We reiterated this process for a total of six waves, when no additional new names emerged, which led us to consider our network sample saturated. Among the total of 275 surveyed individuals, 56 completed the network part of the questionnaire (24 left partial responses with no network information about their network peers). At least one of the 56 respondents nominated 193 professionals as experts. The ties reported between the actors connect into one social network component composed of 411 directed ties.

The low response (20 percent) rate is problematic in a network analytical context, because structural traits of the entire network can rely heavily on ties that are missing from our sample (Marsden 1990; Borgatti *et al.* 2006). Some network analytic measures and techniques are robust enough to reliably handle large shares of missing nodes or edges, but others are fragile when faced with data incompleteness and sampling bias (Costenbader & Valente 2003). We tackle the issue of missing data by estimating and simulating the structural parameters for the underlying tie formation process using an exponential random graph model (ERGM), a class of network models that is well-designed to deal with missing data and demonstrated to be superior to alternative imputation techniques for missing network data (Anderson *et al.* 1999; Robins *et al.* 2004, 2007; Huisman 2009). The ERGM is a form of network regression where the observed network structure is treated as the dependent variable. The aim is to accurately replicate this network by estimating the propensity of particular relational microstructures – for example, the likelihood of public sector actors having ties with industry actors. Network simulations are then used to test the significance of these propensities given the statistical uncertainties, including missing data (Desmarais & Cranmer 2012). We estimate homophily and mixing coefficients from our collected network data using the ERGM package in the statistical software environment R (Hunter *et al.* 2008). Homophily is a trait of many networks, describing the tendency of actors who carry similar characteristics to form ties and social clusters (McPherson *et al.* 2001). Mixing is the propensity of actors with certain attributes to form ties in a network.

In order to have sufficient observations to estimate the model, we coded the regional location of actors as “US”, “Europe” or “Other” and their institutional traits as “Government” (government and military), “Industry” (aircraft and engine manufacturers, airlines, biofuel producers, industry associations, professional services, research and development [R&D] firms, other services) or “Other” (including universities, multi-stakeholder initiatives, and NGOs). Both ERGMs successfully predict the probability of edges in the network at the > 0.05 significance level, even considering the statistical uncertainty that comes with the missing data. We also successfully modeled significant homophily and mixing patterns. We present these results in greater detail in the analysis section. Additionally, we examine the response bias in Appendix 1. Aircraft and engine manufacturers stand out as the most heavily underrepresented group in our sample (eight percent) but our ERGMs take this into account when modeling the propensity of tie formation between different groups in the network. We discuss the implications of both in the concluding section, where we also explain what kinds of implications they may have for our conclusions.

Orchestrating the transnational environmental governance of aviation

As mentioned earlier, aviation is a major and growing contributor to GHG emissions. For a long period, environmental rhetoric in the aviation industry was not backed up by actual regulatory measures that would substantially reduce CO_2 emissions, thus it is now perceived as a major polluter. Improved aircraft and engine design and materials, air control, and airport operations have decreased the rate of emissions per aircraft/Km flown, but these factors alone are not sufficient to curb the predicted increase of emissions given the expected future industry growth (Gössling & Upham 2009). Also, while design changes have doubled the efficiency of commercial aircraft since 1960, progress was slower from the late 1980s to the early 2000s because of lower fuel prices and a tripling in the average age of aircraft (Gössling & Upham 2009). Aviation not only emits a substantial amount of CO_2, it also has a range of other environmental and health impacts – noise pollution, land degradation, disturbance of wildlife and biodiversity, and emission of other air pollutants (Renner 2013). This combination of factors provides a major challenge in orchestrating the TEG of aviation toward lower emissions and in addressing other negative environmental externalities. Yet higher oil prices in recent years have provided stronger economic incentives to improve efficiency efforts, given that fuel costs account for about a third of airline operating costs on average, and thus have made it easier to facilitate the development of alternative fuels (Gössling & Upham 2009).

In the short period of 10 years, we have witnessed the emergence of an aviation biofuel industry, from the development of production pathways, to demonstration-scale operations, and, more recently, to a few commercial-scale production facilities. Many other operations failed, and the mainstreaming of aviation biofuels seems to have slowed down in more recent years. Yet ASTM, a voluntary standards developer, has designed and approved specifications for various biofuels, over 20 major airlines have pledged to use biofuels with lower carbon impact than regular jetfuel, and more than 10 commercial airlines have been using a blend including biofuels in selected scheduled flights. In the rest of this section, we examine *directive* orchestration instruments, including international and national regulation, the threat of (stricter) regulation, the provision of subsidies and mandates, public procurement, and the provision of direct financial support and investment. We then highlight *facilitative* orchestration instruments, where public authorities: facilitate or have hands-off influence on, and cooperate with, industry associations in the aviation and advanced biofuel industries; participate or support multi-stakeholder initiatives on sustainable aviation and/or aviation biofuels; fund large research projects; and are active participants in special aviation panels in the biofuel conference circuit.

Directive instruments

Several directive orchestration instruments in the TEG of aviation have been focused on regulating and supporting the development of biofuels. For the time being, the price of biofuel remains higher than for regular jetfuel, although the gap had been closing before the recent drop in international oil prices. The aviation industry runs on very small margins and individual airlines cannot afford to pay extra for biofuels unless all airlines do. This means that aviation biofuels not only need subsidies and/or a system of taxes on fossil fuels for carbon emissions, but also a global governance framework to set up a level playing field. It also needs investment incentives and the creation of a volume of demand that is not currently present at market prices.

At the inter-governmental level, and in relation to GHG emissions but not strictly related to biofuels for aviation, several directive tools have been applied. Domestic flights were included in the CO_2 emission calculations of the Kyoto Protocol, and remain so in the Paris Agreement. However, international flights were not included in Kyoto, and remain excluded from the Paris Agreement as well. ICAO is supposed to regulate the environmental impact of aviation at the international level, but has done little until very recently. ICAO finally agreed to develop a global market-based measure (MBM) of emissions from international aviation at its 38th Assembly in September 2013, but members were not required to report back until 2016 – with a proposal for a scheme capable of being implemented by 2020. In February 2016, ICAO agreed on a global standard for CO_2 emissions for aircraft, to be applied from 2020 onwards and only to new aircraft. And in October 2016, it finally agreed on an MBM scheme, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The scheme will be voluntary from 2021 to 2026 and mandatory thereafter. Offsets are expected to apply to around 80 percent of emissions, but only above 2020 levels (ICAO website).

At the regional and national levels, the EU's active attempt in 2012 to extend its Emission Trading Scheme (ETS) to international flights arriving in the EU was notable. However, its application was delayed until 2016 as a result of opposition, in particular, from the US and China. Now that CORSIA has been enacted, the EU may actually change its approach, although this is too early to assess. Of specific relevance to our discussion is that for the EU ETS, biofuels count for zero emissions. In addition to its ETS, the EU Commission has taken a number of directive orchestration initiatives that have a direct bearing on the development and use of biofuels in aviation. The Renewable Energy Directive for the promotion of the use of energy from renewable sources, established mandatory targets to be achieved by 2020 for a 20 percent overall share of renewable energy in the EU and a 10 percent share for renewable energy in the transport sector (European Commission 2009). This directive also applies to biofuels used in aviation (including international flights), when sold in a member state. Therefore aviation biofuels qualify for incentives by the member states if they comply with the established sustainability criteria. To avoid the controversies that have plagued "first generation" biofuels produced from feedstock that could be used for food and feed, the industry is developing "advanced" biofuels – based on improved and new transformation processes of cellulosic material and other waste, and/or on the development of algae feedstock.

In the US, government support and the existence of a military/commercial industrial base have been of special importance in supporting the development of aviation biofuels. The Environmental Protection Agency (EPA) sets annual quotas of biofuel to be blended into fossil fuels. Fuel operators are obligated to meet certain quotas and are required to submit a certain amount of Renewable Identification Numbers (RINs). This provides opportunities for developing an aviation biofuel market, as these fuel pathways are now eligible for crediting and generating RINs in accordance with US Renewable Fuel Standards (RFS) regulation.

Important investment has been provided by the US Department of Defense (USDoD), the US Department of Agriculture (USDA), the Department of Energy (DoE) and the Federal Aviation Authority (FAA). The US military has promoted the testing and certification of biofuels, has secured the allocation of $510 million on co-financing production facilities (together with USDA and DoE), and has started purchasing aviation biofuels for use in its aircraft. The justifications for directive public orchestration are multifaceted: from "creating opportunity for rural America," including the production of feedstock from a variety of sources and bioprocessing opportunities in small towns;[2] to improving energy security by decreasing oil imports and increasing oil price stability; and securing the long-term reliability of fuel supply to the military, diversifying fuel sources, and increasing operational flexibility.

Of particular interest to our discussion is the special role that the US Navy has played in this realm. In 2009, the Secretary of the Navy announced that it was on course to reduce its consumption of energy, decrease its reliance on foreign sources of oil, and significantly increase its use of alternative energy – in view of improving its combat capability and increasing energy security. One of the five energy goals of this strategy was to demonstrate (by 2012) and then deploy (by 2016) a "Great Green Fleet" that would include ships and aircraft using alternative sources of energy (Whitty 2013; Matsunaga 2014). The Navy demonstration conducted during the 2012 Rim of the Pacific (RIMPAC) exercise, the world's largest international maritime exercise, was a key step in the direction of the Navy's goal to use a 50 percent biofuel blend in its ships and aircraft by 2016. Although biofuels are still more expensive than regular military jetfuel, the Navy counts on having cost-competitive aviation biofuel in the near future. Therefore, when the Great Green Fleet program was threatened in the US Senate and House armed services committee in May 2012, Congress reversed that decision on the basis of a national security argument of increasing war-fighting capability. This was the result of a unique coalition of military-industrial, environmental, and agricultural interests.

Facilitative instruments

Given the complex constellation of the aviation biofuel industry, any successful orchestration strategy has to provide facilitative support to a variety of actors, interests, and multi-stakeholder initiatives. In order to construct an effective framework for the TEG of aviation, the actions of this complex group of actors need to align with the goals of public policy. To this end, direct orchestration, although necessary, is not sufficient on its own. It needs to be complemented by facilitative means. Yet ICAO has used very few facilitative orchestration instruments. In relation to negotiations leading to the development of CORSIA, it carried out two Global Aviation Dialogues (GLADs) in 2015 and 2016 to facilitate information sharing and exchange of ideas. In relation to aviation biofuels more specifically, we could only identify two initiatives: (i) in 2010, it passed a resolution (A37–19) "encouraging" member states and industry to actively participate in further work on sustainable alternative fuels for aviation as part of the basket of measures to limit carbon emissions from international aviation; and (ii) in June 2012, it created the Aviation and Sustainable Alternative Fuels Expert Group to develop recommendations to further facilitate the global development and deployment of sustainable alternative fuels for aviation.

While ICAO was taking tentative and modest steps, in 2010, the most important industry association, the International Air Transport Association (IATA), decided to commit to carbon neutral growth by 2020 and to reducing carbon emissions by 50 percent by 2050. IATA has 240 airlines in over 115 member countries, carrying 84 percent of the world's air traffic (IATA website). IATA took this step to provide a vision and aspirational goals that could allow its members to keep growing while improving their environmental impact and maintaining their "license to operate" from the political system and civil society, as many industry actors perceived that they could soon be taxed for CO_2 emissions, or would be asked to purchase ET certificates. IATA signaled that they would seek these reductions mainly through the adoption of biofuels, in small quantities at first but with the goal of eventually flying most aircraft on 50–50 percent blends of regular jetfuel and biofuel.

In the absence of substantial ICAO activity in this realm, and given the proactive IATA stance, it was the US and the EU that took initiative as orchestrators, engaging with: *industry associations*, such as IATA itself, but also with Airlines for America and the Advanced Biofuels Association; the *biofuel conference circuit*, in particular the annual Advanced Biofuels Leadership Conference (ABLC) in the US, and the World Bio Markets conference in the EU – both of which organize special sessions on aviation biofuels; and a series of *multi-stakeholder initiatives* (MSIs) on "sustainable aviation."

In the US, the most prominent MSI has been the Commercial Aviation Alternative Fuels Initiative (CAAFI), but the Midwest Aviation Sustainable Biofuel Initiative (MASBI) and Sustainable Aviation Biofuels Northwest (SAFN) have also played important roles. In the EU, regional/national initiatives of this kind are present in Germany (Airreg), France (GiFAS/IFP Energy Nouvelle), the Netherlands (SkyNRG), Spain (Bioqueroseno), and the Nordic region (NISA) (see full list of MSIs on sustainable aviation in Appendix Table 1).[4] These initiatives have benefited from political and sometimes material support by individual governments and the EU. Government agencies (sometimes through these very MSIs) have been key players in forging bilateral/multilateral alliances on aviation biofuels, and government support has included the funding of several research centers focused on biofuels for aviation, both in the US and in the EU.

As we have seen above, in the US, various government departments and agencies played a decisive, direct role in providing political and financial support for aviation biofuels. But they have also played a more indirect role – without resorting to pure intermediation. The FAA, for example, was pivotal in forming and then consolidating CAAFI, the first multi-stakeholder initiative of its kind, established in 2006. At that time, the FAA called on key relevant stakeholders to provide responses to three concerns on aviation fuels: supply security, affordability and price stability, and environmental impact. As a result, the Aerospace Industries Association, Airlines for America and the FAA formally established CAAFI, bringing together key players from the private sector, government, and (later on) civil society. These three organizations (together with the Airports Council International/North America) are the current sponsors of CAAFI, which now counts approximately 300 stakeholders. CAAFI's main aim is to exchange information and coordinate stakeholder efforts in alternative aviation fuels, and its main activities center on technical workshops, industry conference participation and other outreach activities, lobbying, and communication with the news media.[5]

In the EU, several policy documents have provided ideational support to the aviation biofuel industry. In 2011, the EC adopted the White Paper "The Transport 2050 Roadmap to a Single European Transport Area," (European Commission 2011a) which included 40 specific initiatives aimed at reducing Europe's dependence on imported oil and cut carbon emissions in transport by 60 percent by 2050. The report "Flightpath 2050 Europe's Vision for Aviation," also published in 2011 (European Commission 2011b), presented a long-term vision for European aviation and called for further improvement of the energy efficiency of aircraft and operations and highlights the need to produce liquid biofuels. A roadmap developed to support the achievement of Flightpath's goals and challenges called for increasing the share of biofuel use in aviation, from two percent in 2020 to at least 40 percent by 2050 – as set out in the Transport White Paper. Finally, the 2013 "European alternative fuels strategy" provided political strategies and specific actions toward the decarbonizing of transport without impacting on economic growth (European Commission 2013). For the first time, it addressed the potential of new aviation fuels and highlighted the need for financing instruments and market incentives to support the construction of biofuel production plants for aviation.

Together, the US and the EU orchestrated the emergence of an aviation biofuel industry as a key element of enacting the TEG of aviation more generally. It was the *combination* of directive instruments (including the threat of regulation) and facilitative instruments that characterized their strategy, together with an active network engineering approach (see next section). The material presented so far also suggests that four facilitating factors contributed to successful orchestration: (i) high issue visibility, as the industry is consumer-facing and has a reputation for being a high CO_2 emitter; (ii) the alignment of interest between regulators and the main industry association (IATA) in view of the latter's need to address these perceptions and an overall threat of further regulation; (iii) a narrow scope of regulation, given the predominant focus on CO_2 emissions, rather than other environmental impacts of the industry; and (iv) a low level of regulatory fragmentation at the domestic level, given that commercial aviation is regulated by the respective aviation authorities (and the Commissioner for Transport at the EU level).

Orchestrators in the transnational network of aviation biofuels

In view of the weak regulatory presence of the designated "global governor" for aviation (ICAO), what is missing from the orchestration picture so far (and from the literature on orchestration more generally) is an assessment of the extent to which a social network around aviation biofuels has formed at the transnational level and, if so, what place public actors have within it. This analysis is important because it sheds light on the strategies used by orchestrators to achieve their goals, including the possible shaping of some of the key factors we have highlighted above, for example, in terms of actively aligning the interest of public authorities and industry. From our SNA, we offer three main findings that are relevant for orchestration. In the following section, we bring these and the findings from the previous section together to discuss orchestration as a whole.

A cohesive transnational network of aviation biofuels professionals has formed in the absence of a "global governor." Given that we drew our snowball from an objectively qualified sample of professionals, a very real possibility would have been to find several fragmented networks identified through snowballing from regional and institutional groups. The fact that our sampling strategy has identified a fully connected network of 193 professionals in a very young industry is itself a noteworthy indicator that a socially cohesive network is emerging. This is an essential element for successful orchestration because it provides one integrated conduit for building relations of learning, information-sharing, and trust across jurisdictions, as well as public and private agencies. This informal network may well help to coordinate and integrate regulatory effort transnationally in what would otherwise be complete fragmented interventions across separate jurisdictions – making it more likely that the variety of instruments used in orchestration "play the same tune." Twenty-six different countries are represented in this integrated network, with EU countries and the US equally dominant (37 percent) and "other" countries accounting for the remaining 25 percent of professionals. This finding also justifies our focus on the US and the EU in the qualitative analysis of orchestration initiatives carried out in the previous section.

Figure 1 also shows that the aviation biofuel network is made up of a relatively large share of high-level professionals from various sectors (38 percent executive leaders). The most important categories of professionals in the network are from airlines and government agencies (16 percent), followed by biofuel producers (15 percent), R&D professionals (11 percent), and universities (10 percent). Collectively, 18 percent of the network is made up of public sector professionals (government and military), 50 percent are industry professionals broadly conceived (involved in R&D, biofuel production, airline operation, and aircraft and engine manufacturing), 19 percent are professionals involved in knowledge and service provision (universities, professional services, and other services), and 13 percent in collective action (NGOs, MSIs, industry associations). This means that industry operators dominate membership in the network, but public sector professionals have a substantial (but still minority) presence, both directly and indirectly through MSI membership. This configuration provides legitimation to the network (in the eyes of industry) and – combined with the cohesive nature of the network discussed above – an optimal "spreading out" architecture for orchestration.

These propositions are strengthened by the analysis carried out in Figures 2 and 3, which show that the network has a *highly centralized structure*, with a core of actors who were nominated as key professional peers by a regionally and institutionally *diverse set of actors*. Figure 2 is a graphic representation of the network using a spring algorithm, which places actors close to each other when they are connected. Figure 3 is plotted using a coreness layout, placing the actors on a continuum from core to periphery depending on their coreness score.[6] Both graphs reveal a highly centralized network structure, another feature that can help orchestration.

The core-periphery structure demonstrated in the network graphs suggests the presence of a professional hierarchy in the network despite its extra-organizational character. Industry actors from the US and EU dominate the core, yet six public orchestrators are also present. However, the US orchestrators significantly outnumber those from the EU and other countries. At the same time, different institutional and regional traits are represented within the core. This suggests that the core brings together a *diverse* set of professionals from different regions and institutions, and that public orchestrators are centrally embedded but do not completely dominate the core. This indicates not only is there a connected network that can serve as an infrastructure for information-sharing, learning, and trust-building, public orchestrators are central nodes within this network and play a core function within it. Again this enables public orchestrators access information about industry-level activities and to coordinate efforts across jurisdictions and public-private borders, while also placing them in a strategic position to disseminate information to industry about what might be coming ("regulatory threats").

The network is characterized by *regional homophily and by the importance of public agencies in mixing* patterns. Our ERGM estimation yields coefficient estimates as conditional log-odds of directed ties being present (see Table 1).[7] We tested general homophily on regional and institutional traits. We found regional homophily to be strong and significant, suggesting that ties tend to form between regionally similar alters, while this is not the case for institutional homophily (see the results for the nodematch variables in Table 1).[6]

When we look more closely at specific mixing patterns for regional and institutional traits, we find that EU-> US and Other-> US ties are prevalent beyond random, suggesting that being connected to US professionals is important. Although institutional homophily is not significant, a closer look at mixing patterns reveals that homophilous Government-> Government ties are prevalent as well as reciprocated heterophilous ties directed from

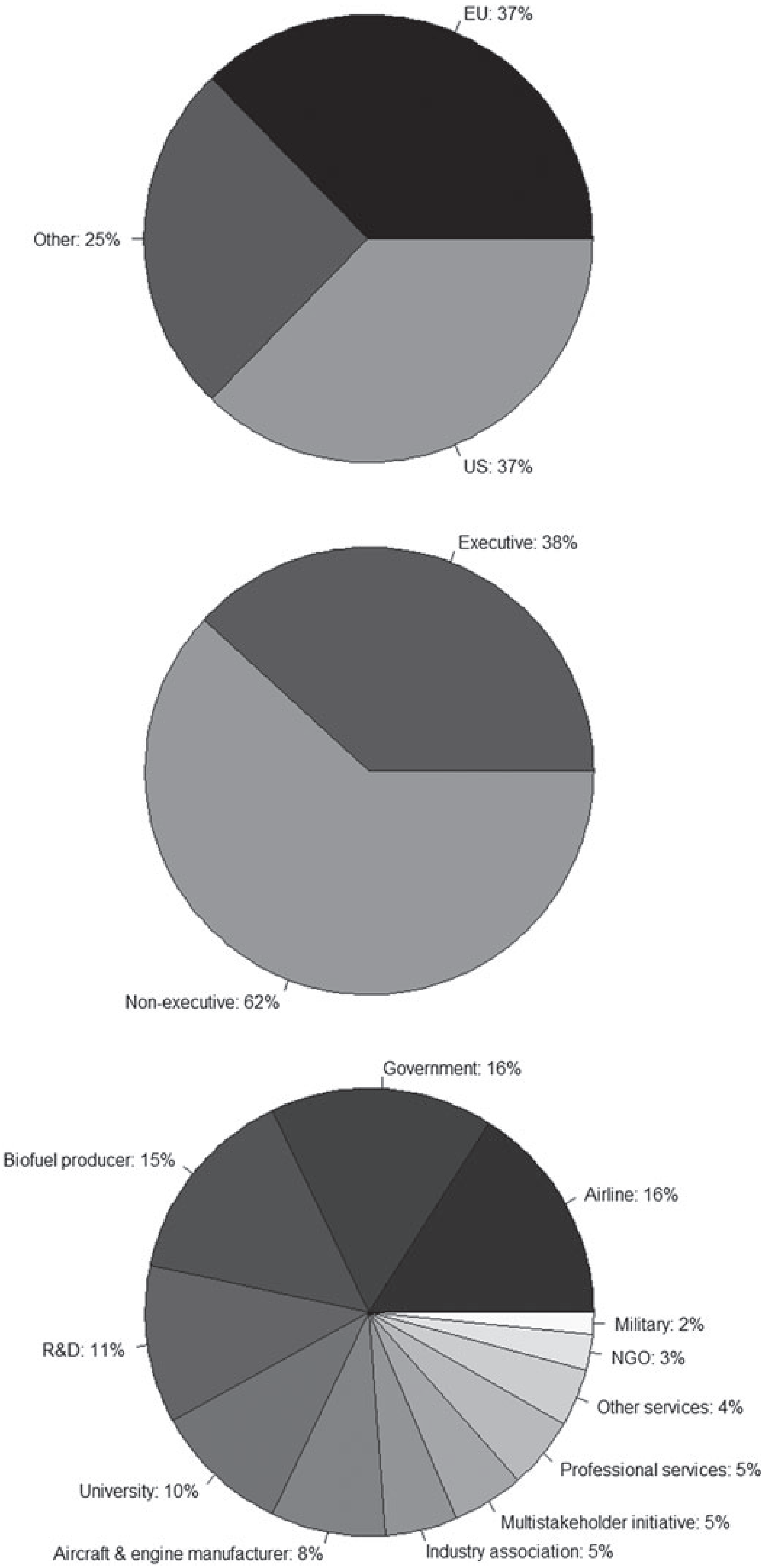
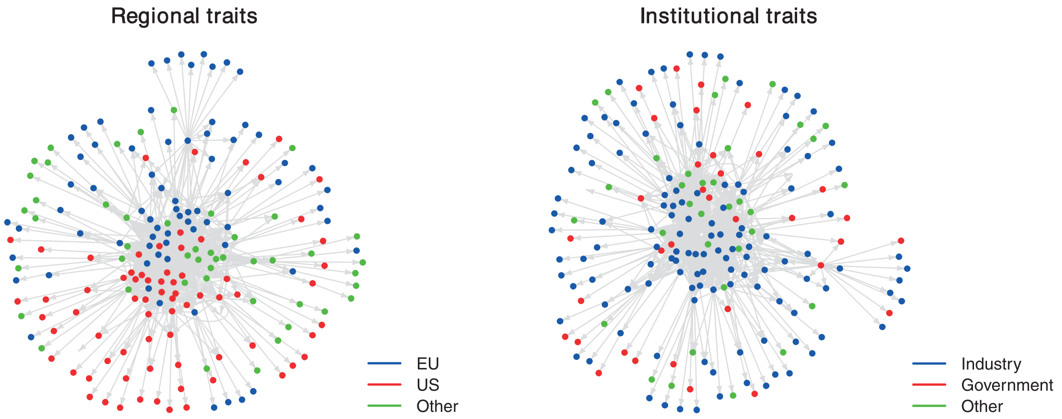


Figure 1 Network representation by categories (region, rank and organizational type).



Note: Spring algorithm used in the top graphs to show network position based on connectivity. Coreness layout used in the bottom graphs to accentuate professional’s position in the network hierarchy.

Figure 2 Spring layout with professionals colored by regional and institutional traits.

Other-> Government and Government-> Other. This is evidence that, in general, *public agencies show a high propensity to be nominated within the network*. It should be noted that the propensity of Government ties directed at Industry professionals is non-negligible and almost significant at the 0.10 level.

Collectively, these three layers of SNA suggest that there is a cohesive transnational network of aviation biofuel professionals, with clear regional and institutional traits. This network has a highly centralized structure whose core consists of a diverse set of actors including public officials – with firm grounding in industry. Finally, network members clearly see public officials as key members of the network. This suggests that public orchestration by national and regional authorities can occur through network formation and/or participation, even in the absence of an active IO. Although SNA alone cannot show directly whether public officials are actively orchestrating the TEG of aviation, in combination with the interview and participant observation material presented in the previous section, it provides strong indications of orchestration in action.

Discussion

Our case study of aviation shows that national and regional governments can and do take the mantle of orchestration when the relevant IOs fail to do so. ICAO did not use delegation or intermediation instruments for TEG, and resorted to cooperation in only very limited ways. Its failure to enact these orchestration instruments is actually explained by several factors in Abbott *et al.*’s (2015) O-I-T model, although it refers more narrowly to intermediation: ICAO has high capabilities in the focal domain, there is no readily available intermediary, ICAO has low focality in the environmental field, it does not have an organizational structure that facilitates entrepreneurship, and there is strong oversight of member states in the focal domain (see Table 2). The characteristics of these five factors suggest that it would indeed be difficult for ICAO to orchestrate TEG in the aviation sector. At the same time, there is strong divergence of goals among member states within ICAO, which would have, in theory, facilitated orchestration.

A comparative analysis with the shipping industry is useful at this point, as shipping is also a capital-intensive industry with mobile assets, and has managed to stay out of the Paris Agreement as well. The scorecard of Abbott *et al.*’s (2015) model as applied to the relevant IO (the International Maritime Organization, IMO) is very similar, and, indeed, IMO has not been successful in orchestrating TEG either (see Table 2). In relation to these two case studies, Abbott *et al.*’s (2015) model seems to yield explanatory power in relation to whether IOs are likely to act as orchestrators.

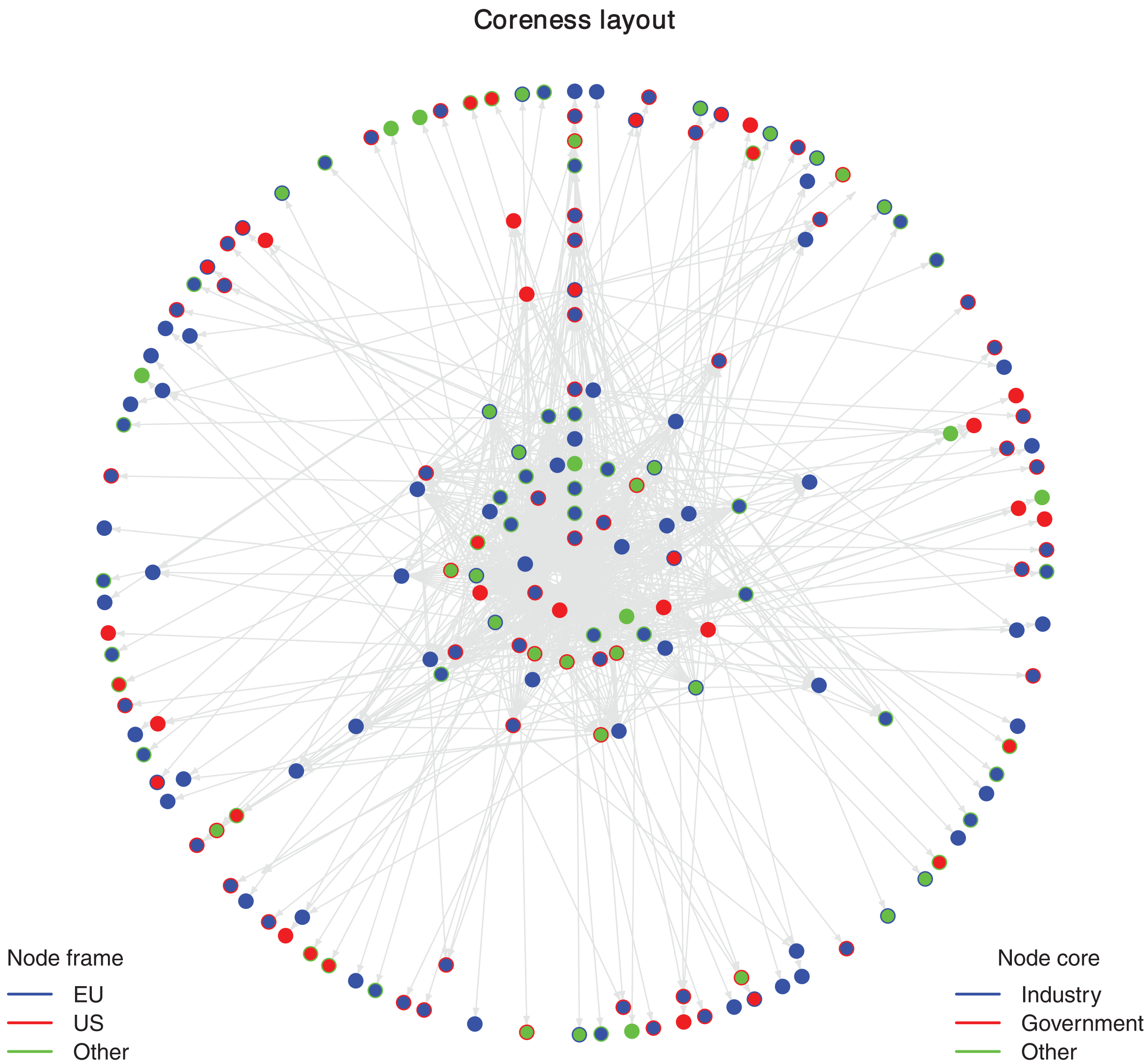


Figure 3 Coreness layout. EU, European Union; US, United States.

However, Abbott *et al.*'s model is unable to account for why and how the US and the EU took up the mantle of orchestration successfully in the absence of orchestration by ICAO. In order to explain this, we now revert to the four explanatory factors we proposed earlier in the paper: issue visibility, interest alignment between government and industry, issue scope, and regulatory fragmentation. In Table 3, we summarize the results from the case study of aviation and compare them with the case study of shipping (Lister et al. 2015). Drawing from our analysis presented earlier, it suggests that successful orchestration of TEG in aviation by national and regional governments can be linked to: (i) high issue visibility, as aviation is clearly perceived by the public and consumers as a high GHG emitter; (ii) alignment between US/EU regulators and the industry (through IATA and CAAFI) that something needs to be done to curb GHG emissions; (iii) narrow issue scope, mostly focused on CO2 emissions; and (iv) low regulatory fragmentation within domestic/regional domains. Show that in the shipping industry, these factors score exactly the opposite, and, indeed, orchestration of TEG by national and regional governments has so far failed to emerge – even in the absence of effective orchestration by an IO.

A final reflection is needed in relation to the actual orchestration *trajectories* observed in our case study of aviation. The two models presented so far clarify what factors facilitate orchestration, but not how orchestration actually unfolds.

Table 1 Results of Exponential Random Graph Model (coefficients conditional log-odds)

	Estimate	Std. Error	(Prob.)	P-value
Edges	-4.60***	.329	(.010)	.000
Nodematch regional traits	1.98***	.309	(.879)	.000
Nodematch institutional traits	.109	.179	(.527)	.544
Regional trait mixing: (base=USA->USA)				
EU->US	1.14***	.321	(.758)	.000
Other->US	0.973**	.341	(.726)	.004
US->EU	-.273	.411	(.432)	.507
EU->EU	.051	.142	(.513)	.720
Other->EU	.393	.372	(.597)	.291
US->Other	.130	.411	(.532)	.751
EU->Other	NA	NA	NA	NA
Other->Other	-.355	.196	(.412)	.070
Institutional trait mixing: (base=Indust.->Indust.)				
Government->Government	.721**	.273	(.673)	.008
Industry->Government	-.103	.233	(.474)	.657
Other->Government	.569*	.262	(.639)	.030
Government->Industry	.372	0.231	(.592)	.107
Other->Industry	-.097	.215	(.476)	.651
Government->Other	.649*	.325	(.657)	.046
Industry->Other	NA	NA	NA	NA
Other->Other	0.167	.252	(.542)	.507

Table 2 Orchestration in aviation and shipping according to Abbott et al.'s (2015) model

	Aviation	**Shipping**	**Model prediction**
Regulatory capability	high	high	low
Intermediary availability	low	low	high
Focality	low	low	high
Enterpreneurship	low	low	high
Divergence of goals among members	high	high	high
Oversight of states in their domain	high	high	low
Orchestration by IO?	**no**	**no**	**yes**

Table 3 Orchestration in aviation and shipping according to Lister et al.'s (2015) model

	Aviation	**Shipping**	**Model prediction**
Issue visibility	high	low	high
Interest alignment	high	low	high
Issue scope	low	high	low
Regulatory fragmentation	low	high	low
Orchestration?	**yes**	**no**	**yes**

Our combined qualitative analysis and SNA suggests that orchestration is more likely to be successful when a combination of directive and facilitative instruments are used, and when orchestrators are successful in forming and embedding themselves within the transnational networks that constitute the infrastructure of TEG. The latter is likely to have been particularly crucial for coordinating the emergence of a transnational aviation biofuel industry, given that network forms of governance are already prevalent within such industries.

Conclusion

In this article, we examined the emerging dynamics of public orchestration of TEG through a case study of aviation, with specific focus on aviation biofuels. While recent discussions in the literature have focused mostly on intermediation and delegation instruments (Green 2014; Abbott *et al.* 2015), we argue that there is analytical traction in studying orchestration as a *combination* of directive and facilitative tools, including network formation and/or consolidation.

Our analysis yields two sets of conclusions. One is that four factors seem to facilitate public orchestration by national and regional governments, in the absence of an actively orchestrating IO: high issue visibility, interest alignment between orchestrators and industry, narrow issue scope, and low regulatory fragmentation. A second has to do with a two-pronged strategy for successful orchestration: (i) public orchestrators have used both directive and facilitative measures to create feasible incentives, backed up by regulation or credible regulatory threat, that drove industry to innovate and change business models and operations in response to challenges of environmental change; and (ii) public orchestrators have supported the creation of a global network of experts and other stakeholders, and actively embedded themselves into it – not only to stay up to speed with crucial industry information, but also to signal where policies are headed. Part of these networks evolved from the mainstream biofuel industry, but a more specific network related to aviation had to be formed and connected to the principal public orchestrators of aviation biofuels – the national and regional governments of the US and the EU.

Industry events are especially important as instigators of such networks, and, in time, can lead to the solidification of social ties – a key condition for orchestrating the interplay of various governance instruments. Public orchestrators placed themselves at a social proximity with their regulatory objects in order to share information and learn, nudge, and coordinate. They facilitated network formation and consolidation – the very infrastructure of collaboration and coordination – as well as occupied particular strategic spaces within such networks to maximize orchestration capacity given the material and institutional resources at hand. Furthermore, they placed themselves at the core of these networks and established links with a variety of stakeholders – without being perceived as dominating them.

However, it must also be underlined that the social proximity that arises from public orchestration also carries a risk of regulatory capture. Public officials working closely with their regulatory targets, in situations of rapid industry upscaling, may be more likely to buy into the business challenges of their network peers – and as a result may be more inclined to soften up on mandatory targets or the regulation of sustainability issues. In the financial industry, for example, a clear tendency has been for the career trajectories of public orchestrators to “revolve” between public and private domains, a social dynamic that has been pointed out as a driver of *de*regulation. The possible feedback mechanisms that may occur between social network structures and public orchestration, and how the structure of these networks influence the capacity of actors to orchestrate in the interest of the general public in the longer run are yet to be fully understood. Finally, the four factors and two strategies that yielded successful orchestration in the aviation industry will have to be empirically tested in other industries and contexts in further research, especially in regulatory fields and industries that: have more effective regulatory presence by an IO; are organized around more traditional hierarchical principles of organizing; and display a different mix of characteristics in terms of issue visibility, interest alignment, issue scope, and regulatory fragmentation and uncertainty.

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Notes

1 The second author attended the World Biofuels Markets –Brazil congress and exhibition (Sao Paulo, 28–29 September 2011), the GreenPower Webinar Advanced biofuels: Steps to reaching the US EPA target of 20 bn gallons by 2012 (online 6 October 2012), the Copenhagen Cleantech Cluster Annual Conference (Copenhagen, 11 October 2011), the Bioenergy International Asia expo and conference (Kuala Lumpur, 7–8 December 2011), the ISCC Global Sustainability Conference (Brussels, 8 February 2012), the World Biofuel Markets congress and exhibition (Rotterdam, 13–15 March 2012), and the Advanced Biofuels Leadership Conference (Washington, DC, 15–17 April 2013). The first author attended the 4th International Conference on Biofuels Standards (Gaithersburg, MD, 13–15 November 2012).
2 Thomas Vilsack, US Secretary of Agriculture, conference presentation at ABLC, Washington DC 15/4/2013.
3 Elsewhere, similar initiatives are present in Brazil (Abraba) and Australia (AiSAF).
4 Sources: CAAFI (website), CAAFI presentations at ABLC, Washington DC 15/4/2013, interviews ABLC21 and ABLC26, 15/4/2013.
5 We applied a K-core decomposition to test if the network consisted of a cohesive core, and it does (for details on this method, see Dorogovtsev *et al.* 2006). The k-core of graph is a maximal subgraph in which each actor has at least indegree k (number of survey nominations). This method recursively prunes nodes with an indegree centrality $< k$ and assigns a coreness score k to each actor in the network, depending on the point where it is excluded in the pruning process.
6 We also report the corresponding probability in parentheses to ease interpretation for non-experts.
7 Note, however, that the category "Other" includes many different countries and that this increases the coefficient.

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APPENDIX

Response rate and bias

The survey response rate was 20 percent, which, in absolute terms, is relatively low. Email-based surveys are well-known for having response rate issues, but for social network surveys, additional factors inhibit individuals from responding, for example, social-psychological barriers of giving away information about personal contacts and the enforcement of rules or policies among organizations (especially firms). We note that missing data on single units can lead to significant measurement errors in analysis, although the introduction of ERGMs comprehensively dealt with this issue. Yet in the interest of transparency, we present below the distribution of response rates for groups based on institutional and geographical traits (the foci of the analysis). We find that individuals from the aircraft and engine manufacturer category are significantly underrepresented in our survey. Conversely, individuals from the multi-stakeholder and university category had a response rate significantly above that of the rest. Surveyed individuals belonging to the broad category of government (including military) were only slightly below the mean and the remaining group of industry individuals was distributed around the mean with no significant outliers. The gender response rate was even.

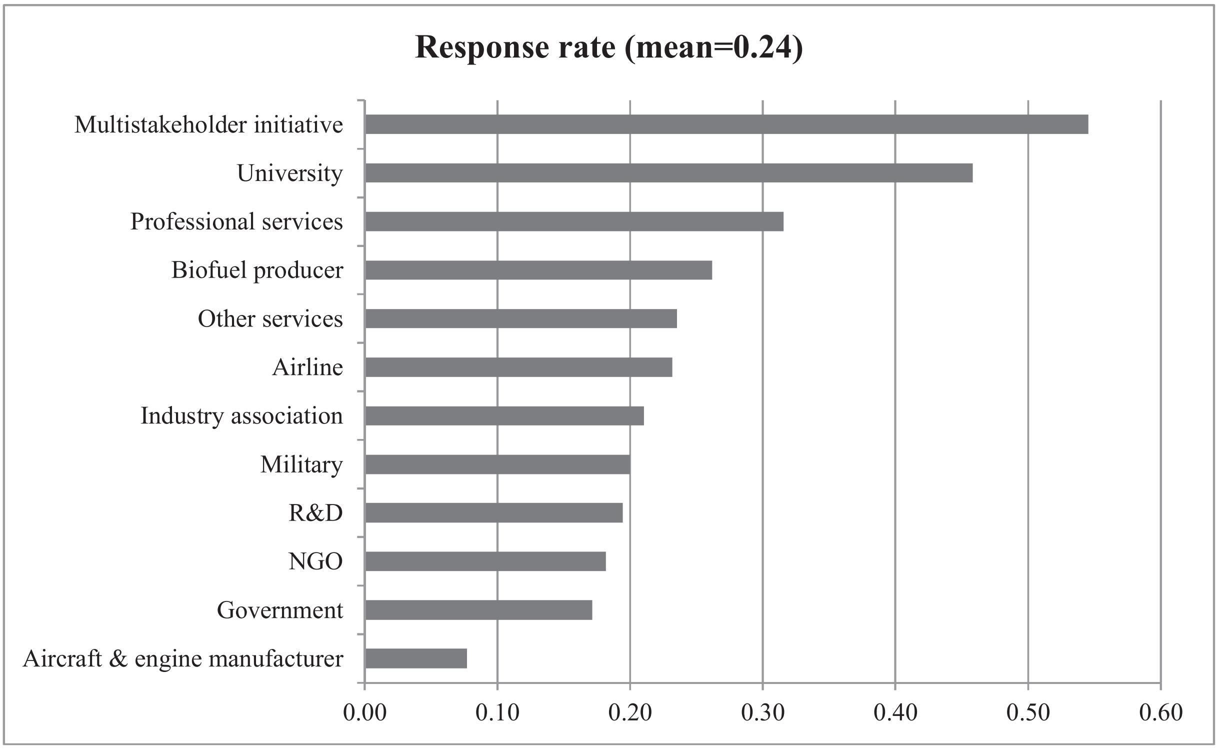

Figure A1 Response rates by organizational type.

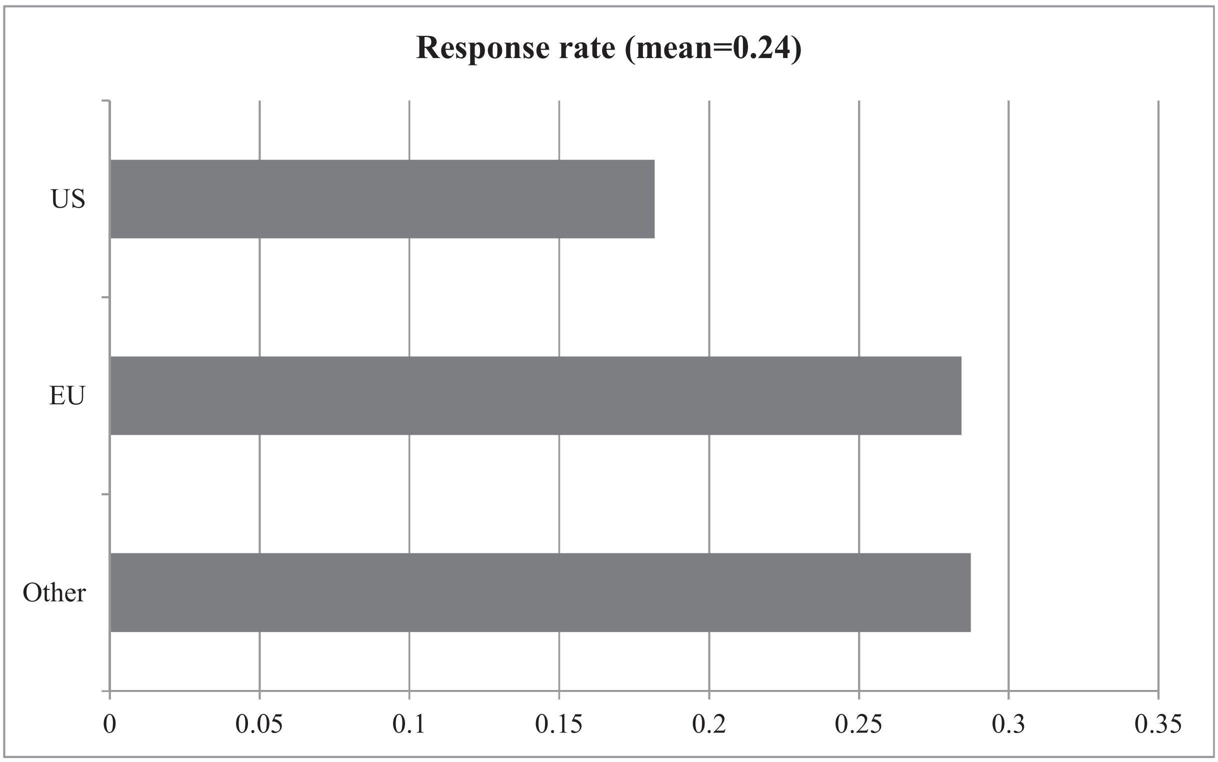

Figure A2 Geographical distribution of response rate.

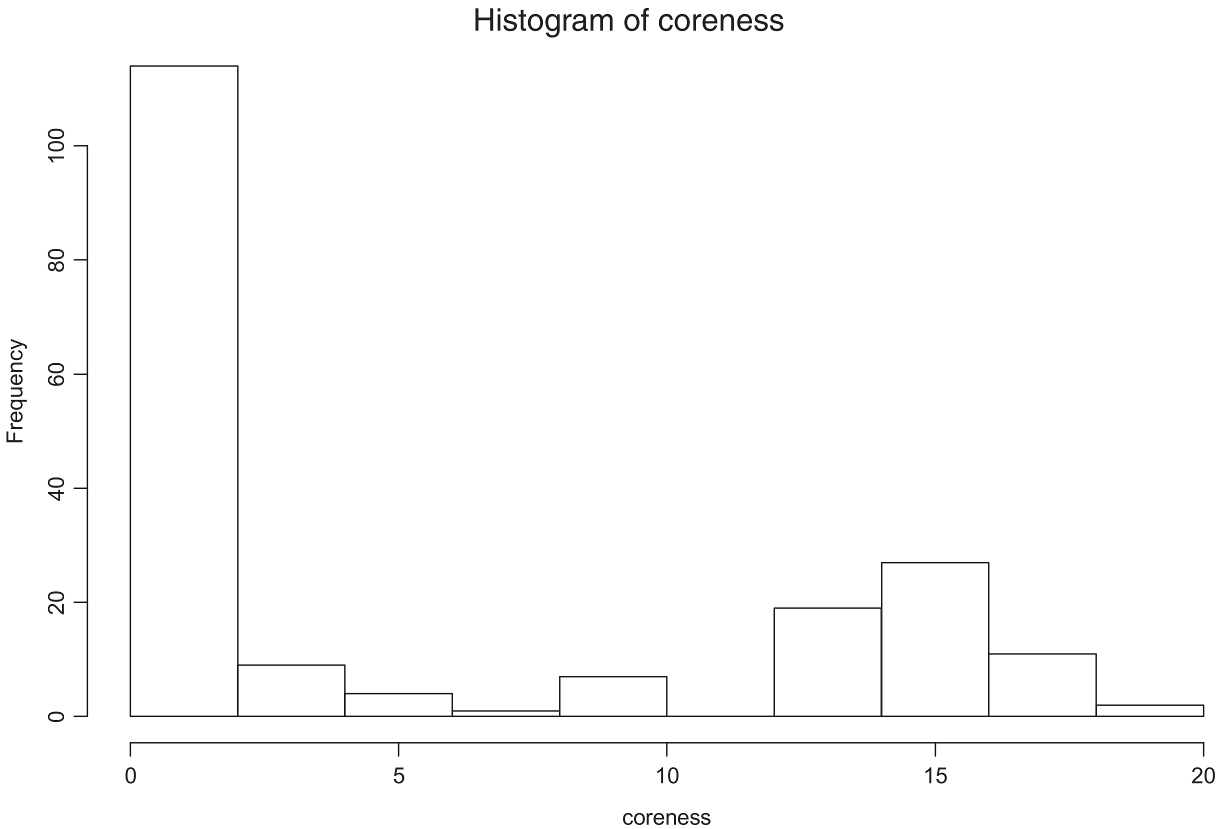

Figure A3 Coreness distribution..

Table A1 List of multi-stakeholder initiatives on sustainable aviation

Australia	Queensland Sustainable Aviation Fuel Initiative (QSAFI)
Australia	Australian Initiative for Sustainable Aviation Fuels (AISAF)
Australia	Sustainable Mallee Jet Fuel Project
Australia	Qantas and Shell Aviation Biofuel Feasibility Study
Australia, New-Zealand	Flight Path to Sustainable Aviation Fuels
Brazil	ABRABA
Brazil	Sustainable Aviation Biofuels for Brazil (SABB)
Brazil	Brazilian Biojetfuel Platform (BBP)
Canada	Technical Feasibility of Bio-Based Jet Fuel Production in Canada
Canada	BioFuelNet's Aviation Task Force
Europe	Sustainable Way for Alternative Fuels and Energy In Aviation (SWAFEA)
Europe	European Advanced Biofuels Flight Path
Europe	Alfa-Bird
Europe	Initiative Towards sustAinable Kerosene for Aviation (ITAKA)
Europe	CORE-JetFuel
Europe	SOLAR-JET: Solar chemical reactor demonstration and Optimization for Long-term Availability of Renewable JET fuel
Germany	Aviation Initiative for Renewable Energy in Germany (AIREG)
Germany	BurnFAIR project
Indonesia	Indonesian Aviation Biofuels and Renewable Energy Task Force (ABRETF)
International	Sustainable Aviation Fuel User Group (SAFUG)
Mexico	Flight Plan Towards Sustainable Aviation Biofuel in Mexico
Norway	Oslo Initiative – Avinor Bioport
Qatar	Qatar University Biofuels Project
Scandinavia	Nordic Initiative for Sustainable Aviation (NISA)
South Africa	Project Solaris
Spain	Bioqueroseno
The Netherlands and Finland	Dutch Initiative - 'Bioport Holland'
The Netherlands and Sweden	Fly Green Fund
United States of America	Commercial Aviation Alternative Fuels Initiative (CAAFI)
United States of America	Northwest Advanced Renewables Alliance (NARA)
United States of America	Sustainable Aviation Fuels Northwest (SAFN)
United States of America	Midwest Aviation Sustainable Biofuels Initiative (MASBI)
United States of America	Farm-to-Fly
United Arab Emirates	Masdar's Sustainable Bioenergy Research Consortium
United Kingdom	Green Sky London

Source: http://www.icao.int/environmental-protection/GFAAF/Lists/Initiatives%20and%20Projects/Projects.aspx

