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# Exploring the borders of a transregional knowledge network. The case of a French research federation in green chemistry<sup>1</sup>

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## Abstract

Competition in research has led to the emergence of numerous consortia of laboratories, designed to improve their participants' visibility. This article aims to understand the determinants of these new structures through the case study of a French federation of laboratories in green chemistry. Working from bibliographic and qualitative data, we examine this federation's geographical and institutional scope, highlighting the importance of i) prior collaborations in French chemistry, ii) interpersonal relations between consortium members, and iii) policy and scientific incentives. This research highlights the role of the territorial scope of the consortium not only as an argument for the consortium to emerge but also as a resource for its development and visibility among academics and industrial partners.

## Introduction

In the current context of academic competition, research organizations are attempting to improve their visibility (Yudkevitch *et al.*, 2016). This quest for international profile can be pursued through at least three strategies: being big (size effects associated with the notion that “big is beautiful”), being in the right place (according to the idea that location matters) or being in the right network (strategic alliances and knowledge flows). The former two strategies often work in combination, in a context where scientific concentration policies tend to favour large laboratories based in metropolises (Grossetti *et al.*, 2016). The latter strategy is best adapted for medium-sized networks in non-central locations. Such strategies are often driven by public policies as they serve the purposes of deconcentration and territorial planning in higher education and research.

In this article, we examine the geographic coherence of a cross-regional scientific network in green chemistry supported by public institutions at both the national and the regional level. The network we look at is a network of research laboratories. We hypothesize that such a network is reliant on research practices and in particular on prior or potential scientific collaborations between network members. By adopting a spatial approach, our intention is to better assess the role of this coordination mechanisms and for instance, its ability to fix “network failures” (Lucena and Vicente, 2019). Such “failures” can be the product of long-term spatial processes, or path dependencies, that shape and restrain the organization and evolution of inter-urban scientific networks.

The name of the network we look at is INCREASE, which is a French green chemistry federation. Led by the CNRS<sup>2</sup>, it comprises of six laboratories and a club of industrial businesses based in Western France. The first part of the article presents some background information on the French green chemistry sector, as well as the theoretical framework used to investigate the emergence and geographic scope of this research federation. The next section presents the data used for this case study, including both bibliometric data as well as information collected through qualitative interviews with consortium

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<sup>1</sup> A longer version of this article is available in preprint: <https://hal.archives-ouvertes.fr/hal-02053595>

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researchers. In the last section, we present research results. This research allows us to highlight three types of determinants that shape the consortium's geography: structure effects (impact of past activities on the geography of collaborations); network effects (role of pre-existing inter-individual relations); and policy effects (link between policy incentives and cognitive factors).

### **Studying the structuring of a scientific network in green chemistry**

#### *Green chemistry research in France*

Along with nano-chemistry, green chemistry is one of the groundbreaking sectors that have over the past fifteen years transformed the way chemistry is taught, organized and practiced (Morris, 2011; Milard and Grossetti, 2017). Although fossil fuels remain the main raw material used by the chemical industry, alternatives to petro-chemistry are the object of a growing number of studies, drawing mounting interest in the industry (Moiseev, 2016). Unlike nano-technology research, which developed in a limited number of scientific hubs due to the spatial concentration of dedicated funding (Bozeman *et al.*, 2007; Robinson *et al.*, 2007; Meyer, 2011), green chemistry in France has benefitted from support mechanisms that encouraged the creation of territorialized networks. In this area, no less than four programs have been supporting the clustering of researchers and industries on a geographic basis:

- *Instituts pour la Transition Énergétique* (Institutes for the Energy Transition, or ITE), including PIVERT (an institute of excellence on low-carbon energy created in May 2012) and the IFMAS (*Institut Français des Matériaux Agrosourcés*) launched in 2013, both in the North of France;
- *Institut Carnot 3BCAR*, created in 2006 with institutions mainly based in Southern France;
- Competitiveness clusters, including AXELERA, created in 2005 in the *Rhône-Alpes* area which now counts 345 partners (industries and laboratories); the IAR cluster (Industry and Agro-Resources), created in 2007 in the same geographic area as PIVERT (Northern France); and Trimatech, a cluster involving Southern cities including Montpellier, Aix-Marseille and Nimes;
- and finally, the INCREASE Research Federation led by the CNRS, involving several laboratories based in Western France (Table 1), which forms the object of this study.

INCREASE (International Consortium on Eco-conception and Renewable Resources) is a public-private collaborative network that was inaugurated on May 13, 2016. Sponsored by the CNRS, it is dedicated to eco-design and renewable resources, with the aim of developing green chemistry by using biomass – a renewable carbon source – as a raw material. It involves firms from different sectors in the chemical industry (cosmetics, agri-food and detergents) as well as eight academic research centers based in Western France (Poitiers, Rennes, Toulouse, Bordeaux, Nantes and La Rochelle). Another of INCREASE's objectives is to promote the training of young researchers and the dissemination of knowledge in the field of green chemistry through the organization of the International Symposium on Green Chemistry (ISGC), which takes place every two years in La Rochelle.

The INCREASE network is the latest addition to a range of institutional programs. According to its participants, the consortium aims to fill a gap in the geography delineated by prior programs. These programs had shaped two major active areas in green chemistry: the *Rhône-Alpes* area, organized around the city of Lyon, and the North-East area between Amiens and Reims. In addition, laboratories in Toulouse, Bordeaux and Montpellier (Greater South-West region) participated in several large networks such as 3BCAR led by the *Institut Carnot*. This map produced the impression that laboratories in the South, East and North of the country were integrated to large networks, while laboratories based in the West were more isolated. INCREASE associates cities located across four different regions: *Occitanie*, *Nouvelle-Aquitaine*, *Pays de la Loire* and *Brittany*. Although this territory has no administrative

existence as such, it more or less coincides with the area known as the “Atlantic arc”. Its territorial cohesion has been the object of historical debates about France territorial development (Brunet, 1993).

**Table 1. Presentation of INCREASE members and their respective urban areas.**

Names	Laboratories			Urban areas			
	Number of permanent staff	Number of INCREASE members	Scientific contribution to INCREASE	Lab location	French rank in urban population	French rank in scientific production <sup>3</sup>	French rank in chemistry <sup>4</sup>
IC2MP	150	7	Catalytic conversion of biomass to fine chemicals.	Poitiers	41st	20th	16th
ISCR	300	32	Organometallic homogeneous catalysis and molecular valorization.	Rennes	10th	9th	8th
LGC	160	24	Chemical engineering and process chemistry.	Toulouse	4th	4th	4th
LCPO	40	10	Synthesis of polymers and development of functional polymeric materials.	Bordeaux	5th	7th	6th
ISM	130	2	Life-cycle assessment.	Nantes	8th	13th	12th
BIA-INRA	190	2	Biopolymers within the biomass and physical chemistry.				
LIENSs	100	21	Assessment of the chemical contamination of coastal areas.	La Rochelle	48th	39th	39th

This coastline running from Brittany to the Greater South-West region is dotted with medium-sized cities of limited influence including Poitiers, which hosts the headquarters of the INCREASE Federation and has the region’s oldest university. Poitiers is located near several other medium-sized cities with more recently established universities: in the sixties for Angers, Limoges and Orléans, and in the nineties for La Rochelle (Milard and Grossetti, 2017). The resulting network of higher education and research institutions is relatively dense, with a positive scientific momentum, in particular in chemistry, both in terms of output, diversity and visibility (Milard, 2012).

While the leadership of chemistry researchers in this area is unquestionably an asset, this does not suffice to conclude that the territory delineated by the boundaries of the INCREASE consortium is necessarily characterized by an outstanding scientific cohesion in chemistry, or for that matter in green chemistry. Actually, the geographic scope of the INCREASE consortium appears to be, at least in part, the product of preexisting relations between its members. As explained by Harrisson (2016), it is interesting to understand how their founders set the boundaries of such “constellations”, and to identify the criteria that determine whether a site is integrated into the consortium or not.

### *Framework and hypotheses*

Since the 1990s, literature on science and innovation has focused either on synergy effects between science and innovation stakeholders on a city-wide or regional scale (Cooke *et al.*, 1997; Asheim and Coenen, 2005; Catini *et al.*, 2015), or on complementarity effects achieved through the networking of clusters, cities and regions on a continental or global scale (Bathelt *et al.* 2004; Sebestian and Varga, 2012; Morrisson *et al.*, 2013). In this literature, exchanges of knowledge that are not intra-local or intra-regional are categorized as “non-local links” (Meyer *et al.*, 2011) and their geographic coherence is hardly ever discussed, except by analyzing complementarities between “distance effects” and “network effects” (Bergman and Maier, 2009; Ter Wal and Boschma, 2009; d’Amore *et al.*, 2013). A few studies suggest however that a more in-depth study of the geography of scientific exchanges can reveal interesting patterns: for instance, the decline of border effects in the organization of European exchanges

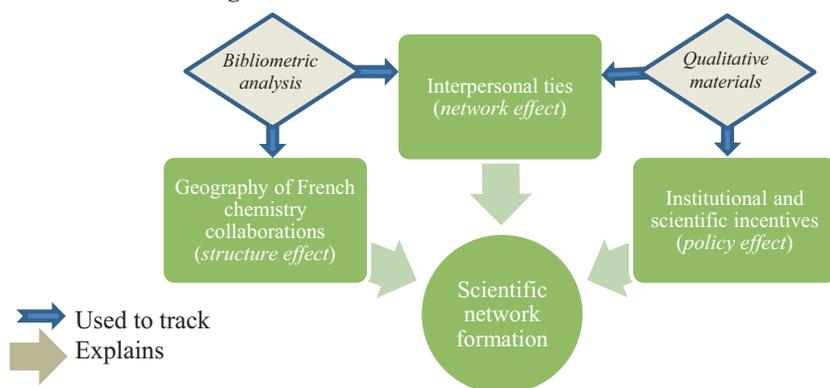
<sup>3</sup> Number of publications across all disciplines in the SCI Expanded in 2013

<sup>4</sup> Number of publications in chemistry in the SCI Expanded in 2013

(Hoeckman *et al.*, 2010); the enduring role of the national scale in the global organization of scientific activity (Maisonobe *et al.*, 2016); or the importance of geographic proximity for science-industry partnerships (Ponds, 2007). Our research on the inter-urban relations that are driven or strengthened by a French green chemistry network of laboratories belongs to this latter line of research.

We developed an analytical framework to examine the scientific cohesion of the territory formed by the INCREASE federation and to understand the determinants that shaped its emergence, looking at different levels of interpretation. In line with the analytical framework presented by Gulati and Gargiulo (1999), we worked from the idea that the embeddedness of relations is decisive in understanding the emergence of inter-organizational networks. To investigate the specific case of a cross-regional research and innovation network, our framework considers three levels of explanation (Figure 1).

**Figure 1. Framework of scientific network formation**



First, to understand the context in which INCREASE emerged, we examine the French map of chemistry – and in particular, special relations in this field. Drawing on the concept of “embeddedness” (Granovetter, 1985; Grossetti, 2008), we consider that the network of scientific collaborations in chemistry that existed prior to the creation of the Federation partly explains the decision of federating laboratories in Western France, as well as the fact that this decision originated from Poitiers researchers. Using a map showing the national organization of scientific activity, we can test the hypothesis that there was indeed a need for a better coordination of laboratories in this part of France. For this purpose, we carried out a bibliometric analysis of scientific collaboration networks between French cities. Along with Katz (1994), we consider that relations of scientific collaboration can be assessed from data on the co-authoring of scientific articles.

*H1: The state of scientific collaborations in chemistry between French cities shows a lack of coordination in the “Atlantic arc”, which justifies the federation’s creation (structure effect).*

Secondly, we focus on interpersonal relations that existed prior to the creation of the consortium, and that could explain its emergence. The presumed need for cross-regional coordination can only be fulfilled if there is at least some level of acquaintance between the parties involved in the emerging network. To assess these relations, we used data collected through interviews with federation members and through data on these members’ scientific collaboration networks, which we extrapolated from a corpus of bibliographic data from the *Web of Science* (the contents of this corpus are detailed later).

*H2: The federation’s geographic scope derives from prior relations of acquaintance and from projects of future collaborations between its members (network effect)*

Finally, although the federation is a “bottom-up” construct, its existence depended on it being signed off by public authorities. As a matter of fact, the consortium would not have any official existence without the CNRS’s moral and financial backing. This means that its scientific agenda is in line with the CNRS’s scientific and organizational objectives. The consortium benefitted from a context that made it possible, acceptable and even desirable in the eyes of CNRS leadership. These circumstances are not just the product of the CNRS’s internal policy, but also of a range of political, scientific and socio-environmental priorities on various scales (local, regional, national, European). To examine the policy level, we used qualitative materials including interviews, reports and grey literature.

*H3: The consortium’s emergence was made possible by its alignment with a number of scientific and political priorities (policy effect).*

By considering these various levels of causality, as represented in Figure 1, we can identify the social, scientific and historical factors that led to the integration of specific members and organizations into the consortium, the choice of its geographic scope and therefore its geography.

## **Data collection**

### *Capturing prior networks through a bibliometric analysis*

The bibliometric corpuses analyzed in this article are from the *SCI Expanded*. We consider three corpuses of publications:

- The first corpus (*corpus A*: 313,165 publications) includes all French contributions to journals listed in the *SCI Expanded*, regardless of their discipline (see Table 1):
- The second corpus (*corpus B*: 37,790 publications) includes all French contributions to publications listed as chemistry journals in the *SCI Expanded*:
- The third corpus (*corpus C*: 1,813 publications) includes all contributions published by consortium members. To delineate this corpus, we asked the representatives of each laboratory to give us a list of all the members whose current work is consistent with the research agenda of INCREASE. As a result, we obtained a list of 98 INCREASE researchers, unevenly distributed across the 7 labs (see Table 1). This unevenness can be explained both by the diverse sizes of the labs and by the diverse views team leaders have of the INCREASE research agenda.

For all three corpuses, we considered publications from 2007 to 2014. 2014 was chosen as a point of reference because we started this research in 2017 and it usually takes between two and three years for information on more recent publications to be up-to-date. 2007 was chosen as a starting point because a large number of initiatives aimed at structuring green chemistry in France were delivered after this date (Schultz, 2016). Those include in particular the launch of a new call for projects, and the creation by the CNRS of a national network of green chemistry researchers (CPDD for Chemistry and Processes for Sustainable Development).

To obtain a global overview of these datasets, we used the spatial bibliometric method developed by one of us in collaboration with a team of geographers and sociologists to process the entire contents of the *SCI Expanded* on the scale of urban areas (Maisonobe *et al.*, 2016). Urban areas were chosen as our resolution level because the administrative boundaries of cities are not comparable, and scopes of universities and labs are very heterogeneous from a place to the next. Knowing that the majority of co-authoring links happen within a single urban area, we consider interesting to focus on co-authoring links that develop between different urban areas. These links reflect collaborations that contribute to structuring scientific communities beyond the local scale (regional, cross-regional, national, macro-regional and global scale). We fraction the links’ weight according to the number of distinct urban areas that contribute to each co-publication (“*Whole Normalized Counting*”).

### *Understanding the emergence of the Federation through stakeholder interviews*

In order to understand the set-up of the INCREASE federation and to qualify the relations between INCREASE members as well as their integration into national and international green chemistry networks, we conducted two stages of interviews.

The first stage focused on INCREASE stakeholders: seven research lab representatives, three industry leaders as well as three institutional partners (University of Poitiers, Poitiers' Regional Council and the CNRS's chemistry department). 13 interviews were completed in 2016, of an average duration of 90 minutes. Their objectives were to question the stakeholders on the consortium's genesis, history and objectives, as well as on the benefits derived by each organization from participating in the network.

The second stage took place during the ISCG (International Symposium on Green Chemistry) organized by INCREASE in La Rochelle in May 2017. At the end of this week-long conference which brought together over 800 participants from 48 different countries, we completed 20 interviews of an average duration of 20 minutes, including 7 with academic members of INCREASE (who had not been interviewed during stage 1), and 8 with researchers or industrials who had co-authored a publication with an INCREASE member. We conducted these interviews with the help of data from the bibliometric analysis of *Corpus C*. Interviewees were asked questions on their co-authoring networks and on their participation in national and international green chemistry networks.

## **Results**

### *The organization of the chemistry field in France*

For many stakeholders in the French chemistry sector, the choice of federating laboratories based in the West of the country was coherent with the discipline's national structure. While laboratories in the Eastern half of France appeared well connected and inserted into diverse networks, those based in the West had little interaction between them in spite of their visibility and notoriety in the field of green chemistry. According to the founder of INCREASE located in Poitiers, whom was interviewed shortly after the launch of the federation in 2016, the French map of green chemistry networks was organized as followed: to the North-East, "a giant banana-shaped area" spanning from Lille to Reims (the PIVERT institute); to the South-East, "Lyon's chemical industry hub, with the Axelera competitiveness cluster"; and further South, Montpellier with the 3BCAR Carnot Institute, and Toulouse with the TWB (Toulouse White Biotechnologies); "but the whole of the Greater West was left out, with isolated laboratories". For this reason, the idea of structuring this field in the "Atlantic arc" emerged, which led to the creation of INCREASE. To confirm this interpretation and understand the national context in which this research federation emerged, we studied empirical data on the co-authoring of chemistry papers. Our analysis embraced urban areas, measuring the number of co-publications associating two different urban areas over the 2007-2014 period, just before the launch of the INCREASE consortium.

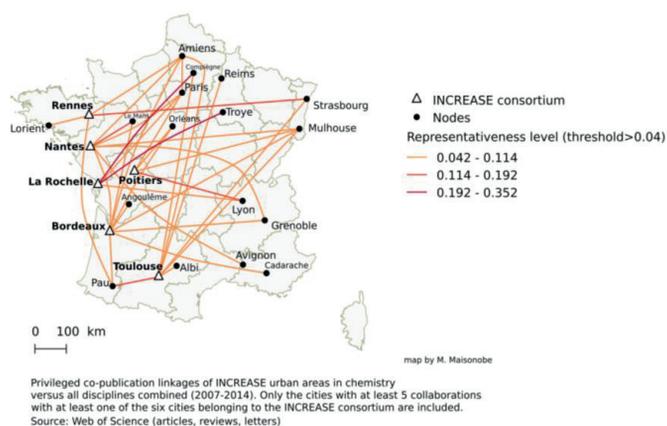
In order to qualify the existing relations between the six cities involved in the INCREASE chemistry consortium, we compare the spatial distribution of cross-urban collaborations in chemistry and across all disciplines. Suppose that  $x_{ij}$  is the number of co-authored papers between urban areas  $i$  and  $j$  in chemistry (corpus B), and  $y_{ij}$  the number of co-authored papers between urban areas  $i$  and  $j$  across all disciplines (corpus A). In order to compare  $x_{ij}$  with  $y_{ij}$ , we normalize them according to the following formula<sup>5</sup>:  $X_{ij} = \frac{x_{ij}}{x_i + x_j}$  for corpus B, and  $Y_{ij} = \frac{y_{ij}}{y_i + y_j}$  for corpus A. Then, we measure the deviation between  $X_{ij}$  and  $Y_{ij}$  using a measure of deviation from independence, which indicates the degree of

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<sup>5</sup> As noted by van Eck and Waltman (2009), there are various ways of normalizing collaboration data. In this article, we chose to normalize values based on the sum of weighted degrees for each city involved in a collaboration.

representativeness of co-authoring links between two cities in chemistry compared to in all disciplines. This indicator of representativeness' formula is:  $p_{ij} = \frac{X_{ij}-Y_{ij}}{\sqrt{Y_{ij}}}$ . If  $p_{ij}$  is greater than zero, then the intensity of relations observed in the field of chemistry is greater than expected in light of scientific collaborations between the two cities across all disciplines. Figure 3 shows overrepresented relations. This map indicates that the chemical industry hub around Lyon accounts for a relatively small share of relations with INCREASE cities. Only researchers from Poitiers and La Rochelle have a special relationship with Lyon in chemistry. Aside from a few exceptions, the main collaborations of the six INCREASE cities in chemistry are mostly located in the North and West of France. In particular, INCREASE cities share strong links with small and medium-size western cities: Pau, Orléans, Le Mans, Angoulême, Albi, and Lorient. Figure 3 thus suggests an East-West divide confirmed by the interviews.

**Figure 3. Privileged co-publication links with INCREASE urban areas in chemistry versus all disciplines combined**



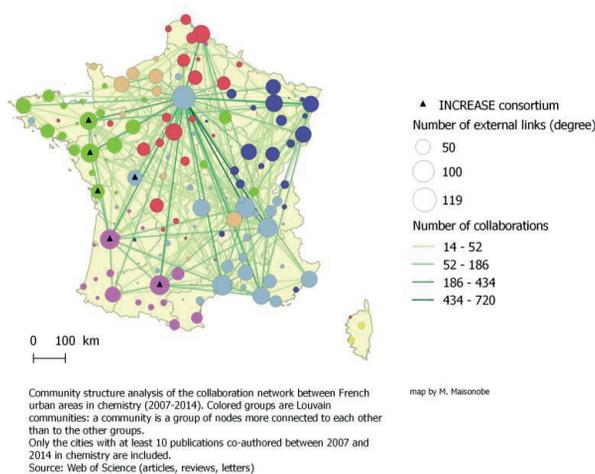
According to our interviewees, aside from their relative independence from the “chemistry valley” (South-East France), Western cities are traditionally isolated from each other. In order to ascertain this second fact, we apply a community detection algorithm to the network of collaborations between French cities in chemistry. This algorithm partitions the network into several groups characterized by a greater density of interactions between their members than with external groups. By applying the “Louvain” method<sup>6</sup>, we identify seven collaboration areas in chemistry represented in Figure 4.

We observe that INCREASE cities belong to different groups. Rennes, Nantes and La Rochelle connect with the Brittany group as well as with a few medium-sized cities in the center of France (green group). Bordeaux and Toulouse are part of a group that includes the Greater South-West (purple group). Located at the intersection of Brittany and Greater South-West, Poitiers is isolated and connected to the central network formed by Paris and Lyon (light blue group). The map shows that Poitiers sits in a unique position. The choice of creating a Poitiers-based consortium thus appears as an ambitious one, as this initiative could transform established networks. Rather than being a satellite of Paris and Lyon, Poitiers aspires to become a bridge in the Atlantic arc. According to the consortium’s founder, Poitiers indeed holds a strategic position in this network of six cities: “*When you look at the map, Poitiers is at the center, so when we have meetings everyone is at about two hours’ distance, which is pretty good for our operations. Proximity is important – you can always use videoconferences but they’re not the same.*”

<sup>6</sup> This method was applied using default resolution parameters (1). The result thus obtained is rather similar to that obtained with other clustering methods. In all cases, cities in Brittany and the South-West are in distinct groups.

This bottom-up decision, signed off by national CNRS leaders, intends to “fix” the lack of connections between the North and South of the Atlantic arc in chemistry, while deeply transforming Poitiers’ position in the overall structure (Lucena and Vicente, 2019).

**Figure 4. Community structure analysis of collaboration networks between French urban areas in chemistry.**



### *The role of interpersonal relations*

In the absence of much prior intensive scientific collaboration between network members (only Toulouse-Rennes; Nantes-La Rochelle, Nantes-Poitiers and Bordeaux-Toulouse had some prior co-authoring linkages according to Corpus C), other types of relations played a crucial role in the design and roll-out of the INCREASE network. In our interviews, we noted that several members of the consortium knew each other, or were at least aware of each other, before the federation’s launch. These acquaintance networks were decisive in the partners agreeing to join INCREASE when contacted by Poitiers’ laboratory. The interviews allow us to distinguish between three types of relations: ties formed through researchers’ professional mobility experiences; ties resulting from teaching and training functions (lectureships, thesis juries, etc.); and finally, ties formed between researchers contributing to common institutions, conferences and research programs.

This confirms the importance of networking in the academia organized as a professional system. Relations can form over the course of an individual’s career, including between laboratories that do not have a record of scientific collaboration. For instance, the Rennes and Poitiers INCREASE representatives met when they were both doing a PhD in Dijon, on subjects with no relation to green chemistry. Furthermore, the federation’s founder briefly worked in Rennes before taking up his post in Poitiers. For this reason, although the Rennes and Poitiers laboratories have never as yet collaborated on green chemistry projects, they will be able to do so in the future thanks to their relation of trust and to the consortium’s incentive mechanisms.

Similarly, although the relation between Poitiers and La Rochelle had not produced any scientific collaborations prior to the federation’s launch, this relation exists – if only because both cities used to belong, unlike the other four, to the same administrative region. The INCREASE representative in La Rochelle explains: *“I’ve never published with anyone from Poitiers (...) I’ve never published with anyone from IC2MP [Poitiers research lab]. But I do keep in touch with them: I take part in their recruitment days, I teach in a training course we run in common and we were in contact at the time of*

*the creation of the Green Chemistry Institute.*” The Poitiers laboratory has indeed long specialized in green chemistry, and has done so even before the arrival of the INCREASE co-ordinator in Poitiers. An initiative led by the previous generation of researchers had helped position the Poitiers lab in the national CPDD program (2007-2009), and federate local researchers with support from the Region.

Aside from those who get to know each other through working or meeting in the same laboratory at a point in their career, or through contributing to common training programs or thesis juries, others are well known to others because of their prominence in the field. For instance, two INCREASE researchers explained knowing each other before because they had been members of the same regional branch of the *Société Chimique de France*. This is also the case with the Bordeaux and Toulouse INCREASE representatives, known for having sat on the CNRS’s National Committee and on the National Research Agency (ANR), an agency in charge of the evaluation and selection of calls for projects. After 2007, some programs led by the CNRS and the ANR contributed to the national structuring of the “sustainable” chemistry field. These programs played an essential part on three levels: they helped the teams working on this subject to become aware of each other; they helped foster links with industrials; and they contributed to setting a scientific agenda.

#### *Policies supporting the emergence of a regional multi-skill network*

The networking of research institutions, as observed in this study through the creation of INCREASE, can be motivated by purely scientific motives: the network is often seen as a way of solving research problems by cross-pollinating skills and knowledge from fields with little communication between them. The development of green chemistry is a good illustration of this need for cross-pollination: today’s challenges require connections between chemistry (reaction, catalysis), processes (chemical engineering), biomass issues (biology) and lifecycle analysis (environmental impact).

From 2006, the CNRS and the ANR contributed to promoting sustainable chemistry’s development and organization in France (Schultz, 2016). In 2006, the CNRS launched a cross-disciplinary program (CPDD), aimed at drawing an inventory of sustainable chemistry teams in France. The CPDD program was led by three laboratories that later formed the core of the INCREASE consortium: Poitiers, Nantes and Toulouse. This initiative offered little funding but created a momentum amongst CNRS researchers. The Toulouse INCREASE representative reported that this program had given him the opportunity to launch a thematic summer school and an international conference on sustainable process engineering. Shortly after this, the ANR launched a large-scale call for projects: “Chemistry and Processes for Sustainable Development”, targeting the entire French community, beyond CNRS researchers. This time, some funding was available to support selected projects and the program offered strong incentives for multi-partner projects. The first phase was successful but its outcomes in terms of building links with the industry were disappointing. A second phase was launched in 2010 under the title: “Sustainable Chemistry – Industries, Innovation”. The program supported research projects with the ability to produce technology transfers that could benefit the industry, and focused on two aspects: improving communication between chemistry, processes and biotechnology; and assessing the costs and environmental impacts associated with resources, reactions and processes (Schultz, 2016).

These incentives significantly oriented the selection of labs contacted for the creation of the INCREASE consortium. The issue of environmental impacts was first built into the agenda of the ISGC international congress, organized bi-annually since 2013 by the Poitiers lab. Individuals who expressed their interest in this aspect of the congress were then invited by the founder of INCREASE to join the consortium. By involving chemists from Rennes, Nantes and Poitiers, the consortium also brings together specialists on all three types of catalysis, which are hardly ever associated (enzymatic, homogeneous and heterogeneous). This diversity of research subjects is the reason why the various teams had never had the opportunity to collaborate much before. Combining diverse specialties has both scientific and

economic benefits: the joint objectives are to further sustainable chemistry *and* to create a “toolbox” that industrials can access by directly contracting with the consortium rather than having to negotiate with each separate team.

The interviews produce the impression that the INCREASE consortium’s geographic coherence is more the result of multiple decisions than that of a clear intention to stay within the boundaries of a pre-defined geographic perimeter. According to the consortium’s leader, geographic proximity was not initially perceived as a must. It was even envisaged for the consortium to be “international” from the outset and to include foreign laboratories. Some interviewees explained that the Lille team could also have been part of the consortium due to its prior connections with Poitiers and Rennes, to its scientific specialism in characterization and to its international reputation. Similarly, Montpellier has a significant collaboration record with Bordeaux in the field of polymers and could legitimately have been part of the consortium. However, geography appears to have gradually become a resource on different levels.

Indeed, the consortium’s geographic coherence is a strong asset to rally support from national and international institutions and from industry partners. This coherence makes the French map of green chemistry more readable. It also contributes to the international visibility of Western France. In a context of growing international competition with the emergence of new congresses on this theme in Germany and New-Zealand, it appeared relevant to anchor the Poitiers group into a structured local network with an established reputation for its diverse skill base. In terms of science-industry transfers, this geographic coherence is also an asset. Overall, the emergence of INCREASE responds to a trend that is broadly encouraged by today’s public authorities and policies: clustering and/or networking research institutions located within one same area that offer a combination of diverse resources and skills. This response to existing needs is driven by the founder of INCREASE, who wants to develop his leadership in a context where the CNRS is keen to train professional research executives. Ultimately, the creation of INCREASE owes as much to his skills as a researcher as it does to those as an academic entrepreneur (Jain *et al.*, 2009; Perkmann *et al.*, 2013): an entrepreneur who took advantage of geography to build a consortium that could in turn transform the geography of connections.

## Conclusion

Green chemistry refers to a drive in chemistry towards adopting more environmentally friendly practices (Marion *et al.*, 2017). These practices, which can be expected in term to spread across all of chemistry, are today becoming structured as a specialism – or at least, as a cross-disciplinary area of work. Its development parallels that of nano-chemistry, which has also contributed to transforming the discipline. In both areas, change does not only affect major international hubs. The emergence of new perspectives in chemistry makes it necessary to move beyond old collaboration habits and to build links between teams that had not been accustomed to collaborate in the past. Coordination mechanisms, such as national or European calls for research projects, were created for this purpose. Another structuring initiative in France has been the opportunity to form consortia of laboratories around specific themes. This opportunity, although rarely taken up, is one of the mechanisms developed by the CNRS to structure the national map of scientific activities. It can facilitate the emergence of cross-regional networks whose boundaries are original in that they do not match existing administrative units – such as for instance the INCREASE consortium, which forms the object of this study.

This article had a three-fold objective: better understanding the creation of the INCREASE cross-regional thematic network; examining the level of scientific structuring of the cross-regional space shaped by this network, or “Atlantic arc”; and studying the determinants of its delineation and of its scientific and geographic scope. For this purpose, we examined the recent map of scientific collaborations in chemistry (structure effect – H1), the various types of existing relations between consortium members (network effect – H2) as well as the impact of policy incentives, scientific and

socioeconomic issues on the scope of this inter-organizational creation (policy effects – H3). These three levels of explanation shed an interesting light on the structuration processes that affected this cluster of Western France cities in green chemistry.

Unlike the alliances studied by Harrisson (2016) initiated by the UK government to facilitate the allocation of higher education and research funding and let alliance members distribute the funds between themselves in proportion with their weight or evaluation scores, the instrument we studied is a flexible one, born from the scientists' desire to federate around a common theme. Member laboratories retain their full autonomy and freedom to work with any other laboratory<sup>7</sup>. Some members may question the consortium's boundaries and wish that such or such laboratory had been included; others are not very convinced by the need for geographic coherence (as discussed above, this coherence is a resource more than a necessity); but all understand the benefits of a consortium of this type.

If a lesson had to be drawn from this study, it would be that it is not for geography to constrain public policies, but instead for public policies to facilitate the activation of connections on different geographic scales. No single level should be privileged above others – for instance through pooling all efforts into the development of local synergies (as was the case with the development of “technopoles”), or into the consolidation of international links. On the contrary, the INCREASE case shows that cross-regional links can also be productive. As shown by recent studies on “network failures” (Lucena and Vicente, 2019), scientific collaboration policies should not set constraints but instead ambition to support researchers and industrials. This involves giving them the instruments they need to facilitate connections that appear to have potential but that are challenging to implement for historical reasons to do with collaboration habits and institutional boundaries (such as the administrative unit of the region). The creation of the INCREASE network was made possible by the flexible model of the “research federation” proposed by the CNRS, which appears particularly adapted to this type of approach.

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<sup>7</sup> If a collaboration is developed between two of the seven labs involved in the consortium, then this collaboration can benefit from the federation's support in the form of a PhD grant, internship, industrial contract, etc.

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