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Personal Communication Ties and Organizational Collaborations in Networks of Science, Education, and Business

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Abstract

The literature suggests that the success of innovation clusters is based on personal networks that connect members of scientific, educational, and business organizations, stimulating more formalized cross-boundary collaborations between the three sectors. But it is still unclear if such organizational collaborations actually correspond with these personal ties and which aspects of personal communication are most strongly associated with organizational collaborations. To investigate these issues, the authors applied network analysis to study an innovation cluster in Algarve, Portugal. They found that cross-boundary organizational collaborations corresponded with personal ties. Moreover, they found that collaborations appeared to correlate most strongly with emotional attachments between individuals.

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The collaboration between science, education, and business has been found to provide benefits to each of the sectors and to society as a whole because it stimulates the creation of new knowledge and innovation (Bruneel, d'Este, & Salter, 2010). Building innovation systems that integrate science, education, and business despite differences in the specific goals of the sectors is now a common policy task for many countries striving to become knowledge-based economies. Network structuring of organizational collaborations across sectoral boundaries is considered to be one of the most important means to provide such integration. Such structures (a) involve joint innovation efforts that put research results into new products and services introduced to the market, (b) enable flexible exchanges of resources and knowledge that are crucial for innovation, (c) induce cross-sectoral personnel mobility, and (d) stimulate the creation of new innovation-oriented enterprises (Breschi & Lissoni, 2003; Jaffe, Trajtenberg, & Henderson, 1993; Krätke, 2011; Malerba, 2009; Robinson, Rip, & Mangematin, 2007).

The majority of studies on innovation-oriented science, education, and business collaborations have focused primarily on generalized science and industry collaborations or formal interorganizational links between research and business, mostly in the so-called "high-tech" industries (Bania, Calkins, & Dalenberg, 1992; Meyer-Krahmer & Schmoch, 1998). These studies addressed the aggregate effects of university research on knowledge production in companies (Anselin, Varga, & Ács, 1997; Jaffe, 1989); certain types of knowledge interactions such as citations of university research in company patents (Jaffe et al., 1993); personnel mobility (Bania et al., 1992); joint publications (Hicks, Isard, & Martin, 1996); and the formation of new "spin-off" companies by university members (Parker & Zilberman, 1993).

But in recent decades, researchers have also recognized the value of less formal networks of personal communication ties in forming the basis for trust (Newell & Swan, 2000), information exchange (Grandori & Soda, 1995), practice sharing (Brown & Duguid, 2001), and knowledge creation (Easterby-Smith, Lyles, & Tsang, 2008; Pinch & Henry, 1999). Scholars have seen such networks as underpinning the emergence and development of relations between organizations because personal ties involving informal

interactions enable a common "language" and culture (Bonaccorsi & Piccaluga, 1994) as well as cognitive closeness (Balconi & Laboranti, 2006; Gubbins & Dooley, 2014; Lorenzen, 2001). These ties also induce a "personal chemistry" between the individuals involved that makes them more open to hearing each other's new ideas, recognizing each other's needs, and accepting that they can learn from each other (Taylor, 2005, p. 481); as a result they become bonded by feelings of personal obligation and emotional closeness (Huber, 2012, p. 1179)—such as sympathy, friendship, or astonishment—which are achieved over the course of joint work or leisure activities. Hence, networks of personal ties can be expected to provide a good basis for mutual understanding and collaboration across the boundaries of science, education, and business despite each sector's specific goals, strategies, norms, and values.

The role of communication across boundaries in a knowledge-based economy including organizations, activities, disciplines, and fields has been emphasized by business and technical communication researchers (Rice, 2009; Spinuzzi, 2007). Yet to the best of our knowledge, the relationship between concrete personal communication ties and cross-boundary organizational collaborations between science, education, and business has not been examined. In other words, it is still unclear if the personal communication ties between members of two organizations belonging to different sectors are related to the more formal collaborations between the organizations. Consequently, there is no information on which particular aspects of such personal ties are most relevant to cross-boundary collaborations. To fill this research gap, our study focuses exclusively on networks of links across sectoral boundaries in order to investigate the following question: How are organizational collaborations across the boundaries of science, education, and business related to different aspects of the personal ties between these organizations?

This investigation applies *network analysis*, a structural approach broadly used to understand patterns of relationships between nodes, such as people or organizations. Network analysis explains phenomena primarily according to the ways these relationships are configured into larger structures. It gives a secondary role to the properties of nodes and meanings of the relationships between them (e.g., the particular ways interactions unfold and the contexts of interactions). Consequently, the data collection techniques used in network analysis, such as the most widespread method of sociometric questions (Wasserman & Faust, 1994), first and foremost capture who is linked to whom.

This focus on the structures of links has significant explanatory capacity. The patterns of relations, when mapped, allow us to visualize and explore the set of connections between individuals or organizations. This structure can then be described with statistics that capture network characteristics in order to explain various phenomena. For instance, such measures as network density and centralization allow us to locate blocks and overloads in information exchanges, knowledge, and resources. They also enable researchers and practitioners to identify whether information, knowledge, and resources tend to be channeled via a few central nodes or distributed more evenly among the nodes, thus identifying the possible imbalances in the distribution of information, knowledge, and resources—and hence imbalances in power. Centrality measures characterize the positions of certain nodes in networks and therefore help to identify the roles that particular individuals or organizations play within structures of exchanges with others. For example, Zwijze-Koning and de Jong (2015) showed how network analysis can be applied to assess communication in organizations and uncover communication problems.

Moreover, network analysis allows us to see how structural properties of relational patterns affect performance, knowledge diffusion, and innovation potential. For instance, using network analysis of technology-based alliances in the pharmaceutical, chemical, and automotive industries, Gilsing, Nooteboom, Vanhaverbeke, Duysters, and van den Oord (2008) found that novelty creation, the absorption of innovations, and the number of patents depend on the overall density of the network and the ability of the organizations to connect the network parts, the latter being captured by the betweenness centrality measure. In a study of collaborations between universities and industry in microelectronics, Balconi and Laboranti (2006) applied network analysis to reveal how research progress is enabled by the specific patterns of personal ties between academic and industrial researchers. The study detected particular types of interpersonal structures that were associated with higher research performance (measured by patents applied for and citations received): strongly connected teams composed of researchers from both academe and industry. Cowan and Jonard (2004) analyzed networks of research institutes and of innovating companies and found that the extent of knowledge diffusion in these networks was affected by the network structure and that the highest diffusion performance was achieved when the networks contained denser clusters of links with sparser structures between the clusters. And Ouimet, Landry, and Amara (2004) explored network positions of companies within the Quebec optics and photonics cluster and found that the amounts of ties organizations have are positively related to radical innovation.

A series of studies (Cooke, Porter, Cruz, & Pinto, 2011; Cruz, Gonçalves, Pinto, Pintassilgo, & Guerreiro, 2011; Gonçalves, Cruz, Pinto, Pintassilgo, & Guerreiro, 2011) used network analysis to study a science-driven maritime innovation cluster located in the Algarve region of Portugal. The cluster, composed of 25 entities (university faculties, research centers, and companies), is an attractive case for analysis not only because marine science research and education in the Algarve are among the global leaders in this field but also because, for maritime clusters in general (Chang, 2011) and for this cluster in particular, cooperation between science, education, and business is essential (Cooke et al., 2011). Based on interview data that captured collaborations between organizations, the researchers showed that despite the efforts that administrators, innovation intermediaries, and cluster participants put into stimulating cooperation, organizational collaborations across the sectoral boundaries in Algarve were still insufficient (Comissão de Coordenação e Desenvolvimento Regional do Algarve [CCDR], 2008, 2009; Cruz et al., 2011; Gonçalves et al., 2011). Researchers suggested that these collaborations could benefit from personal communication ties between members of organizational entities (Cooke et al., 2011; Cruz et al., 2011; Gonçalves et al., 2011).

These studies provided insights on the importance of personal communication for the cluster and showed the high relevance of network analysis for studying this case. But their data on the structures of relations included only organizational collaborations, not personal ties, which the analysis found to be crucial for the collaborations between science, education, and business. Besides, the network analysis conducted by these researchers was limited to mapping the network and interpreting several basic, network-level descriptive statistics and did not look for the underlying principles of structure formation. Therefore, the extent to which the personal ties are actually relevant for developing organizational collaborations in the cluster is still not clear. Our study, then, collects data on personal ties and uses network correlation analysis in order to test for the association between structures of personal communication ties and structures of organizational collaborations.

In the following sections, we build on the literature on correspondence between personal communication networks and organizational collaboration networks in regional innovation clusters—including collaborations between universities and industry—as well as specific aspects of the personal communication ties. Then we describe our empirical case study and the data collected from it and outline our network mapping procedures and analysis techniques. We compare the networks, visually inspecting them and interpreting standard network statistics. Further on, we use the

quadratic assignment procedure (QAP) to test to what extent organizational collaborations are associated with different aspects of personal ties. Finally, we discuss the findings, some possible future avenues for research, practical implications, and the study's limitations.

Literature Review and Analytical Focus

Organizational networks, in which organizations are nodes and lines are the connections between them (e.g., collaborations, alliances, and resource exchanges), have been thoroughly investigated in recent decades. This research has shown that such networks are highly relevant to innovation (Hargadon & Sutton, 1997; Malerba, 2009) and that the relationships within the networks are always embedded in interpersonal communication networks across boundaries of organizations or units (Granovetter, 1973, 1985). In these personal networks, nodes represent individuals and lines stand for the connections between individuals. Personal networks—especially through face-to-face interactions—enable the sharing of practices and knowledge between organizations (Brown & Duguid, 2001; Easterby-Smith et al., 2008) as well as the diffusion of innovation (Ceci & Iubatti, 2012). Therefore, organizations embedded in personal networks are more innovative (Brass, Galaskiewicz, Greve, & Tsai, 2004). Moreover, personal networks create common interests, worldviews, and cultures, allowing organizations to overcome what Grandori and Soda (1995) termed the "psychological distance" between their cognitive and emotional orientations as well as the distance between their organizational profiles, hence enabling trust (Eisenhardt & Schoonhoven, 1996). As a result, being embedded in personal communication structures motivates organizations to pursue goals linked not to immediate economic revenues but rather to the long-term strengthening of their networks. And personal ties are "capable of generating other, more institutionalized forms of coordination" (Grandori & Soda, 1995, p. 199). Overall, then, personal networks form the basis of integration and cooperation between organizations.

The Role of Personal Ties in Relations Between Science, Education, and Business

Research reports that personal communication plays a particularly important role in collaborations between universities and industry (Kaufmann & Tödtling, 2000). For instance, studies on knowledge interactions within such collaborations reveal that personal communication is the most widespread type of exchange between universities and industry (Arundel & Geuna, 2004)

and that researchers' individual characteristics have a stronger impact on knowledge interactions between universities and industry than do the characteristics of their department or university (D'Este & Patel, 2007). Research also shows that knowledge dissemination and technology transfer between universities and industry are often carried out via informal contacts (Østergaard, 2009), especially in collaborations between university scientists and managers or entrepreneurs in the private sector (Siegel, Waldman, Atwater, & Link, 2003), for which informal communication, public events, and consulting are among the main knowledge transfer channels (Gubbins & Dooley, 2014). Such contacts are also the reason why the literature suggests that the agglomeration of research institutions and companies within innovation clusters appears to be important (Arundel & Geuna, 2004).

Personal contacts between science, education, and business entities have also been shown to enrich the pool of candidates for recruitment, create intellectual capital, raise the effectiveness of cross-functional teams, enable employee turnover, provide the competencies of entrepreneurs to science and education, give universities access to regional production networks, and facilitate the internationalization of business and education (Chakrabarti & Santoro, 2004). Via personal ties, faculty members and students can engage in joint consulting projects between universities and industry so that universities gain practical expertise and resources while companies receive creative and high-tech solutions (Perkman & Walsh, 2007).

Consequently, we can expect that personal communication ties across the boundaries of science, education, and business stimulate the establishment of organizational collaborations, promoting further integration between the sectors. But to date, most studies of personal relations in collaborative innovation and organizational cooperation have focused on the benefits and negative effects for individuals and organizations in occupying certain network positions (Burt, 1980; Granovetter, 1973; Inkpen & Tsang, 2005; see Provan, Fish, & Sydow, 2007, for a summary). To our knowledge, however, no studies have examined the correlations between personal communication ties across organizational boundaries and organizational collaborations in networks of science, education, and business (or universities and industry).

Aspects of Personal Ties Across the Boundaries of Science, Education, and Business

Personal ties have multiple aspects. They cannot be reduced to simple indicators, such as the frequency of communication. In his influential work, Granovetter (1973) has suggested that communication ties might be

distinguished by "the amount of time, emotional intensity, intimacy (mutual confiding), and reciprocal services which characterize [them]" (p. 1360). Padgett and Powell (2012) later argued that the multidimensionality of network relations particularly contributes to knowledge sharing and the establishment of new relations. Thus, another important task is to identify which aspects of personal communication ties are particularly relevant to the existence and development of organizational collaborations.

Little is known about the impact that different aspects of personal communication have on organizational collaboration, particularly in regional innovation clusters—such understanding would come from more generalized studies. First, network studies traditionally account for communication frequency (e.g., Granovetter, 1973): The more often individuals interact, the higher the chances that their organizations might be involved in more formal collaborations.

Second, there is a consensus that the important functions of personal communication ties across boundaries between universities and industry are to exchange knowledge between organizations, develop a joint language and a common research culture, form a common knowledge base (Bonaccorsi & Piccaluga, 1994), and provide cognitive coordination (Gubbins & Dooley, 2014; Lorenzen, 2001). Therefore, the intellectual (cognitive) dimension of personal communication ties should be taken into account when considering knowledge-sharing and innovation-oriented collaborations between science, education, and business.

Third, as Granovetter's (1973) classical work suggests, the emotional attachment that develops between individuals throughout communication is important. Cova and Salle (2000) referred to the "emotional superstructure" of a relationship. And Matzler, Renzl, Müller, Herting, and Mooradian (2008) found empirical evidence of the impact of enduring individual characteristics on knowledge sharing. As Taylor (2005) put it, "personal rapport and chemistry among the individuals" are what make organizational alliances emerge and work because "inter-personal trust is also built up when people are prepared to be open to new ideas, to listen to each other and to accept that there is something to learn from the other alliance partners" (p. 481). Such alliances go beyond formal relations (Gilsing, Nooteboom, Vanhaverbeke, Duysters, & van den Oord, 2008). Huber (2012) even reported that "the most important knowledge relations are based on high levels of feelings of personal obligations and emotional closeness" (p. 1179).

Based on this literature, then, we suggest focusing on such aspects of personal ties as frequency of communication, intellectual influence, and

emotional attachment to determine whether these aspects correspond to organizational collaborations and to what extent.

More recent research has suggested that an interesting extension of the network analysis of regional clusters would be to account for tie strength (Giuliani, 2013). Studies including empirical research of knowledge and innovation collaborations argue that complex knowledge transfer in networks requires what Granovetter (1973) called "strong ties"—those based on intense and frequent interactions between partners (Hansen, 1999). Such ties especially stimulate the development of trust and mutual understanding, most often through face-to-face interactions (Storper & Venables, 2004). Strong ties allow going beyond actors' self-oriented interests and therefore are particularly relevant for developing cross-boundary collaborations between science, education, and business. Following this literature, we focus here on studying personal ties that exhibit a higher frequency of communication and a stronger intellectual influence and emotional attachment.

The Empirical Case

To get an insight into the relations between different aspects of personal ties and organizational collaborations in networks of science, education, and business, we studied a specific regional innovation setting: Algarve maritime cluster in Portugal.

The Algarve region includes unique marine ecosystems (e.g., the Ria Formosa) that provide numerous opportunities for maritime studies that are unavailable anywhere else, putting marine research and education in Algarve (which primarily involve the biology, chemistry, and physics disciplines) among the global leaders in the field. The region has many unique natural tourist attractions as well. But the Algarve maritime cluster has drawn our attention because administrations and local experts strive to use its existing innovative potential in order to transform the region from a peripheral economy driven by agriculture and fisheries to a knowledge-based innovation cluster. As we will show, the integration of science, education, and business in the region is pivotal for this effort.

The ocean is central to Algarve's economy, and its essential role in the progress and diversification of maritime activities is the essence of the region's development, as acknowledged in the major programs and strategic plans for the region pushed by the Regional Development Coordination Commission (CCDR, 2006, 2007, 2008, 2009) as well as in scientific studies (Cruz et al., 2011; Gonçalves et al., 2011). In maritime-oriented

regions, business, research, and education organizations usually operate in diverse areas, such as shipping, shipbuilding, offshore services, inland waterways, pharma, yacht building, marine equipment, seaports, maritime services, fishing, marine food production, navy, waterworks, and coastal tourism (for an extensive overview, see Cooke et al., 2011). Involvement in maritime economy leads all those diverse areas to join into maritime clusters, creating "a network of firm, research, development and innovation units and training organizations . . . which cooperate with the aim of technology innovation and of increasing maritime industry's performance" (Chang, 2011, p. 489). In Algarve's case, maritime production and services (food production and aquaculture, coastal tourism, and knowledge-driven services) become linked with research units that produce knowledge in maritime science and educational institutions that provide human resources (CCDR, 2008, 2009; Cruz et al., 2011; Gonçalves et al., 2011).

In the Algarve maritime cluster, the research and education entities are a group of different units from the University of Algarve (faculties and schools, research units, etc.). They are the main group not only to provide knowledge, technology, and human resources but also to create innovation-oriented business organizations as spin-off and start-up companies founded by alumni and employees of the university. In coastal tourism, Algarve companies engage in collaborative research and development (R&D) projects with university faculties and research centers in order to deliver innovation in tourist services, management, economic and environmental issues, and energy use for tourist activities. In maritime food production and maritime services, research centers generate knowledge that companies can use. Faculties provide training and human resources for both the companies and the research centers.

Although cooperation does take place, qualitative studies have reported insufficient collaborations between research centers, companies, and faculties (Cooke et al., 2011; Gonçalves et al., 2011). The most important barriers to collaborations between science, education, and business in the region appear to result from the lack of mutual understanding across sectoral boundaries. Consequently, the potential benefits of cross-boundary cooperation for each of the sectors, though highlighted by administrations and experts, are often underestimated. Companies, for instance, do not clearly comprehend how the science done in university research centers potentially contributes to business. Managers tend to have limited vision of their business's broader innovative potential, often relying on core innovations that their companies initially started with as well as on internal R&D and neglecting other opportunities for research-driven development.

Hence, they have little interest in cooperating with research centers and faculties. At the same time, research units experience difficulties in communicating science and transferring knowledge (Cooke et al., 2011, pp. 42, 44, 66). The demand of companies in human resources and services is not satisfied by research centers and faculties (p. 45). Education does not seem to respect the needs of science and business, giving faculty teaching loads that leave time neither for fundamental research nor for R&D. Meanwhile, those pursuing an academic career are required to publish, which hinders their participation in applied research for business. Thus, differences in the goals, norms, and values of science, education, and business hinder their collaborations in the cluster. The experts highlight the necessity of better coordination between different types of activities and of a common vision on how the cluster should be developed: "We need a strategic vision that encompasses within Sea activities more than fisheries, that includes several sectors and other communities" (p. 42).

Our literature review suggests that personal relationships could be a solution for achieving such coordination. According to local experts and cluster participants, personal communication across boundaries is important for overcoming existing barriers to cooperation, enabling a common vision of organizations in the cluster (Gonçalves et al., 2011) and facilitating the knowledge transfer for which people are central, and informal channels are pivotal——and trusting relationships are crucial components of this informal personalized communication (Cooke et al., 2011, pp. 65, 67). In the cluster, there are many communication activities (e.g., conferences, meetings, informal interactions) organized to bring together representatives of science, education, and business in order to form personal communication ties between them and thereby induce cross-boundary collaborations.

It seems plausible, then, that personal communication, which is known to induce trust and personal closeness, could help to overcome the barrier of misunderstanding that hinders cooperation between science, education, and business in the cluster. Nevertheless, prior research has only addressed the patterns of organizational collaborations without investigating either the concrete structures of personal ties or the relations between these ties and organizational collaborations in the cluster. Our ambition is to explore the role of personal ties, overcoming the barriers to cooperation between science, education, and business. We use statistical network analysis techniques to test the extent to which different aspects of such ties correspond to the network of cross-boundary organizational collaborations.

Method and Data

The empirical study included three steps: (a) mapping and analyzing the organizational collaboration network, (b) mapping and analyzing the personal networks, and (c) analyzing the correlations between organizational collaborations and personal networks.

Network of Organizational Collaboration

The network of organizational collaboration between science, education, and business that we examine here includes 25 nodes across the three sectors: (a) businesses in aquaculture, marine equipment, fishing, maritime services, food production, waterworks, coastal tourism and leisure, and entertainment; (b) university departments in marine sciences and technology, economics, management, and hospitality and tourism; and (c) scientific research centers in marine technology, marine and environmental sciences, hydrology, fish farming, information science, and tourism and leisure studies (see Table 1).

This network is based on a data set collected by Cruz, Gonçalves, Pinto, Pintassilgo, and Guerreiro (2011),[1] who conducted 45 semistructured interviews with experts participating in the Algarve maritime cluster, including company employees, university faculty, research center scientists, and innovation intermediaries. Their collaborations involved knowledge and technology exchanges, personnel mobility, joint R&D projects, and spin-off and start-up creations. To trace the collaboration linkages, the interviewers asked these participants, "Who are your organization's partners?" Each of the organizations and the partners named were then considered as network nodes. The resulting network included 154 nodes.

We supplemented and verified the network using open-source data on partnerships, filtering out intermediaries and those nodes in the initial set that were not based in the Algarve region but were only linked to local organizations.

Further, because we wanted to study only links between science, education, and business, we removed ties that did not cross the sectoral boundaries so that the final network exclusively represented the direct links that corresponded to collaborations between science, education, and business.

Next, we calculated conventional descriptive statistics for the network, such as the overall network density and the degree, closeness, and betweenness centrality measures for all the nodes (Wasserman & Faust, 1994). *Network density* was calculated as the proportion of existing links in relation to all the possible links in the network. In other words, this

Table 1. Nodes in Algarve Maritime Cluster Network.

Full Title	Short Name	Sector
Aqualvor–Activities in Aquaculture Ltd	AQUALVOR	Business
Big Game Fishing	Big Game	Business
Centre of Marine Sciences, University of Algarve	CCMAR	Science
Coastal and Marine Environments Research Centre, University of Algarve	CIACOMAR	Science
Centre for Marine and Environmental Research, University of Algarve	CIMA	Science
Technological Research Centre of the Algarve, University of Algarve	CINTAL	Science
Centre for Studies in Travel and Leisure, University of Algarve	CITel	Science
Company of Fisheries of Algarve	ComPes	Business
Ecoceanus, Unipessoal, Lda	ECOCEANUS	Business
School of Management, Hospitality and Tourism, University of Algarve	ESGHT	Education
Faculty of Sciences and Technology, University of Algarve	FCT	Education
Faculty of Economics, University of Algarve	FE	Education
International Centre for Coastal Ecohydrology, University of Algarve	ICCE	Science
Inovsea, Lda	INOVSEA	Business
Research Institute of Fisheries and Sea, University of Algarve	IPIMAR	Science
Marsensing, Lda	Marsensing	Business
Natura	Natura	Business
Necton, Portuguese Culture Marine Company, SA	NECTON	Business
Portuguese Company of Sanitized Salt, SA	SALEXPOR	Business
Information Processing Laboratory, University of Algarve	SIPLAB	Science
Sparos, Lda	SPAROS	Business
Sunquays	Sunquays	Business
Vitacress	VITACRESS	Business
Waters of Algarve	Águas Algarve	Business
Zoomarine	Zoomarine	Business

measure indicates the thickness of the network. *Degree centrality* was calculated as the sum of links a node has. This measure indicates the amount of direct connections linking a node to other nodes. *Closeness centrality* was calculated as the inverse of the sum of the distances between a node and all other nodes, distance standing for a connection between two nodes via

the smallest number of links. Hence, this measure shows how close the node is to all other ones in the network. *Betweenness centrality* stands for the amount of shortest network paths (routes composed of sequences of links leading from one node to another) passing through a node. This measure indicates how often the node appears to be on the shortest path between other nodes. High values of these centrality measures indicate that a node has a powerful position in the structure of relations, especially when that node is the most central according to several centrality measures.

Networks of Personal Ties

To map different aspects of personal ties between employees of science, education, and business entities, we conducted an e-mail survey using sociometric questions, specifically tailored for each sector, that infer who is connected to whom. This technique is conventionally used in network analysis of regional innovation clusters (Ceci & Iubatti, 2012; Giuliani, 2013). These questionnaires covered the three aspects of personal ties between individuals: frequency of communication, strength of intellectual influence, and strength of emotional attachment.

In particular, we sent the questionnaires to the faculty members, researchers, and company employees in the cluster after having obtained their names and e-mails from the organizations' Web pages and via direct contacts with representatives of the organizations. Each questionnaire, first, asked the respondents for their name, place of employment, and position as well as the size of their organization. In addition, it asked the following: "In your opinion, to what extent is trilateral collaboration between companies, research centers, and university faculties/schools developed in Algarve?"

Second, to track personal ties, each questionnaire invited respondents to list their contacts from other sectors, selecting for each contact the entity where the contact is employed from a drop-down list. Then for each contact named, it asked respondents (a) "How many times a month do you communicate?" (b) "How strong is the *intellectual* influence of this contact on you?" and (c) "How strong is your *emotional* attachment to this individual?" Participants could respond to the questions by selecting the strength of the tie from 0 to 4 from a drop-down list. For the communication frequency scale, 0 meant *1 or less times per month* whereas 4 meant *15 or more times per month*. For the intellectual influence and emotional attachment scales, 0 meant *no influence/attachment* whereas 4 referred to *very strong influence/attachment*. An exemplary questionnaire (version for employees of companies) is presented in the Appendix.

In describing the strength of their ties, respondents could have different interpretations of the terms *intellectual influence* and *emotional attachment*. For instance, respondents might interpret intellectual influence to mean how much they value the other person's work, follow the other's ideas, are affected by the other's opinion, and so forth. Emotional attachments, in general, refer to the respondents' feeling of emotional closeness to the other person, which could involve feelings of enduring sympathy, friendliness, joy and happiness, gratitude, astonishment, or other positive emotions. Diverse positive emotions, then, could induce personal attachment and create strong bonds between individuals (Bowlby, 1973; Mikulincer & Shaver, 2005; Shaver & Hazan, 1993). Because we wanted not to differentiate between but to compare these various interpretations within the three aspects of personal ties, we did not specify any particular emotion to the respondents. Similarly, we did not differentiate between different types of intellectual influence. We also did not trace the history of the personal relationships. Intellectual influences and attachments could occur from working as teammates, studying together at the university, participating in the same professional associations, being neighbors, and so on.

In total, 128 respondents took part in our study. Out of them, 61 were on university faculties, 47 came from research centers, and 20 came from companies.

We aggregated the survey data by mapping each unique combination of an organizational entity and a contact's name as a separate node. Thus, when an individual was a member of more than one entity—for example, a company and a faculty—one node was recorded for the company and another for the faculty, following the interlocking directorate tradition (Burt, 1980). The resulting network, then, included 155 nodes linked with ties of strength varying from 0 to 4. The nodes representing members of more than one entity were linked with ties of maximal strength.

Next, we produced three networks connecting the 25 organizations included in the analysis and representing different aspects of personal ties: (a) frequent personal communication, (b) strong intellectual influence, and (c) strong emotional attachments. To do so, for each of the three aspects of personal ties, we took the average of the strengths of all the ties connecting the employees of every dyad of organizations. The resulting average numbers were considered as the strengths of personal ties between the organizations in each of the three networks. Tie strengths varied from 0 to 4.

To produce networks of frequent communication, strong intellectual influence, and strong emotional attachment, we kept only the ties that were stronger than 2.

Then we calculated the degree, closeness, and betweenness centralities of the nodes in the three personal networks using the same procedures as those we used for organizational collaboration networks.

Correlations Between Networks of Personal Ties and Organizational Collaborations

To check for correlations between organizational and personal networks in the Algarve maritime cluster, we applied the QAP correlation (Hubert & Schultz, 1976) to the pairs of networks[2]. QAP is designed to test for codependencies between different types of links connecting the same nodes. QAP uses existing links to establish correlations (Broekel, 2015), which is useful in such a loosely connected setting as science, education, and business collaboration. For example, to check whether information exchanges were related to monetary exchanges, Hanneman and Riddle (2005) used a data set of the two types of links between 10 organizations. They hypothesized that the network of information links would positively correlate with the network of monetary links. In other words, they expected that the pairs of organizations that exchanged information would also be more likely to exchange money. Similarly, we hypothesize that collaborations between organizations positively relate to strong personal ties between their employees. Moreover, we compare the relevance of different aspects of personal ties to collaborations—by comparing the correlation coefficients that collaborations have with the different aspects of personal ties.

To test our hypothesis, we measured the correlations between links in the organizational collaborations network and each of the three aspects of personal ties: (a) frequent personal communication, (b) strong intellectual influence, and (c) strong emotional attachment. A conventional proportion of .05 or less suggested a nonchance relationship. Using permutation trials (10,000 per run), we computed the statistical significance of the correlations with UCINET for Windows 6.512 (Borgatti, Everett, & Freeman, 2002) and considered the Jaccard coefficient as recommended by Hanneman and Riddle (2005).

Results

The results of our analysis showed that the organizational collaborations between science, education, and business in the Algarve maritime cluster were fewer than we had expected. Network density was only 5%, which

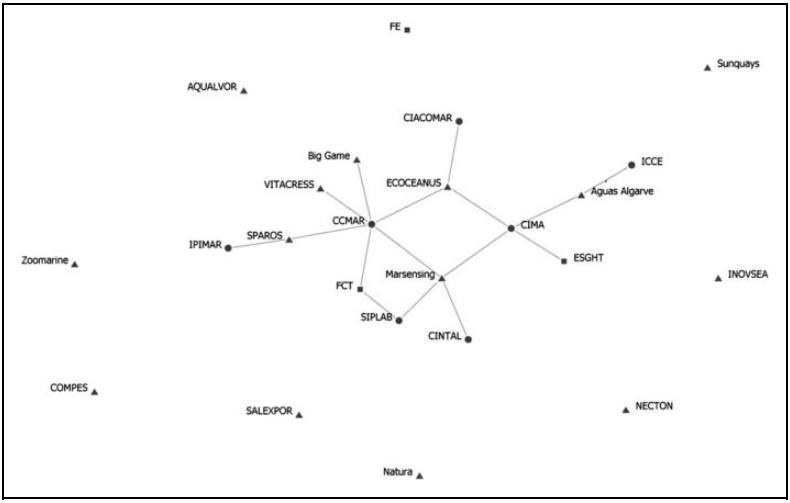

Figure 1. The organizational collaborations network.

characterizes the level of collaboration in the cluster in general as well as the conditions for knowledge diffusion (cf. Krätke, 2011, which found that densities ranged from 17% to 26% in networks between research centers and industry in Germany). The network of cross-sectoral collaborations is plotted in Figure 1. As Figure 1 shows, many of the companies in the cluster, such as Aqualvor (food), Natura (tourism), and Zoomarine (entertainment), are completely disconnected from the network.

But Figure 1 also shows that the network of cross-boundary organizational collaborations includes several companies, such as Marsensing (marine sensing and underwater acoustic technologies), Ecoceanus (ecological tourism), and Sparos (fish feeding and nutrition), that do maintain sustainable collaborations with research centers. For example, Marsensing carries out R&D projects on underwater acoustics, collaborating with the Information Processing Laboratory (SIPLAB), Centre for Marine and Environmental Research (CIMA), and Centre for Marine Sciences of Algarve (CCMAR), which do research in acoustics, marine ecosystems, and oceanology. Some of the companies were also created as spin-offs of the research centers (e.g., Sparos is a spin-off of CCMAR).

Although there are some cross-boundary collaborations in the cluster, these are scarce. The network structure, then, demonstrates that there are barriers for collaborations between science, education, and business sectors.

In addition to the isolation of most of the companies in the organizational collaborations network, the faculties (e.g., School of Management, Hospitality, and Tourism, University of Algarve [ESGHT] and Faculty of Economics, University of Algarve [FE]) occupy peripheral positions in the network. Consequently, despite the research centers being quite well connected, the development of the cluster in general is hindered.

The network of personal ties across science, education, and business entities in the cluster (the three aspects of personal ties are aggregated) is mapped in Figure 2. In comparing this map with the one in Figure 1, we can see the striking differences in the amount of links and the positions of many of the nodes. Namely, in the personal ties network, research centers are not dominant, as they were in the organizational collaborations network; rather, faculties and companies are in significantly more central positions. Especially prominent is the Faculty of Sciences and Technology of the University of Algarve (FCT), which—probably because its alumni are employed in the companies and the research centers—has more ties than does any other node.

Positions of Organizational Entities in the Two Networks

Our analysis of the positions of organizational nodes in the two networks showed that science nodes had the highest levels of degree, closeness, and betweenness centralities in the organizational collaborations network (see Table 2). This finding is visible even in the network plot (see Figure 1), which shows that many network paths inevitably pass through CIMA and CCMAR. These two research centers also have more connections and shorter paths to other nodes than do other entities. Thus, these centers are likely to have contractual relations and alliances with many other entities. They are also likely to control the flow of resources passing through the network and have easier access to more diverse resources possessed by other entities. For example, by using its connections with the five companies to which it is directly linked, CCMAR has many ways to benefit from relationships across sectoral boundaries (e.g., by selling its research results, developments, and expertise or by conducting joint ventures with companies).

Considering the university not as a single entity but as a network connecting research centers and faculties allowed us to reveal that faculties are in fact almost absent from the list of central nodes in this organizational collaborations network. So it is not the whole university that is central but rather the university's research centers, and its faculties are peripheral. For instance, the company Aguas Algarve (Waters of Algarve) would search for employees or

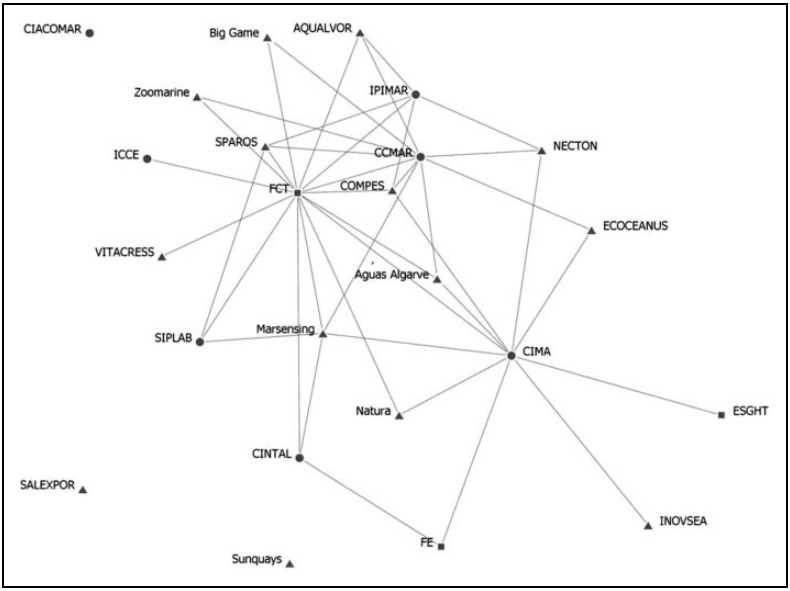

Figure 2. The personal ties network.

Table 2. Nodes With Highest Degree, Closeness, and Business Centralities in the Organizational Collaborations Network.

Node (Sector)	Degree	Node (Sector)	Closeness	Node (Sector)	Betweenness
CCMAR (science)	.26087	CCMAR (science)	.09504	CCMAR (science)	.21344
CIMA (science)	.17391	Marsensing (business)	.09465	CIMA (science)	.14888
Marsensing (business)	.17391	ECOCEANUS (business)	.09388	Marsensing (business)	.13241
ECOCEANUS (business)	.13043	CIMA (science)	.09350	ECOCEANUS (business)	.09618
Águas Algarve (business)	.08696	FCT (education)	.09091	Águas Algarve (business)	.05138

Note. CIMA = Centre for Marine and Environmental Research; CCMAR = Centre for Marine Sciences of Algarve; ECOCEANUS = Ecoceanus, Unipessoal, Lda; FCT = Faculty of Sciences and Technology of the University of Algarve.

Table 3. Nodes With Highest Degree, Closeness, and Business Centralities in the Personal Ties Network.

Node	Degree	Node	Closeness	Node	Betweenness
Frequency of communication					
FCT	.21739	FCT	.05852	FCT	.06126
CCMAR	.13043	CCMAR	.05808	CIMA	.02372
Big Game	.08696	Big Game	.05793	CCMAR	.01186
CIMA	.08696	CIMA	.05793	IPIMAR	.00791
IPIMAR	.08696	IPIMAR	.05793	SPAROS	.00198
Intellectual influence					
FCT	.30435	FCT	.06628	FCT	.11462
CCMAR	.13043	CIMA	.06553	CIMA	.05929
CIMA	.13043	CCMAR	.06516	CCMAR	.00198
SPAROS	.13043	SPAROS	.06516	SPAROS	.00198
Big Game	.08696	Big Game	.06497	Other nodes	.00000
Emotional attachment					
FCT	.34783	FCT	.08214	FCT	.15244
Marsensing	.21739	Marsensing	.08127	CCMAR	.05573
CCMAR	.17391	CCMAR	.08042	CIMA	.04348
CIMA	.13043	CIMA	.07986	CINTAL	.04348
CINTAL	.13043	CINTAL	.07986	Marsensing	.04058

Note. CIMA = Centre for Marine and Environmental Research; CCMAR = Centre for Marine Sciences of Algarve; ECOCEANUS = Ecoceanus, Unipessoal, Lda; FCT = Faculty of Sciences and Technology of the University of Algarve; IPIMAR = Research Institute of Fisheries and Sea, University of Algarve; CINTAL = Technological Research Centre of the Algarve, University of Algarve.

expertise from the CIMA, with which it had an established collaboration, rather than from the ESGHT. Even if Aguas Algarve wanted to collaborate with ESGHT, it would probably have to go to CIMA in order to establish this contact. The same situation would happen to the other companies that CIMA had direct links to, such as Marsensing and Ecoceanus.

The different aspects of personal ties are clearly dominated by the FCT, which has the highest measures of network centrality (see Table 3). Its central position in the network in regard to frequency of communication allows FCT staff to receive information from employees of many other entities and to most often be on the information route between employees of different entities in the cluster; hence, it can obtain valuable information most quickly via informal channels. Regarding intellectual influence, FCT's central position in the network allows it to accumulate knowledge from multiple sources via direct and indirect personal connections. Such a

position makes it easier for faculty members to spread and absorb ideas, create work teams, and start joint projects. And FCT's high centrality measures in regard to emotional attachment show that FCT personnel have a basis for forming mutually supportive relationships with employees of many other entities. Thus, FCT's beneficial position in the personal ties network enables its personnel to generate new scientific and business ideas, create start-ups, and engage in interorganizational mobility across sectoral boundaries.

As for the companies, they do not dominate in the network of personal ties, being less central than research centers and the FCT. But they are significantly more central in the personal ties network than in the organizational collaborations network, often having personal ties to FCT and to one or several research centers. For instance, the Sparos company is quite high in all three centrality measures in the intellectual-influence network, allowing it to informally collect knowledge on R&Ds in marine biology from multiple sources (e.g., CCMAR and Research Institute of Fisheries and Sea, University of Algarve) and to bridge informal knowledge flows in the network. And the company Marsensing is one of the most central nodes by degree and betweenness in the emotional-attachments network. Hence, its employees not only have close friendly relations with researchers, developers, and faculty members involved in acoustics, studies on marine ecosystems, and oceanology but also bridge chains of emotional attachments in the cluster.

Correlations Between Personal Ties and Organizational Collaborations Networks

Our analysis of the correlations between organizational collaboration links and the three aspects of strong personal ties found a correlation rate of 28.57% for communication frequency ($p < .0001$; $M = 2.45\%$), 30.43% for intellectual influence ($p < .0001$; $M = 2.88\%$), and 40.00% for emotional attachment ($p < .0001$; $M = 3.40\%$). These percentages indicate the extent of correspondence between direct cross-boundary organizational collaborations and the particular aspects of interpersonal communication—frequency, intellectual influence, and emotional attachment. The percentages are not too high, which confirms our earlier observations about the limited correspondence between organizational collaborations and personal ties in the cluster that we made in our comparison of the network maps in Figures 1 and 2.

Of the three personal ties aspects, emotional attachments had the strongest correlation rate. In other words, emotional attachment ties had a greater

occurrence of links with organizational collaborations across the sectoral boundaries than did frequency of personal communication or intellectual influence.

Discussion

The literature shows that performance and technology innovations in the maritime industry depend on local networks of companies, research centers, and educational organizations. In the Algarve maritime cluster, administrations and local experts saw a common goal in developing a cluster that links maritime business (food production and aquaculture, coastal tourism and knowledge-driven services) with research units and educational institutions. Research centers offer companies and educational institutions knowledge and technology. They also participate with alumni and university faculty in creating innovation-oriented spin-offs or in founding companies. Companies collaborate in R&D projects with faculties and research centers in order to deliver innovative equipment and technologies in acoustics, marine ecosystems, oceanology, and so on. Faculties conduct educational programs and provide human resources for both the companies and the research centers.

Nevertheless, despite the acknowledged need for such collaborative efforts, scholars studying the maritime cluster, local experts, and cluster participants report insufficient collaborations across the boundaries of science, education, and business. As we have found, the crucial barrier to these collaborations is the lack of mutual understanding across the sectoral boundaries. Hence, the three sectors in the cluster have developed rather autonomously. Research centers, companies, and faculties often do not know each other's needs and underestimate the potential of cooperation and its impact on the development of the cluster as a whole. Consequently, most of the companies are isolated from the network of organizational collaborations, and the faculties occupy peripheral positions in it. Even though the research centers are quite well connected, the development of the cluster in general is hindered.

Based on the literature on the role of personal networks in integrating science, education, and business, cross-sectoral collaborations could be expected to benefit from personal ties between members of organizational entities. Such ties could induce trust, mutual obligations, and intellectual closeness across the sectoral boundaries and hence stimulate more formal collaborations. Informants, including administrators, local experts, and employees of organizations in the cluster, also stress the potential of personal ties.

To formally check the relevance of personal ties, we mapped the structure of the personal ties network in the cluster and compared it to the network of organizational collaborations. The personal ties network appeared to be quite dense, with a university faculty (FCT) and several companies being in significantly more central positions than they were in the network of organizational collaborations. But when we statistically tested the extent to which different aspects of personal ties correlated with the network of cross-boundary organizational collaborations, we found only a modest level of correlations between personal ties and organizational collaborations in the cluster. This finding indicates that the cluster is not realizing the potential of its existing interpersonal ties in overcoming the barrier of insufficient coordination between science, education, and business.

Based on the literature, then, we argued that to understand how personal ties might be better used, we needed to compare different aspects of these ties. In doing so, we found that of the three aspects of personal ties that we considered, emotional attachments were most strongly associated with organizational collaborations across the sectoral boundaries. This result, which corresponds with Taylor's (2005) and Gilsing et al.'s (2008) arguments, suggests that developing personal "chemistry" and going beyond formal relations are pivotal. Huber (2012) also pointed out the importance of "high levels of feelings of personal obligations and emotional closeness" between collaborators (p. 1179). In a similar vein, a stream of studies on buyer–supplier relationships has empirically shown the role of emotions in their communication experience (Witkowski & Thibodeau, 1999) and argued that the personal emotions of boundary spanners are important (Andersen & Kumar, 2006). And network studies on diffusion of emotions have revealed that over time, emotions promote perceptions of trustworthiness and stimulate more formal exchanges, not vice versa (Andersen & Kumar, 2006; Schaefer & Kornienko, 2009).

Our findings might be interpreted using the attachment theory, which argues that diverse positive emotions, such as gratitude, joy, and happiness as well as feelings of being accepted and valued, are crucial for developing strong bonds between individuals. Positive emotions and feelings motivate individuals to be continually sensitive and responsive to each other, creating a cycle that induces mutually positive behavior and therefore strengthens personal ties (Bowlby, 1973; Mikulincer & Shaver, 2005; Shaver & Hazan, 1993). Hence, emotions might not only help to sustain and strengthen personal cross-boundary ties but also encourage sensitivity to and acceptance of the needs, goals, and values of a person belonging to another sector, helping to deal with misunderstandings across the boundaries.

Therefore, efforts in overcoming barriers between science, education, and business can be enhanced by the sustainable emotional bonds between individuals. In particular, emotional attachments can help to create mutual understanding across sectoral boundaries and thus enable cross-boundary organizational collaborations. For example, such personal ties between people who do research, teach in university faculties, and work at companies could help to create mutual understanding and confidence by encouraging each other to go beyond self-oriented sectoral interests to work together as a cluster. For instance, the emotionally supportive communication between company and research center representatives and faculty members about each other's needs and opportunities could enable them to find solutions and give them the confidence to create joint, university-sponsored educational programs between business and science that would meet the human resource needs of companies and research centers. With the emotional support of company managers or researchers, faculty members might become interested in applied research and generate particular project ideas, which might later result in the formal establishment of company-endowed professorships and chairs. Company employees might gain emotional support from fellow researchers and professors in understanding the available research findings, be encouraged to see the potential benefits of putting these findings into practice, and gain confidence in the success of joint R&D projects and training programs. As a result, company employees might obtain broader visions of the existing opportunities for science-driven innovative development and start more joint R&D projects with research centers and educational programs with the faculty members.

In Algarve, the FCT, occupying a central position in the personal network, might become the driver for spanning the boundaries between science, education, and business, building on its existing personal ties. The network position of the faculty implies that certain individuals in the FCT are personally close to people in other entities. These individuals could drive organizational collaborations by drawing on the enduring sympathy, friendships, and emotional support that they have gained from those personal ties in order to motivate joint work. They could promote mutual confidence and understanding, encouraging the sectors to go beyond their self-oriented interests with their specific goals, norms, and values in order to jointly develop the cluster. These individuals might be supported in their efforts to overcome existing institutional, cultural, and legal barriers in order to form organizational collaborations that particularly emphasize nurturing the emotional aspect of personal ties. Individuals who are central in personalties networks could be trained in leadership and put into positions of cross-boundary project leaders and event organizers.

Limitations and Future Prospects

First, this study indeed carries the traces of its single-case study methodology, limiting opportunities for the generalization of its conclusions (Ceci & Iubatti, 2012; Giuliani, 2013). For instance, Portugal is characterized by the "high context culture," which, according to Hall (1976), is relational, collectivist, intuitive, and contemplative. Therefore, further comparisons with other regional clusters embedded in different cultural, economic, and institutional contexts replicating this research design are needed to make the results more generalizable. In particular, those could be extreme cases with strongly differing cultures, levels of regional economic development, and institutional environments.

Second, our interest in this article was in comparing the relationships between different aspects of interpersonal networks and organizational networks across the boundaries rather than in investigating the nuances within the aspects, such as the particular kinds of emotions and how they formed. Thus, the importance of the emotional aspect was an outcome rather than the focus of the analysis. Consequently, our findings are limited in that they do not specify various interpretations of emotions, which would, indeed, be interesting to have, considering the results obtained. These variations could be addressed by further—qualitative—studies. While we used surveys, future studies could draw on the mixed-method network approach (see Basov, in press; Bellotti, 2014) to gather and examine qualitative data on the different dimensions of emotions in interpersonal communication. In addition, future studies should use data collection tools that are more nuanced than surveys are in order to account for relations that individuals are not aware of, including those with nonhuman agents, such as documents, ideas, beliefs, and objects. Qualitative analysis would be crucial for considering not only the structure but also the content of exchanges taking place in the networks. Above that, further studies of interpersonal emotional structures as networks, probably involving the reinterpretation of what conventional network statistics mean, could help in understanding how integration between science, education, and business can be achieved using the potential of personal communication ties.

Third, existing theorizations on how emotions affect interpersonal ties are still scarce. Most of the studies on emotions focus on individual properties, even in the literature on interpersonal relationships. For instance, "much of attachment research has become the study of internalized features of personality, rather than the study of current attachment relationships" (Cassidy & Shaver, 1999, pp. 21–43). Hence, there are limited opportunities for broader interpretations of our findings. Perhaps the results of this study, together with

those of other empirical inquiries considering emotions in the relational perspective of network analysis, will stimulate further theorizations.

Conclusion

This study has applied network analysis to investigate the integration between science, education, and business sectors in the maritime cluster of the Algarve region of Portugal. Experts and previous researchers have argued that such integration is important for the development of the cluster and that personal ties are crucial for the integration. We sought to explore the relationship between organizational collaborations and different aspects of personal ties across the boundaries of science, education, and business. The distinctive feature of this analysis is that it goes beyond focusing on the node-level properties of individuals and companies or the content of dyadic exchanges to examine the overall structural patterns of personal and organizational links. Using a statistical network–analytical approach, we were able to reveal, among other things, that structures of strong emotional attachments are more relevant for cross-boundary collaborations between research centers, university faculties, and companies than were frequent communications or strong intellectual influences. Moreover, network analysis enabled us to find the entity capable of spanning the boundaries in the Algarve maritime cluster—the Faculty of Sciences and Technology. Using its central position, especially in the network of emotional attachments, FCT could support mutual understanding and trust, thus inducing coordination between the three sectors and helping to establish cross-boundary organizational collaborations. The results of applying this network analysis have also highlighted the need for developing theorizations on networks of emotional attachments—in contrast to the currently prevailing focus on individuals' emotions.

Appendix

The Questionnaire Version for Employees of Companies (Translated from Portuguese)

1. Please state your name in the field below.

   _____

2. Please state the name of the company you currently work at in the field below.

   _____

3. Please state your position in the company in the field below.

   _____

4. Please select the number of employees in your company from the drop-down list below.

   <Please select>

5. In your opinion, to what extent is trilateral collaboration between companies, research centers, and university faculties/schools developed in Algarve?

   <Please select>

6. Please describe your interaction with the most important contact persons in the research centers and/or university faculties/schools of Algarve. Write down contacts' names in the first column and select their research centers and/or university faculties/schools in the second column. (There may be two or more important contact persons from the same organization.) Then answer the questions about each contact person in respective rows by selecting from the drop-down lists.

Contact Person Name	Research Center/ Faculty/School Name	How Many Times a Month Do You Communicate?	How Strong is the Intellectual Influence of This Contact on You?	How Strong is Your Emotional Attachment to This Individual?
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>
	<Please select>	<Please select>	<Please select>	<Please select>

Do you want your name to be kept confidential?

<Please select>

Would you give a 30-min interview on the topics covered by this questionnaire?

<Please select>

Thank you for your kind assistance!

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Note

1. The data set on organizational collaborations was kindly provided by R. Pinto, University of Algarve.
2. For a recent alternative technique to analyze such networks, also known as "multiplex," see Wang, 2013, and Basov and Brennecke, 2017.

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