OPERATIONALISING TELECOUPLINGS FOR SOLVING SUSTAINABILITY CHALLENGES FOR LAND USE

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The multi-dimensional character of distance in telecoupling research

Report on the outcomes of VMS 3 (Distance)

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About COUPLED

Human consumption of food and agricultural products has a significant impact on the environment and the societies in the regions where they are produced. Different sectors, consumers, businesses and politicians are increasingly demanding more environmental and social sustainable land use both inside and outside Europe. Yet, there is increasing recognition of the limitations of current research approaches to adequately understand and address the increasing complexity of land system dynamics, which are often characterized by strong non-linearity, feedback mechanisms, and local contexts, and where places of production, trade, and consumption of land-based products are increasingly separated.

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COUPLED trains Early Stage Researchers capable of:

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- considering distant, unexpected feedbacks and spillovers and to account for their social and environmental impact
- fostering new and enhanced governance measures that can shape land-use couplings to deliver more sustainable outcomes of land use decisions

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Executive Summary

Although the notion of distance is central to the telecoupling framework, a clear definition and thorough discussion of this concept are lacking in the literature. With this report, we aim to address this gap and contribute to further operationalizing the telecoupling framework. We do so by 1) identifying key underlying concepts that influence the way distance is perceived and defined, 2) providing insights on the multiple dimensions of distance, and 3) critically reflecting on the relevance of these insights for telecoupling research. We draw on knowledge from various academic disciplines, assembling different ontological and epistemological perspectives on the notions of ‘space’ and ‘distance’.

In this report, we present ‘connectedness’ and ‘similarity’ as two key transversal features of distance. We further introduce the environmental, economic, institutional, cultural and social dimensions of distance, which play an important role in telecoupling research and add to the commonly applied notion of geographic distance. We illustrate these findings by applying them to the case of the Brazilian soybean trade complex.

We find that, while a certain degree of geographic distance is a necessary requirement for telecoupling dynamics to take place, a multi-dimensional perspective on distance is key for understanding how telecouplings are assembled and transformed, and how system boundaries are drawn in telecoupling research.

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1. Introduction

Distal interactions between human-environment systems form the basis of the telecoupling framework, as both its etymological roots and theoretical foundations intrinsically relate to the notion of distance. When initially proposing the telecoupling framework as an analytical approach, Liu et al. (2013) strictly referred to distance as the physical separation in a Euclidean understanding of space, suggesting that geographic distance is a necessity for a telecoupling phenomenon to be identified (Figure 1). Since then, different approaches have evolved for identifying and analyzing telecoupled systems (Friis et al., 2016). With these advances, varying understandings of distance and different interpretations regarding the way they are used to define telecouplings have developed.

Several authors have proposed to go beyond geographic distance and incorporate additional dimensions of distance into the telecoupling framework; in particular, social and institutional distance (Eakin et al., 2014; Niewöhner et al., 2016; Eakin, Rueda & Mahanti, 2017; Friis & Nielsen, 2017). Eakin et al. (2014), for instance, argue that the "analysis of telecoupling demands the integration of different epistemological perspectives on space and spatiality—one in which Cartesian space is the primary frame and point of departure, and one in which social space and its contingent aspects of agency and power are critical" (p. 153). Adding to this perspective, Friis and Nielsen (2017) indicate that an understanding of social distance is needed to better grasp why networks are formed across two or more geographically distant systems, and why flows of materials, energy or information are exchanged between them. While the notions of social and institutional distance have since been applied to other specific telecoupling examples (e.g., Boillat et al. (2018) on protected area governance), other dimensions of distance, such as environmental, economic, and cultural ones have also come up in the telecoupling literature (e.g., Liu et al., 2018).

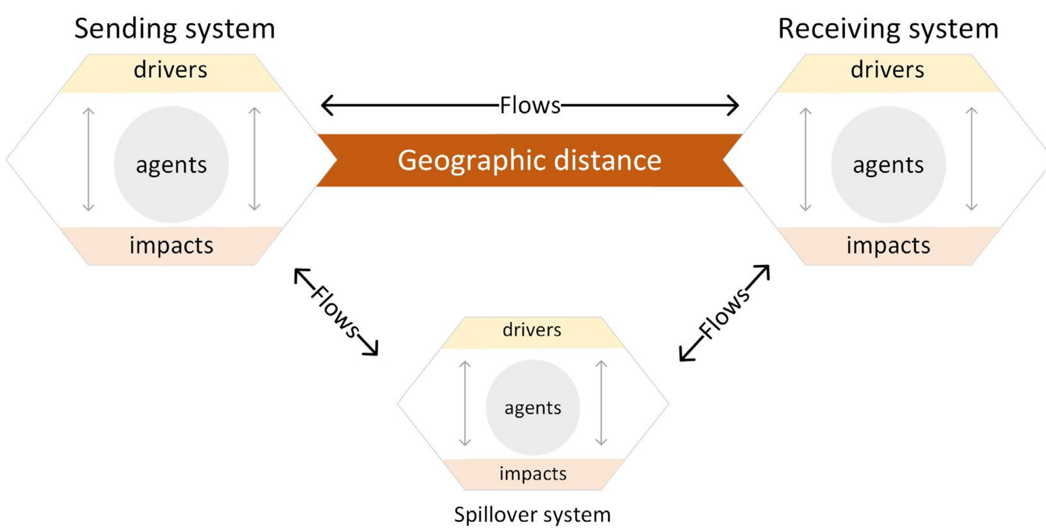

Figure 1. *Geographic distance as a precondition of telecoupled systems. The elements of telecoupled systems are displayed as in Liu et al. (2013): sending, receiving and spillover systems, drivers, agents, flows and impacts.*

Besides calling for a more encompassing, multi-dimensional approach to distance in telecoupling, some researchers have also challenged the initial assumption of using geographic distance as a basic parameter to define a telecoupling. Friis & Nielsen (2017) point out that in addition to defining system boundaries by the large geographic distances between them, telecoupling studies have also used territorial governance structures to measure separation between systems. Eakin et al. (2017) propose to further broaden the scope of telecoupling based on an expanded notion of distance, arguing that telecouplings can arise between physically overlapping systems that are socially and/or institutionally distant.

To understand how the interactions between two or more telecoupled systems are assembled and transformed, it is hence necessary to adopt a multi-dimensional approach to distance, that takes account of the social, economic, cultural, institutional and environmental dimensions of distance, besides the geographic one. While some telecoupling literature briefly elaborates on some of these dimensions, clearly defined concepts and definitions, as well as more in-depth reflections on the role of distance and its different dimensions in telecoupling research, are lacking. With this report, we aim to address these knowledge gaps. Our objectives are threefold: 1) to identify important concepts used to define distance, 2) to provide insights into the multiple dimensions of distance, and 3) to reflect on the relevance of these concepts for telecoupling research. For these purposes, we draw on insights from various academic disciplines, assembling different ontological and epistemological perspectives on the notions of 'space' and 'distance'.

In the subsequent sections, we first discuss the main features used to define non-geographic distance: 'connectedness' and 'similarity'. Then, we present insights on the different dimensions of distance that add to the geographic dimension commonly used to define telecouplings, namely economic, environmental, institutional, cultural and social distance. We then apply these concepts to the case of the Brazilian soybean production and trade. Finally, we critically discuss the relevance of the multiple dimensions of distance for telecoupling research.

2. Defining distance: connectedness and similarity

Distance is a concept that is central to the human experience. While countless definitions and equations exist to capture this notion conceptually or mathematically (Deza & Deza, 2009), distance typically describes the degree of closeness or remoteness between physical or mental objects. The telecoupling framework clearly determines the nature of the distant objects: human-environmental systems. When it comes to defining the degree of closeness and remoteness between telecoupled systems, however, there is less clarity. There is little reflection about the exact nature of distance and the underlying assumptions and concepts used to define it, particularly when it comes to non-spatial distances.

We propose two transversal features of distance that may be useful for characterizing how non-geographic distance is expressed in telecoupled systems: 'connectedness' and 'similarity'. We use these two concepts because in most cases, we found that distance appears either as a function of linkage connections, through which there may or may not be flows, or as a comparable assemblage of features, thus similarity. In this section, we will explore both of these concepts, using insights from the field of network science.

The notion of **connectedness** is central to telecoupling research as the very nature of the framework suggests that distant systems are linked through flows of capital, material, energy, information or living beings. Hence, distance is commonly interpreted in terms of the level of connectedness. In graph theory or the study of networks, connectedness is defined as the number of independent paths between points (Newman, 2010). Empirically, measurements of connectedness have been used to identify the number of connections between nodes in a network in contexts such as food webs (Luczkovich *et al.*, 2003), social networks (Barnes, 1969), ports connectivity (Wang and Ng, 2011), and supply chains (Gibbon et al., 2008). These connections can take multiple forms, depending on the actual number of connections versus the possible number of connections given the existing network structure (Newman, 2010; Newman & Newman, 2003): the absolute number of independent connections, the absolute number of indirect connections, the relative number of direct connections, and the relative number of indirect connections (see Figure 2). Metrics such as the nearest neighbor, betweenness centrality, and other centrality measures can indicate connectedness (Seaquist & Johansson, 2019). Nevertheless, building on these definitions and adjusting it to our purpose, distance can be characterized by connectedness as the number of linkage connections between two systems, the degree of those connections (i.e. the number of intermediary points), and the number of connections relative to the total possible number of connections.

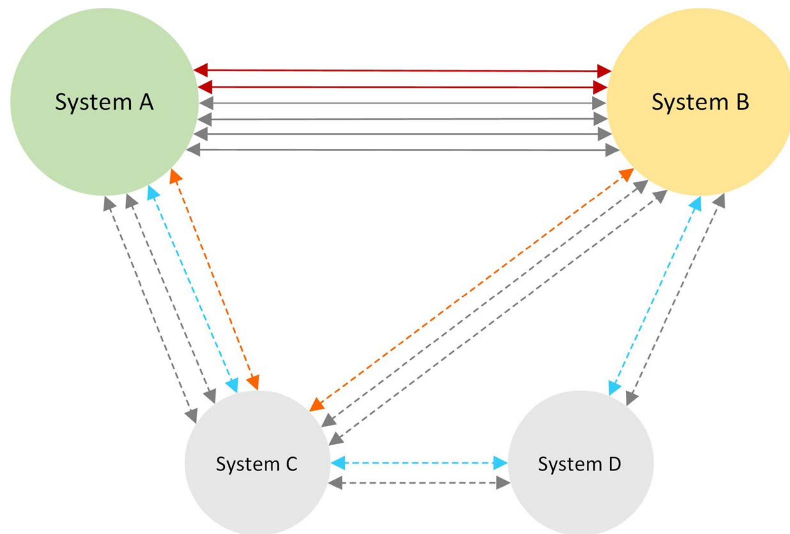

Figure 2. *Different forms of connectedness between two systems (A and B) based on direct (full arrows) or indirect (dashed arrows) connections. Red arrows represent the number of actual connections between the two systems; gray arrows represent other possible connections that contribute to the total potential number direct or indirect connections between systems; orange arrows represent an indirect connection between system A and B with one intermediary point (system C); blue arrows represent an indirect connection between system A and B with two intermediary points (system C and D). Connectedness is defined as the relative number of connections between system A and B which is calculated by dividing the number of actual connections (color arrows) by the number of total potential connections between (gray arrows plus color arrows).*

Similarity, interpreted as a measure of identity, is another important concept used to define distance between telecoupled systems. According to Lin (1998), similarity can be defined as a set of assumptions and intuitions that allow us to compare two objects or nodes in a network. Adapting this definition to the telecoupling framework, the two objects or nodes under comparison can be two telecoupled systems or two elements of the telecoupled systems (e.g. agents or spillover, sending or receiving systems). The features that define similarity are (i) commonality, (ii) differences, and (iii) identity. The function of commonalities (i) and differences (ii) between a system A and B defines the degree of similarity between them. As a result, “the similarity between A and B is measured by the ratio between the amount of information needed to state the commonality of A and B and the information needed to fully describe what A and B are” (Lin, 1998). See Figure 3.

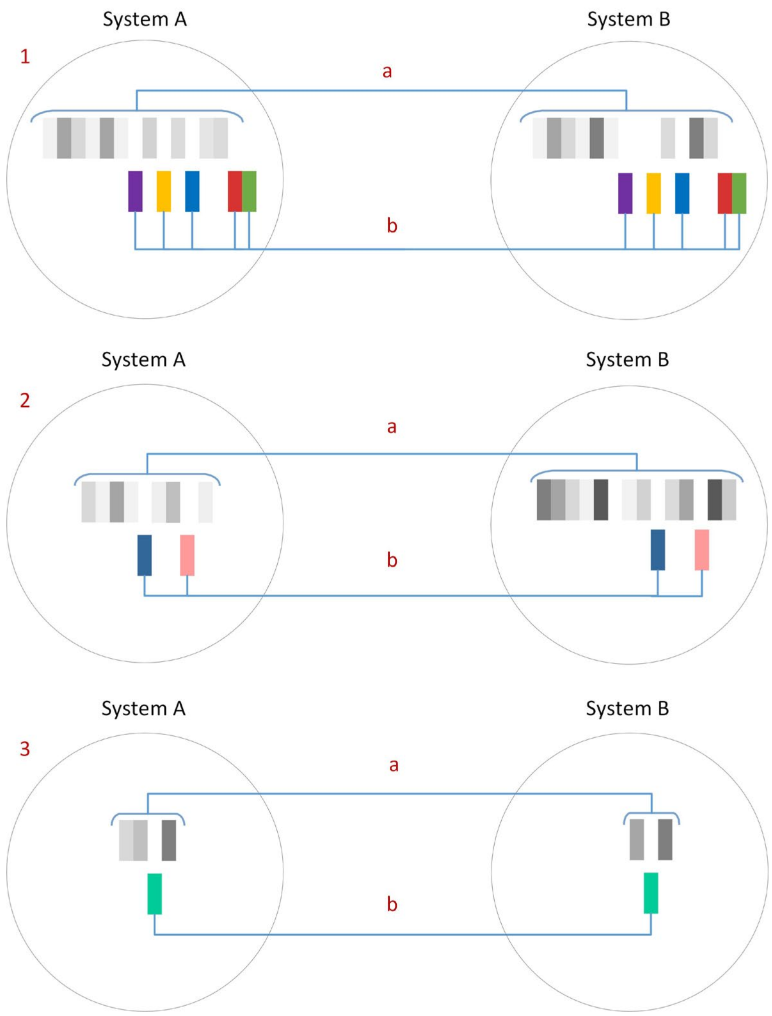

Figure 3. *Example of different forms of similarity between two systems. a) represents the differences between the two systems, while b) represents the commonalities between them. 1) and 3) represent cases where the relative number of commonalities is high (the number of commonalities divided by the total number of features), resulting in more similarity between the two systems. 2) represents a case where the relative number of commonalities is low; therefore there is less similarity between the two systems.*

In this report, we consider connectedness and similarity as **two transversal and not mutually exclusive features** that characterize distant interactions. They can be used to define and analyze distance within each of the different dimensions that will be described in the following section. For instance, one could analyze institutional distance through the feature of similarity by identifying key common/dissimilar institutional arrangements of telecoupled systems. In order to analyze the institutional distance between two systems in terms of their laws and regulations governing the use of native forests, one can identify the key principles and purposes of the set of laws and regulations of each system and compare them in terms of similarity.

3. The multiple dimensions of distance

While distance has always been at the heart of those disciplines traditionally concerned with physical space, it has also attracted the attention of scientists in other fields of research, which have opened their view to approach space in other terms. The dominant type of distance in telecoupling research, geographic distance, is defined following Liu et al. (2013) as the physical separation in a Euclidean understanding of space. However, to expand this definition of distance, in the following sections, we introduce a multi-dimensional perspective on distance, providing insights on social, economic, cultural, institutional, and environmental distance.

Economic Distance

An economy, or economic system, is a set of activities related to the production, consumption, and trade of goods and services within a delimited area. Economic distance is generally used in the context of trade and resource flows. Researchers have referred to it both in terms of similarities and connectedness between economic entities, which may be countries, sectors, industries, or firms.

Between countries, economic distance refers to similarities or differences between economic structures, primarily in wealth (measured by consumer income) but also in the cost and quality of natural, financial, human or other resources (Ghemawat, 2001). In this case, economic distance influences bilateral trade and foreign direct investment between countries (Le, 2017; Disdier & Head, 2008; Ghemawat 2001). While the widely accepted gravity theory of international trade posits that bilateral trade between two countries increases proportionally to their wealth and inversely proportional to the geographic distance between them, trading intensity has also been found to be influenced by economic distance and other factors. According to the Linder hypothesis, similarities in the per-capita incomes of trading partners infers more similar demand structures as their people consume similar types of goods, which leads to more bilateral trade (Linder, 1961). Ghemawat (2001) found that wealthier countries tend to engage in more trade than poorer countries, and mostly with other wealthy countries. Firms are also sensitive to economic distance when considering their investments in foreign countries. Firms that rely on standardization and economies of scale are generally more successful in countries that are more economically similar to the parent country, where they can use the same business models to expand their operations. On the other hand, firms that exploit lower costs of production in other countries, such as of that labor, invest in countries with different economic structures, factor costs, and technological capabilities (Ghemawat, 2001; Le, 2017). The environmental significance of this type of economic distance is that trade between rich and poor countries tends to lead to disproportionately high environmental impacts in poorer countries, who export undervalued land and natural resource intensive goods (Prell, Sun, Feng, He & Hubacek, 2017).

Economic distance has also been used to refer to the degree of connectedness between countries, industries or locations. For example, Wang & Sun (2017) used the concept to measure the number of intermediate linkages between the mining industry and other industries through which energy and other resources flow, and thus explain the rapid co-development of these industries in and between certain regions of China. When applied to international trade, economic distance could refer to the degree of openness of trade, based on economic linkages such as trade costs, market mechanisms, and institutional arrangements that support or inhibit trade flows between two countries (Anderson & van Wincoop, 2017; Conley & Ligon, 2002; Eakin et al., 2017). Having trade agreements, membership in the same trading bloc, and common currencies facilitates trade (Ghemawat, 2007; Eakin et al., 2017), while the costs of transport, tariff barriers, regulation, and distribution hinder trade (Anderson & van Wincoop, 2017; Conley & Ligon, 2002).

Environmental Distance

The environment is a physical construction composed of biotic and abiotic elements that exchange flows of materials, energy, and information that are part of ecological processes such as trophic cascades, edaphic cycles, geological processes, hydrological flows, and atmospheric interactions, whether direct or indirect (Odum & Garret, 2005).

Telecoupled systems and their components can have different natures and boundaries. They can have environmental natures such as landscapes, protected areas, watersheds, and biomes, or more organizational or administrative natures such as countries, districts, institutions, and companies (Liu et al., 2013). Just as environmental units, telecoupled systems exchange (within and between them) material, energy and informational flows that are mediated by distance of an environmental nature. Environmental distance can be defined by the degree of connectedness originated by abiotic and biotic flows that link the elements of telecoupled systems. Abiotic flows include physical or chemical flows driven by oceanic currents, atmospheric dynamics, hydrological cycles, or geological processes. Biotic flows include genetic flows, migratory patterns, trophic relations (e.g. predation), and symbiotic relations (e.g. mutualism or parasitism) (Odum & Garret, 2005).

These abiotic and biotic flows exist at different ecological levels and can create teleconnections between geographically distant places. For instance, Australia and the west coast of South America are geographically distant but are environmentally close due to the El Niño phenomenon that can simultaneously cause severe droughts in Australia and heavy rains in the west coast of South America (McPhaden, Zebiak, & Glantz, 2006). Conversely, two geographically close places can be environmentally distant when the abiotic and biotic flows between them are weak or non-existing. For instance, a large forest experiencing forest fragmentation can give rise to two distant forest patches whose plant and animal populations might be genetically distant due to the reduced genetic flow that leads to significantly high inbreeding processes, less genetic variation, and eventual speciation (Cascante, Quesada, Lobo, & Fuchs, 2002; Keller, Nentwig, & Largiadèr, 2004).

Systems or agents of telecoupled systems can be simultaneously environmentally close and distant depending on the abiotic or biotic environmental flow(s) used to define the proximity. For instance, two systems or agents can be environmentally close in terms of hydrological flows but environmentally distant in terms of trophic relations. When studying telecoupled systems, it is important to acknowledge these intrinsic and pre-established biotic and abiotic flows that influence key driver-impact relationships between different components of the systems. Even if these flows are not officially included as elements of the telecoupled system, they might have important effects on overall system dynamics and give rise to spillover systems. Considering environmental distance might, therefore, help identify important environmental flows and set better system boundaries and analytical scope for the telecoupled systems in question.

At the same time, environmental distance can also be defined in terms of the degree of similarity between two telecoupled systems. Two systems may share common features such as biodiversity composition, species richness, trophic relations, tree cover, vegetation types, ecosystem services provision, rainfall patterns, soil quality and composition, etc. that make those distant systems environmentally close when studied with the telecoupling framework. The realization of the environmental similarities between two or more telecoupled systems can ease the comparison and understanding of cause-effect relationships that may arise due to other types of flows (e.g. social, economic or institutional flows). For instance, two telecoupled systems whose relation is mainly established due to monetary transactions may be environmentally close or distant if the biotic and abiotic interactions within them are similar or dissimilar. If the goal is to understand the environmental impacts caused by these monetary flows, understanding the environmental similarity between the two systems can facilitate the analysis and provide explanatory elements to qualify and quantify those impacts.

Institutional Distance

Institutions are the main object of study in many disciplines (e.g., economics, sociology, political sciences, and anthropology). Consequently, various understandings and multiple definitions of institutions can be found in the literature. For instance, institutional economist Douglas North (1990) famously characterized them as the “rules of the game of society, or more formally, the humanly devised constraints that shape human interaction” (p. 3). In her seminal work on the Institutional Analysis and Development Framework (IAD), Elinor Ostrom refers to institutions rather as shared concepts that people use in repetitive situations (Ostrom, 2010).

Similarly, there are different interpretations and uses of the concept of ‘institutional distance’. A common reference to it can be found in the field of international management, where institutional differences are assessed to better understand foreign direct investment practices (Xu & Shenkar, 2002; Aleksynska & Havrylchyk, 2013). Institutional distance is thereby defined in terms of similarities between the regulatory, cognitive, and normative dimensions of institutions that are located within the countries that engage in such practices (Kostova & Zaheer, 1999). In telecoupling literature, institutional distance is generally discussed in terms of differing (or dissimilar) territorial governance structures (e.g. administrative regions or nation-states) (Friis & Nielsen, 2017; Boillat et al., 2018)[1]. 'Similarity' thus alludes to be the predominant notion used to define institutional distance in telecoupling research.

Although not explicitly linked to institutional distance in the literature, the notion of institutional 'connectedness' is also an important theme in telecoupling research. For instance, Eakin et al. (2014) point to 'governance vacuums', which come into play if existing governance arrangements do not address the full scope of newly emerging telecouplings. In this sense, institutional distance can also refer to the level to which existing (similar or dissimilar) institutions are connected to each other and to the problems that they are supposed to govern. This interpretation of institutional distance strongly relates to debates on institutional interactions and institutional (mis)fit held in the field of political science (see e.g. Young, 1996, 2002; Oberthür & Stokke, 2011). Gaining a better understanding of the (mis)matching scope and content of institutional arrangements that govern telecoupled processes is important to identify potential governance challenges in a timely manner, as well as to develop new and possibly more effective governance institutions. Network or flow governance arrangements, for instance, can help to bridge the spatial disconnect of existing territorial governance arrangements (Sikor et al., 2013; Lenschow et al., 2016; Challies et al., 2014).

Cultural Distance

Telecoupled systems are also influenced by other non-economic and non-material flows and linkages such as knowledge, ideology, and culture, which may ultimately be more instrumental in assessing telecoupling outcomes and feedbacks (Eakin et al., 2017, Eakin et al., 2014).

Culture generally refers to systems of shared social meanings, which are produced symbolically and allow members of a certain group to make sense of the world and to construct meaningful practices (Barker, 2002). It is concerned with tradition as well as with social reproduction, creativity, and social change. The concept has undergone significant change in its usage. It should not be understood as referring to a deterministic, monolithic constant tied to a specific location, but rather as a dynamic, hybridized constellation of webs of interaction across space.

Given the contested, intangible and complex nature of the concept of culture, notions of cultural distance are difficult to assess. Cultural distance has been conceptualized mainly in the fields of cross-cultural psychology and international business research.

In cross-cultural psychology, the term was defined by Triandis (1994) and refers to differences in languages, family structures, religions, standards of living and values between groups or individuals. Greater cultural distance results in perceived dissimilarity and tends to increase intergroup conflict or at least decrease the chances of good intergroup relations (see Triandis & Trafimow, 2001). In this tradition, perceived cultural distance is often assessed by means of questionnaires and can be correlated with the prevalence of certain attitudes (see e.g. Mahfud, Badea, Verkuyten, & Reynolds, 2018).

In international business studies, the concept of cultural distance has a longstanding tradition and, despite calls for more rigorous definitions and measurements (Shenkar, 2001; Zaheer, Schomaker, & Nachum, 2012), continues to be used widely. It has been applied to research questions relating most notably to foreign direct investment, but also to organizational transformation or technology transfer. Here, it is usually used as a variable to describe, explain and predict business relationships between different countries (see for example Knoll et al., 2018).

Therefore, cultural distance can be expressed in terms of similarity by evaluating the shared identification with certain practices or symbolic understandings between individuals or groups. Further, it can also be approached through measures of connectedness by observing the formation and endurance of links, for example through communication or other exchanges between geographically distant individuals or communities (e.g. communication between or remittance payments from diasporic communities). Hence, considering the cultural

[1] This points to an interpretation of institutions as the formal rules of the game (North, 1990), i.e., laws and regulations that exist within certain functional territories or other formally established governance arrangements.

distance between the elements of telecoupled systems can positively contribute to set correct and inclusive system boundaries and to improve the analytical approach when studying telecouplings.

Social Distance

Bourdieu (1989) introduces the concept of social space, understood as the system of relations and relative positions among social actors, which collectively give rise to social structures. Social distance can then be understood as the degree of similarity in properties (such as class, lifestyle, gender etc.) between agents, groups or institutions. Social distance can also be defined and measured by connectedness between agents, groups, systems or institutions, identified through flows and linkages. The positioning of actors or groups within social space will give rise to differentiated interests, relations of power, and different types of interactions mediated by the use of symbols (e.g. language, writing, art). In the social sciences, structuralist approaches will focus on the nature of the social positioning, while more constructionist approaches are interested in the nature and meaning of the symbols manifest in interactions and expressions.

The ways in which social space and geographic space overlap or differ are very dynamic. For example, while the geographic distribution of residential areas tends to reflect and also further reinforce social differentiation, interaction between socially distant agents occurs regularly in close physical proximity (e.g. interactions at the workplace). Actors in the social space, or countries in a telecoupling system, can be socially distant by presenting dissimilarity in properties e.g. class, gender, lifestyle, or literacy rate and life expectancy. Alternatively, actors or countries can be socially distant by not presenting linkage connections for information flows, or for social relationships. Furthermore, the formation of transnational classes (e.g. corporate actors) (Robinson, 2017) brings together agents from distant geographical locations who share physical space in their moments of interaction (e.g. at conferences or business fairs). In this case, they present geographic distance, social proximity by having social connectivity through professional links, and they may be socially distant in terms of not presenting the same identity values, beliefs and cultural values, hence dissimilar.

Understanding the encounters of distal actors, which are growing closer in terms of similarity in social space due to processes of transnational class formation (e.g. the process described by Waroux (2019)), is key for telecoupling research, since the networks formed by these interactions give rise to or facilitate long-range flows of resources, information or capital. The distribution of costs and benefits in telecoupled systems will depend on but also influence the dynamics within social space. For example, new economic opportunities with large profit margins, which arise from telecoupling processes, will typically only be available for agents with certain social properties (Waroux et al., 2018), which can consequently further marginalize other groups.

4. Distance in the telecoupled soybean complex: an illustrative case

The case of global soybean production and trade is a recurring one in the telecoupling literature. This is no surprise, since soybeans have become one of the most important agricultural commodities globally. The shifting centers of production, processing and consumption over time, as well as the emergence of soybean frontiers in highly sensitive biomes, have attracted many scholars who have tried to disentangle these patterns and detect dominant drivers.

In this section, we use the case of the Brazilian soybean production and trade to further illustrate the multiple dimensions of distance introduced in the previous section, as well as to exemplify the use of the concepts of ‘connectedness’ and ‘similarity’ to define distance within these dimensions.

Economic Distance

Global commodity value chains span across firms and countries that have differing roles within the value chains, from production and processing to trading and consumption. These roles and relations arise from the dissimiliarity between these countries in terms of economic structures, or in other words, their economic distance. Within the soybean sector, increasing agro-industrial demand, emerging agribusiness players and changing trade policies have shifted the economic distances between major trading partners over time, leading to a global restructuring of the soybean trade (Oliveira & Schneider, 2016). Large South American agro-industrial companies have emerged to compete with historically dominant US and European soy processing and trading companies, reducing economic distance and power differences between what used to be primarily South American exporters and US and European importers. In addition, Brazil's export trajectory for whole, unprocessed soybeans has switched from Europe to China due to the EU's increased preference toward processed soy meal and China's growing demand for whole soybeans for agro-industrial livestock feed, which China has the capacity to process domestically. On the other hand, Argentina has taken over the supply of processed soy meal to Europe because of its more developed processing capacity compared to Brazil (Oliveira & Schneider, 2016). In this case, China has emerged as an importer and processor of soy from Brazil due to their different technological capacities, leading to trade between Brazilian exporting companies and Chinese agro-industrial businesses. This market restructuring has implications for tracing the responsibility for the environmental impacts of soybean expansion in South America. Therefore, the identification of economic distance between the agents embedded in the telecoupled soybean example is a key step to understanding the drivers and impacts of global production-trade dynamics of this commodity and others.

Environmental Distance

The analysis of the environmental distance between and within telecoupled systems allows for a proper definition of system boundaries and a correct accounting of causes and effects. To do this in terms of connectedness, it is necessary to identify the abiotic and biotic flows that exist between the different systems and agents embedded in a telecoupled system. Water flows, for instance, are disturbed beyond the limits of the case's boundaries: the increasing soybean demand drives deforestation in the Brazilian Amazon rainforest, which translates into reduced tree cover (Fuchs et al., 2019). Research shows that moisture recycling plays an important role in precipitation patterns along the Amazon basin. Evapotranspiration in the Amazon rainforest contributes significantly to rainfall in the central and south-eastern Andes (Staal et al., 2018; Zemp et al., 2014) which later flows through the Amazon rainforest. Because of this hydrological process, areas geographically distant as the Peruvian, Bolivian or Argentinian Andes are environmentally close to the Brazilian Amazon rainforest and are affected by the change in moisture recycling driven by deforestation and soybean production. Therefore, a proper system boundary delimitation might consider the inclusion of Andean countries as spillover systems when studying the dynamics and impacts of Brazilian soybean production and international trade. For example, Dou, da Silva, Yang, & Liu (2018) use environmental distance to draw system boundaries in their study of soybean expansion due to their interest in spillover effects between the Amazon biome and the Brazilian Cerrado.

Institutional Distance

The soybean trade is characterized by a diverse and complex governance landscape, with many different actors involved at varying scales. The US, Brazil and China each have their own differing national and sub-national norms, regulations, and stakeholder initiatives in place that govern parts of the soybean supply chain, e.g. deforestation laws or farmer's cooperatives in Brazil. This dissimilarity across institutional arrangements suggests some degree of institutional distance between these countries. Yet, if the different territory-based institutions governing the soybean trade are well aligned, coherent, and complementary, the telecoupled systems can be considered as institutionally closer, in the sense of being well-connected. However, if they are instead contradicting, disconnected, and failing to adequately address all adverse social and environmental impacts of the overall soybean supply chain, they could be regarded as institutionally distant.

In addition to such territory-based governance regimes, many flow-based initiatives exist that aim to contribute to the governance of the soybean supply chain. Examples are bilateral and multilateral conventions between the respective countries, private sector agreements such as the soy moratorium, Reducing Emissions from Deforestation and Forest Degradation (REDD) programs, soybean certification schemes, and multi-stakeholder platforms such as the Roundtable on Responsible Soy (Nepstad et al., 2014). Although such initiatives can help fill the governance gaps arising from institutionally distant yet telecoupled systems, they also add more complexity to the overall governance landscape and come with their own challenges (Lenschow et al., 2016; Okereke & Stacewicz, 2018).

Cultural Distance

Perceived distance or closeness in the cultural domain can also be relevant when studying telecoupled systems. For example, in the case of soybean production many migratory movements have been essential for the development of commodity frontiers, which are now major soybean exporting regions. Gaucho farmers from Southern Brazil and immigrants from North America have come to many regions in the Cerrado biome to acquire farmland and grow soybeans. Some studies have shown how these actors have portrayed the local population as lazy or otherwise culturally different. In this way, these farmers can characterize their work as being part of a project for modernization or development, which supposedly helps those who are perceived as culturally backward. This is an example how cultural distance, here in terms of (perceived) dissimilarity, not only shapes interactions in a telecoupled system, but is even actively constructed by different actors to justify certain dynamics and outcomes. A study of North American farmers in Brazil (Ofstehage, 2016) sheds light on these processes through an ethnographic lens.

Social Distance

Interactions between systems that are geographically and institutionally distant, such as in the case of soybean trade between Brazil and China, can rely on social processes that facilitate these interactions. For example, certain actors from both Brazil and China form transnational assemblages, such as a transnational class of businessmen and bureaucrats. These social assemblages, which are characterized by social similarity, facilitate the emergence of telecoupled systems through their interactions. Social similarity can foster the creation of linkages between actors in these systems, and the existence of connectedness through direct linkages can also facilitate the process of increasing similarity. Consequently, social similarity and connectedness are two different elements that can overlap and reinforce each other. The individual actors share certain domains of knowledge and interests, which are rather independent of geographical space. This demonstrates how a sense of closeness in the social domain can help overcome institutional and geographical distances and act as a connecting element between two systems. Oliveira (2018) provides a multi-sited ethnographic account of such assemblages between businessmen from Brazil and China in the context of the soybean agribusiness, relating to social similarity based on business values and interests.

5. Discussion

The relevance of defining and measuring distance in telecoupling research is multi-fold. Firstly, geographic distance is used to qualify interacting systems as telecoupled systems. This gives rise to the question of a minimum distance required for telecoupling to occur; that is, how distant is distant enough for two interacting systems to be considered telecoupled? While the telecoupling literature does not yet have a response to this, it would likely be in terms of spatial separation, whether in terms of geographic distance or disparate territorial governing structures. The latter can challenge the need for ‘large’ distances as commonly implied in telecoupling studies, as interacting regions, provinces or other sub-national entities within the same country might also be telecoupled systems, but nonetheless are geographically near. Therefore, we argue that, at a fundamental level, geographic distance between interacting systems, based on the notion of Euclidean distance, is still a precondition for their telecoupling.

Nonetheless, geographic distance alone does not allow us to adequately characterize and study telecoupling systems and interactions in their full scope and complexity. The very observation that has given rise to the telecoupling framework, namely that any system can be affected by the dynamics of other geographically distant systems, urges us to consider other dimensions of distance in our understanding of telecouplings. Technological innovations, for instance, have created a global infrastructure that has facilitated global transportation, trade, financial transactions and information exchange to a degree where geographical space is not necessarily correlated to what is or seems distant. Other factors such as cultural closeness, common economic interests, social similarities, and intrinsic environmental linkages can moderate the interconnections between two geographically distant or nearby systems. Therefore, the defining and measuring of non-geographic distances helps us explain why and how telecoupled processes emerge and operate. In some way, a 'distal connection' always involves a paradox: to connect, at least some of the elements have to be close. Thus, in telecoupled systems, one dimension of distance which separates two systems tends to be overcome by other dimensions, bringing certain elements of these systems into close proximity and triggering interactions. Our exploration of different dimensions of distance and their application to the soybean trade telecoupling example illustrates that each dimension helps to better understand how and why networks of agents and systems relate to each other and collectively assemble and transform telecouplings.

The use of the concepts of 'similarity' and 'connectedness' in defining and measuring these non-geographic distances helps us pinpoint the intrinsic causes and natures of telecoupling interactions. As seen from the previous sections, they are highly context specific, and can exist side-by-side in ways that do not invalidate the other; that is, two telecoupled systems can be strongly connected while also being highly dissimilar. We argue that expanding the analysis of distance beyond the geographic perspective contribute to a more holistic analysis of the causal mechanisms that determine the interaction between systems. Commonalities between two systems may help to explain some of the reasons why a certain interaction is established and why in a specific intensity. Interconnections that go beyond the specific flows under study (or that are less evident) may help to explain the earlier a well. Because telecoupling research need a system thinking perspective, the use of similarity and connectedness to determine the distance in multiple dimensions between systems is key to achieve a deeper understanding of the causal (and sometimes hidden) mechanisms that drive telecouplings and, as such, to generate more accurate and applied transformational knowledge.

We also found that critically considering non-geographic dimensions of distance can help researchers draw better systems boundaries in telecoupling research. Drawing system boundaries based only on geography oversimplifies the complex interactions that modulate the flows between systems. We have highlighted that identifying and analyzing other dimensions of distances that influence the interactions under study can point the examiner to, for instance, negative impacts that occur beyond the obvious geographic boundaries of the sending and receiving systems, as well as to social groups in and beyond those systems that are disproportionately impacted. This is essential for defining the spillover systems and feedbacks, often unexpected, that characterize telecouplings. It is also essential in considering how to effectively address the negative outcomes of telecouplings, as seen from the use of institutional distance analysis.

6. Conclusions

Distance is a defining element of the telecoupling framework. It is relevant for telecoupling research in two ways. Firstly, the geographic dimension of distance is used to initially qualify interacting systems as being telecoupled. Secondly, different notions of non-geographic distance are used to explain why and how telecoupled processes emerge, operate, and transform, as well as to help draw more effective system boundaries in telecoupling research. Moreover, we have illustrated the use of defining the non-geographic dimensions of distance between telecoupled systems in terms of connectedness and similarity. For a visual summary see Figure 4.

Based on these findings, we recommend more in-depth research on the use and nature of distance in telecoupling research, possibly resulting in a practical framework that provides tools to assess or measure distance and trace its dynamics over time. This can only be achieved by an interdisciplinary and collaborative effort.

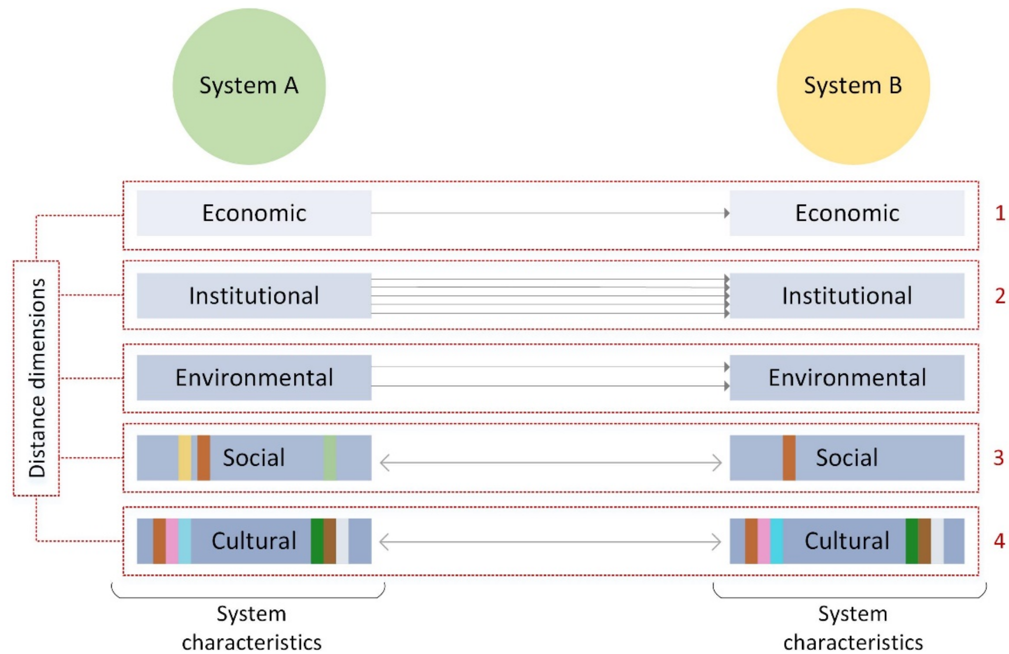

Figure 4. *Exemplification of the five non-geographic dimensions of distance (economic, institutional, environmental, social and cultural) that can exist between two different systems (A and B). 1–4 represent different levels of connectedness and similarity: Connectedness is represented by 1 and 2 where the number of arrows represent the number of interconnections between system A and B for a specific system characteristic: 1) weak connectedness defining the economic distance (one interconnection); 2) strong connectedness defining the institutional distance (five interconnections). Similarity is represented by 3 and 4 where the color bars represent features of system A and B for the specific system characteristic. Similar colors represent the commonalities: 3) low similarity defining the social distance (only one commonality); 4) high similarity defining the cultural distance (six commonalities).*

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