Symbiotic relationships among formal and informal institutions: Comparing five Brazilian cultural ecosystems

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A B S T R A C T

This paper draws on ecology to advance insights on the relationships between formal and informal institutions. We are interested in observing change in such relationships in different cultural contexts. Extending the research traditions of institutional complementarities and of institutional analysis inspired by biology, we focus on symbiotic relationships to understand interdependence patterns between formal and informal institutions. We compare five Brazilian macroregions, which have experienced different historical processes. We treat each region as a different "cultural ecosystem" within which institutional symbiotic relationships unfold. Building on correlation network analysis, we compute networks of multiple and contemporaneous symbiotic relationships for each macroregion. Our results suggest that formal institutions tend to be "symbionts," which are more "dependent" on informal institutions acting as "hosts" within asymmetric symbiotic relationships. Our comparison shows that asymmetry between formal and informal institutions is more evident in cultural ecosystems in which institutions have traditionally been more extractive, such as in the northern Brazilian macroregions. In cultural ecosystems with historically more inclusive processes, formal institutions have greater tendency to become a nurturing ground for other institutions, confirming Pritchett's (2013) argument that successful formal institutions are consolidations/formalizations of a successful societal struggle.
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1. Introduction

The interaction between formal and informal institutions has been greatly investigated. Formal institutions are legally stipulated rules (Hodgson, 2001), whereas informal institutions are social norms enforced by society (Voigt, 2018). Most research in this tradition has tried to determine the prevalent direction of causality between formal and informal institutions (Grosjean, 2011; Gruendler and Koellner, 2020; Maseland, 2013; Williamson, 2009). Informal institutions play a key role in guaranteeing legitimacy and enforcement of formal institutions (Acemoglu and Jackson, 2017; Bisin and Verdier, 2017; Hodgson, 2006; Maré et al., 2020; Mathers and Williamson, 2011; Tabellini, 2008, 2010), thereby also affecting which formal institutions are more or less viable for

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change (Belloc and Bowles, 2013; Graafland, 2020; Williamson, 2009). Yet formal institutions also contribute to shaping values and norms (Grosjean, 2011). Crossing findings across the literature therefore suggests bidirectionality between them (Andriani and Bruno, 2022; Alesina and Giuliano, 2015). Yet more detailed evidence on the variegated relationship between formal and informal institutions—and changes in such relations in different contexts—is lacking, despite of its implicit relevance: How the two interact with each other is key in trajectories of societal and economic development (Acemoglu and Robinson, 2013; 2019; Alesina and Giuliano, 2015; Pritchett, 2013; Touré, 2021). We propose to recast the perspective typically adopted in the field through some analytical and methodological innovations: we rely on extensions of correlation network analysis (Horvath, 2011; Jacobi, 2018) to map multiple, simultaneous relationships among formal and informal institutions in a network.

Within the field, the object of empirical investigations tends to remain a single relation or few, highly specific relations (for an exception, see Kaasa and Andriani, 2022; Pryor, 2007). Yet any investigation of a specific relationship lacks "context" by being unable to provide information on how the relation is inserted into the broader web of existing institutional interdependencies. Although a relationship may be causal, it may be embedded within a "path" or a "constellation" of relationships that is overlooked in a purely dyadic perspective. We seek to shed light on change in these constellations of relationships—in different cultural contexts. Culture has typically been used as a synonym for informal institutions, juxtaposing it against (formal) institutions. In our research design, we attribute a different, contextualizing role to culture, in order to compare institutional interdependencies across different cultural ecosystems.

To avoid a multitude of potential confounding factors that plague cross-sectional analysis even if identification strategies have been carefully devised (Gutmann and Voigt, 2020; Hofstede et al., 2010), Putnam (2004) and Tabellini (2010) have paved the way for subnational investigations in the field. Their work has brought the relation between historical facts and present institutions into focus, demonstrating a certain path dependence of institutional outcomes (see also Inglehart and Baker, 2000). However, such studies have not specifically addressed how such path dependence affects the delicate relation between formal and informal institutions. We seek to fill this gap by adopting a systemic perspective (Kuran, 2009) and an innovative research design: we focus on multiple interdependencies and—mimicking the investigation of complexity (Arthur, 1989)—seek to identify emergent properties (Grimm et al., 2005; Marinari and Parisi, 2000) within—and across—different contexts.

The goal of this paper is to investigate whether the relationship between formal and informal institutions changes in different (subnational) cultural ecosystems that are path dependent on historical facts. We propose the following two analytical innovations in the field. First, we suggest partially distinguishing culture from informal and from formal institutions, in line with who criticizes treating culture and informal institutions as clear equivalents (Gutmann and Voigt, 2020; Graafland, 2020; Pitlik and Rode, 2017; Voigt, 2018). While we acknowledge important overlaps between culture and informal institutions, we suggest that culture is a broader concept that can serve as context (Oyserman et al., 2009) in which the interaction between formal and informal institutions unfolds. In line with social psychology literature, our take on culture does not rely on individual endorsement of values but, rather, on collective experiences of meaningful situations that affect common knowledge, cognitive schemata, and, possibly, goals (Oyserman, 2017). These experiences are tied to the specific geography and history that societies collectively face in the quest to find solutions to their problems. Second, in line with a consolidated research tradition that traces analogies between institutional analysis and biology (Auyang and Hoover, 1995; Richerson et al., 2010 both in Hodgson, 2004; Nelson and Winter, 1982; Nicita and Pagano, 2013; Vatiero, 2017; Vromen, 1995), we use two analogies to ecology: we treat culture as an ecosystem, in other words, the context within which multiple relationships across diverse formal and informal institutional factors occur simultaneously. Following Jacobi (2018), we frame these relations as interdependencies, in other words, asymmetric symbiotic relationships, in which a symbiont "feeds upon" a host and is therefore dependent on it (Overstreet and Lotz, 2016). This implies combining symbiosis theory (Cain et al., 2011; Margulis, 1984; Watkins, 1998) with institutional complementarities (Amable, 2000; Aoki, 2001; Pagano and Rowthorn, 1994; Pagano and Vatiero, 2015).

In our study, we build on Brazilian historiography (Leff, 1997; Musacchio et al., 2014; Naritomi et al., 2012; Ribeiro, 1995), and find confirmatory evidence that the five Brazilian macroregions (North, Northeast, Center-west, Southeast, and South) qualify as sufficiently different cultural ecosystems. Despite having a common, national background holding legal origins, macro-institutional factors and official language constant, Brazil has experienced historically diverse labor immigration patterns. It is one of the countries with the largest number of imported African slaves (Soares et al., 2012), but it also experienced one of the largest state-sponsored immigration of European settlers at the turn of the nineteenth century (Carvalho Filho and Monasterio, 2012; Rocha et al., 2017). These different subnational histories (Cao et al., 2021; Nisbett and Cohen, 1996; Nunn, 2012) interacted with diverse geography, coevolving with its indirect effects (Engerman and Sokoloff, 2002; Oyserman, 2011, 2017). Within each cultural ecosystem, different "cultural value orientations" (Licht et al., 2007; Schwartz, 2004) are likely to prevail, through which institutions and their legitimacy and operation is perceived and evaluated (Andriani and Bruno, 2022; Boranby and Guerriero, 2019; Schwartz, 2004). Some examples of what are considered key drivers of culture (Alesina et al., 2013; Inglehart and Baker, 2000, Tabellini, 2010) are a prevalence of foraging, farming, or herding (Barry et al., 1959; Voigt, 2022) or relative isolation from other communities (Buonanno and Vanin, 2017), and exposure to different religious beliefs (Hill, 2020).

We adopt an exploratory approach in order to detect emergent patterns between a pool of formal and informal institutional factors, which we measure in 5565 municipalities. We adopt correlation network analysis tools (Horvath, 2011) to compute weighted directed networks that map multiple institutional interdependencies in a complex network. By performing our empirical analysis separately for each macroregion, we extend Jacobi (2018) through a systemic comparison of institutional landscapes.

We detect two emergent patterns: first, the prevalent dependence is of formal institutions on informal ones, corroborating the critical importance attributed to informal institutions in the literature (Alesina and Giuliano, 2015; Maseland, 2013; Mathers and Williamson, 2011; Williamson, 2009). Second, we find that this symbiotic "dependence" of formal institutions on their informal

counterparts is more evident and prevalent in contexts that were subject to historical processes in which extractive—rather than inclusive—political processes (Boranby and Guerriero, 2019) prevailed. We think that our comparison across different cultural ecosystems sheds light on how context-specific institutional analysis should be and that kicking off institutional change may not be easy unless different institutions are targeted jointly.

The paper is structured as follows. First, we introduce our definitions of formal and informal institutions and of culture (Section 1). We then specify the concept of a cultural ecosystem and why it may explain differences in institutional landscapes (Section 2). Section 3 is dedicated to Brazilian historiography, sketching the differentiated paths of the five macroregions. After introducing our data and methods (Section 4), we present our results (Section 5) and conclude with some research implications (Section 6).

2. Formal and informal institutions and culture

All institutions are functional for structuring social interactions, making the behaviors of others more predictable (Basu, 2018; March and Olsen, 1983; North et al., 2009). We distinguish formal from informal institutions mainly in terms of the locus of enforcement. We define formal institutions as systems of legally stipulated, codified rules that regulate behaviors in line with socially accepted values through state-controlled enforcement mechanisms.[1] We regard informal institutions as systems of undesigned yet potentially codifiable norms that reflect socially accepted expectations with respect to interpersonal interactions and are socially enforced.[2] Although codifiability is essential for enforcement, because it implies that "breaches of the rule can be identified explicitly" (Hodgson, 2001:13), we suggest that informal institutions—because of their reliance on expectations—are blurrier in terms of their codifiability, therefore, some norms are enforced not by potential sanctions but through social copying mechanisms that reflect the desire to align with a certain part of society.[3]

In framing culture, we do not rely on individual conceptions of intergenerationally transmitted values, as typically used, for example, in World Values Surveys (see Guiso et al., 2003, 2006; Tabellini, 2010) but, instead, elaborate a perspective that stresses its collective nature. There is already some ongoing debate over whether cultural differences can and should be reduced to individual differences (Chen et al., 2020; Na et al., 2010). Empirical evidence suggests that variance in terms of expressed values is greater between individuals than between cultures (Fischer and Schwartz, 2011). Some of these debates is related to multilevel measurement concerns, which show, for instance, that cross-level isomorphy is not always present: "attributes that can differentiate individuals may not be the best ones to capture differences at group-level" (Chen et al., 2020: 7).

But there are also ontological concerns. For example, Bisin and Verdier (2022), who have investigated cultural transmission mechanisms, explain that intergenerational transmission is a blended process that combines vertical (parent to child) and oblique transmission in which children learn from the (collective) cohort of their parents. The distribution of values among the members of the cohort is relevant for cultural transmission. Further, within social psychology, culture is defined as the set of meanings that a group in a time and place come to adopt or develop (Geertz, 1984; Markus et al., 1996; Oyserman, 2017). Time and place represent specific ecologies, within which culture evolves as a set of "good enough working solutions" to basic problems, such as sustaining the group over time, organizing relationships, and facilitating individual welfare (Oyserman, 2011:166 referring to Schwartz, 1992). Such solutions become a part of culture if they permeate many/all aspects of daily life and behavior—becoming a blueprint for a series of different situations.

By doing this, we identify the first element through which informal institutions can be distinguished from culture: whereas norms tend to be situation specific, culture is likely to have a broader reach by proposing core themes and cognitive schemata that are not specific to situations (Oyserman, 2017; Schwartz, 2007).

Such permeation is compatible with our approach to treating culture as an ecosystem, because we refrain from identifying specific cultural determinants and, instead, treat it as a gestalt in line with Pryor's (2007: 822) suggestion to focus on the system of cultural characteristics, rather than on its single components. In characterizing such a "gestalt," we follow Nunn (2012), Nisbett and Cohen (1996), and Cao et al. (2021) and focus on historical processes as key drivers of culture (Alesina et al., 2013; Inglehart and Baker, 2000, Tabellini, 2010). This focus on history corroborates the social psychology take on culture as sticky or slow to change, inasmuch as "once absorbed, no single specific element can be excised," mainly because culture is more than a single core theme, it is a detailed, rich, and particularized set of norms and implicit assumptions about how everyday life will unfold, which can be applied to everyday life. Being acculturated means knowing how things are likely to unfold within one's society, so that systematic processing is not needed to get through the mundane details of the day. (Oyserman, 2017: 454–455).

Such reflexive cognitive processing facilitated by culture is antithetical to reflective thinking, which requires a more conscious analysis.[4] The human brain frequently makes unconscious choices because the individual informational background is insufficient for dealing with limited or non-objective cognition. Some papers have suggested that the collective knowledge implied by culture (Bénabou and Tirole, 2016:143; Greif and Mokyr, 2017) complements and fills up missing data in human cognitive processes (Cordes, 2004; Gifford, 2005). It works as a kind of natural assessment (Tversky and Kahneman, 1983) because it does not require intention or effort. Crucially, the reflexive system is not incompatible with the reflective one but remains activated, so culture is "always experienced as a natural and immediate basis for choice and action" (Oyserman, 2017:444). Individuals, then, do not need to actively

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[1] Based on Greif and Mokyr, 2017; Gutmann and Voigt, 2020; Hodgson, 2001, 2004; North, 1991.

[2] Based on Gutmann and Voigt, 2020; Hodgson, 2001, 2004; North, 1991; Opp, 1982; Voigt, 2018.

[3] We thank an anonymous reviewer for pointing out that this feature characterizes informal institutions.

[4] Reflexive thinking recalls the "built-in/wired-in" mechanisms that affect individual cognition and dispositions in Benabou and Tirole, 2016: 142; Gutmann and Voigt, 2020; and rapid responses without conscious deliberation in Wilson et al., 1993).

endorse the content of their culture. It is merely necessary for them to assume the cultural elements "to be the way that others in one's group experience the world" (Oyserman, 2017:443; see also Morris et al., 2015; Mourey et al., 2015; Schokkaert and Truyts, 2017).[5]

From a social psychology perspective, a certain cultural context activates the "relevant" or cultural mindset, momentarily or continuously (Oyserman, 2011). This implies the activation of a set of mental representations or cognitive schema with culture-congruent mental content (knowledge about the self and the world), cognitive procedures (e.g., "find relationships and connect" or "find the main point and separate"), and goals (e.g., "fit in and be sensitive to context" or "stick out and do your own thing"). Schwartz (2007) and Huebner (2013) propose, in a very similar way, a kind of "situational sensitivity," which means that the cultural context influences "both what comes to mind and how it is made sense of" (Oyserman et al., 2009: 219).

In this sense, we identify a second, tentative element that can help distinguish culture from institutions, inasmuch as institutions always regulate or condition social interactions specifically, whereas culture is likely to have a broader influence on the way in which we think (i.e., on our worldviews) in the first place.

We stress that the literature presented suggests that the collective nature of culture is based on a time and place: culture emerges as a "good-enough solution" to problems that are context specific to ecology, history, and other factors. Crucially, the questions that seem relevant or the problems for which a solution needs to be found may differ in different contexts. Geography plays a key antecedent role because it sets the scene for the kind of environmental challenges that groups need to face: are they exposed to risks or natural disasters? Do they need to work in teams to obtain food? And so on.

Oyserman (2017) suggests that finding cultural solutions is a group phenomenon and that cognition emerges as "moment-by-moment interaction with the environment." We suggest that the fact that this environment is shared makes the cognitive processes related to culture a collective phenomenon. This is corroborated by papers investigating the geographical clustering of values (e.g., Chen et al., 2020; Rentfrow, 2010). However, history is another likely antecedent, in particular because it implies exposure to "psychologically meaningful situations" (Oyserman et al., 2009: 219). Selective migration, ecological influence, and social influence cumulatively lead to spatial clustering of psychological characteristics (Gelfand et al., 2011; Triandis, 2018) and, therefore, have been seen as "socio-ecological causes of cultures" (Chen et al., 2020: 2).

Based on the treatment presented, we synthetically propose that culture reflects shared mindsets and "value structures" that could result in "decreased variability in individual response to stimuli" (Erez and Earley, 1993: 40). This definition is compatible with our goal to identify geographically clustered subcultures within the territory of Brazil. Subnational cultural ecosystems reflect a distinct shared history or geographically based experiences that have determined which cultural mindsets are activated more often and the values of the group (Schein, 2010; Triandis et al., 1973). Although we treat such values as latent factors and do not specifically investigate them (cf. Pryor, 2007), we expect macroregions to potentially differ in terms of values, such as the acceptance of equality, autonomy, hierarchy, and embeddedness (Schwartz, 2004; Torres et al., 2015; see online Appendix).[6]

These values have been found to matter for the content and functioning of institutions (Andriani and Bruno, 2022; Boranby and Guerriero, 2019; Licht et al., 2007), as well as for socioeconomic aspects. For example, the past prevalence of slavery is associated with current levels of inequality (Reis, 2014; Soares et al., 2012), suggesting strong path dependence in social inequality. Past labor immigration policies further reflect the establishment of extractive versus inclusive institutions, which has long-term effects on institutional quality (Acemoglu and Robinson, 2013, 2019; Engerman and Sokoloff, 2002).

Given the context specificity and the cumulative historical nature, which we attribute to culture, we therefore propose culture as the context for the unfolding of relations between formal and informal institutions. Designed and undesigned codified rules are both closely related to socially accepted values and expectations based on our definitions (Greif and Mokyr, 2017; Gutmann and Voigt, 2020; Hodgson, 2001, 2004; North, 1991; Opp, 1982; Voigt, 2018). Our main target of investigation is whether differences in cultural mindsets (Oyserman, 2011) are linked to differences in how formal and informal institutions are related to each other. This extends the literature on the relevance of historical processes for (single) socioeconomic or institutional aspects prevalent in a society (Alesina et al., 2013; Cao et al., 2021; Nisbett and Cohen, 1996; Nunn, 2012; Putnam, 1993; Tabellini, 2010), because we look at how historical processes associate to how these institutional aspects relate to each other in multiple ways.

3. Cultural ecosystems and symbiotic relationships

Cultural ecosystems propose an interpretation of culture that is spatially delimited (Andriani and Bruno, 2022; Greif, 1994; Giuliano and Nunn, 2017).[7] We use ecosystems as an analogy as they account for a holistic environment in which life unfolds. Ecosystems are characterized by complex patterns formed by multiple and specific interactions that take place (1) between organisms that populate it and (2) in interaction with their environment, which has an explicit spatial extent (Lawton, 1999; Likens, 1992; Odum, 1993; Tansley, 1935; Pickett and Cadenasso, 2002).[8] Ecosystems and the organisms that populate it are subject to "coupling,"

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[5] Schokkaert and Truyts (2017) investigate the preferences for redistribution and show that, under imperfect information, individuals rely on their reference group to make choices, in addition to having their own idea(l)s.

[6] Available at https://www.dropbox.com/s/9w812pzyyr1gtfi/Online%20Appendix.docx?dl=0/.

[7] The "adequacy" of available shared mental models increases with "stability of the environment" across generations (Giuliano and Nunn, 2017:451). Examples of space-related factors influencing culture are climatic variability, physical proximity and geographic obstacles (Durante, 2009; Grosjean, 2011; Tabellini, 2008.)

[8] Boundaries are always subject to discussion but tend to be used to make the analysis tractable and to identify external forcing functions (Odum, 1993).

which implies deeply intertwined coevolutionary processes (Waring and Richerson, 2011). Therefore, ecosystems do not only provide a static habitat for their organisms but, rather, are in constant exchange with them (Judkins et al., 2008; Kallis, 2007).

By treating culture as an ecosystem, we can stress its multidimensional and not fully deterministic nature (Norgaard, 1994; Pickett and Cadenasso, 2002).[9] For example, ecosystems host elements that operate at "qualitatively different speed from the others" (Holling, 1995: 25). Therefore, they resist change even though some of their components are in the process of transformation until a critical tipping point—which is usually unknown *ex ante*—is reached (Beinhocker, 2007; Pierson, 2004). Therefore, cultural ecosystems insinuate a sticky (see Williamson, 2000; Pryor, 2007) yet not fully exogenous nature of culture, in which phases with slow change succeed rapid, disruptive adaptations in the system. This phenomenon is known in biology as a "punctuated equilibrium" (Eldredge and Gould, 1977) and has been applied to the analysis of institutions and culture (Baumgartner and Jones, 1993; Hodgson, 1991; Mokyr, 1990; Neyapti, 2013).

With this framing in mind, culture plays a contextualizing role in the short term but can absorb feedback effects from, for example, institutions in the long term, as demonstrated in Grosjean (2011). The "coupling" of an ecosystem with its components stresses the coevolutionary nature of linkages between institutions and cognitive structures (Beckert, 2010; Boyer and Petersen, 2012; Licht et al., 2007).

Within cultural ecosystems, we replace organisms with formal and informal institutions, which eventually engage in multiple and simultaneous symbiotic relationships (Jacobi, 2018). This means going beyond seeing informal and formal institutions as substitutes or complements, which tend to describe a symmetric relationship. The symbiotic perspective introduced by Jacobi (2018) emphasizes asymmetric interdependence, in which one institutional factor "feeds" (or is dependent) on another. The "nurturing" factor can be harmed (in the case of parasitism) or not (in the case of commensalism).[10] Following Overstreet and Lotz (2016), we simplify the symbiotic framework by distinguishing between a (1) symbiont, feeding on a (2) host.

The analogy between institutional interdependence and symbiotic relationships can be imagined as the provision of resources, adequate habitat, or services (Cain et al., 2011) that, for example, enable an institutional factor to thrive better in proximity to another factor that provides these "nutrients": think of the informal institution of "life-long relationships" in which a couple expects to stay together until one of them dies. This norm provides the "service" of reduced costs of enforcement (see Acemoglu and Jackson, 2017) for legally stipulated patrimonial arrangements within a family or can become a "habitat" in which the degree of acceptance is higher (Tabellini, 2010; Voigt, 2013) for formal rules that favor married couples over unmarried ones. Manifold asymmetric relationships are likely to unfold between formal and informal institutions, eventually assuming different patterns regarding which institutional factors act as hosts for the others.

The key focus of our analysis is precisely how relationships between formal and informal institutional factors unfold within different cultural ecosystems. We acknowledge that a key difficulty in this conceptual and empirical exercise is the distinction between culture and informal institutions. To some extent, the two concepts are not clearly separable, but we suggest that the overlap between culture and informal institutions is such that culture tends to comprise informal institutions, not vice versa, in a similar vein to ecosystems that comprise organisms, although they exchange and evolve in a "coupled" fashion. We next reconstruct subnational differences in historical cumulative processes in Brazil.

4. Cultural differences in Brazil's macroregions

The official division of Brazil into the five current macroregions dates back to 1969 (Torres et al., 2015). The distinctions are based on climate relief and landscape, hence, mainly on ecosystem properties. In our historiographic reconstruction (Table 1 and below), we draw on Ribeiro (1995), who also proposed five subcultures in Brazil, which roughly reflect the official geopolitical division of the current administrative macroregions. In characterizing our cultural ecosystems, we do not rely on values surveys, as, currently, value surveys such as the World Values Survey conducted in Brazil are not statistically representative at the macroregional level. However, the extant literature exploring the potential for using values surveys has suggested that the five macroregions are culturally different. In a meta-analysis that compares 19 independent studies, Torres et al. (2015) confirm the value differences across the five macroregions using Schwartz's (1992, 2006) values scale. Van Horn et al. (1995) further show the potential heterogeneity in collectivist attitudes and power distance between Brazilian regions. Focusing on middle- and upper-class college students, they find that in southern regions students perceive low distance to power and are more like their US counterparts in terms of self-reliance. Hofstede et al. (2010) discuss the results of three studies that rely on values surveys implemented within Brazilian companies. They also detect some differences between regions in terms of power distance, uncertainty avoidance, individualism, masculinity, and long-term orientation.

Based on this extant evidence, we depart from the assumption that the five macroregions may be different cultural ecosystems. We briefly sketch key historical processes that are likely to have shaped this difference. Our narrative concentrates on regional differences in the colonial era up to the 1930 s

Brazil combines a modern state history characterized by marked centralization efforts, with historically rooted subnational differences. It has undergone important waves of cultural unification, such as the Vargas period in the 1930 s[11] and cumulative

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[9] Our analogy does not consider cultural evolution unintentional, as often implied in biological evolution (see Kallis, 2007).

[10] Commensalism is asymmetric because it is never obligatory for the benefit giver but may be so for the benefit taker. Mutualist symbiotic relationships may be of minor or existential importance to both organisms involved, but in a symmetric fashion (Simard, 2021).

[11] Under the rule of the president Getúlio Vargas.

Table 1
Synthesis of historically differentiated paths of the five Brazilian administrative macroregions.

	North	Northeast	Center-west	Southeast	South
Ecosystem	*Amazon* (tropical rain forest)	*Caatinga* (thorny shrub), tropical semideciduous Forest and *Cerrado* (Savanna)	*Cerrado* (Savanna) & plateau with periodically wet land	Tropical semideciduous Forest & *Cerrado* (Savanna)	Tropical semideciduous forest & *Pampas* (Grassland)
Historical Matrix	Atomized and isolated society, prevalence of diseases, short-lived extractive waves of economic growth based on forest resources	Hierarchical, export-oriented, extractive, authoritative	Pastoral economy and community centered on cattle; poor free people immigrate from Northeast	Society initially based on looting, enslaving of Indios and their selling to the Northern plantations, then on war services, gold and coffee	Three different settlement patterns, original gauchos are pushed to the margins by different waves of European settlers
Power in the hands of	Jesuits; later owners of transportation means (water)	Landowners, merchants; last moving to South	Cattle owners first, landowners later, local patronage	Men, bureaucracy, landowners later	Shared between gauchos and landowners, first, then landowners only
Minority/ majority subjugated	Indios (detribalized, enslaved); later indebted workers from Northeast	Africans (imported slaves)	Working poor (shepherds first, cotton-sharecroppers later), "reserve army" of unskilled workers	Indios, Jesuits, in part slaves, poor agricultural workers without land ownership later	Pastoral-centered populations (gauchos), impoverished European settlers: those without land ownership
Prevalent product (historical)	Spices and products collected in the forest; later latex; later Mercury	Sugarcane; later tobacco, coffee	Cattle and derived products, from meat to leather; cotton; later capital-intensive agriculture	Trading of slaves, later gold (rush), later coffee for export	Leather and meat; cattle; trade of horses, mules and oxen as beasts of burden for gold mines
Religious history	Indio beliefs, Jesuits	Afro-Brazilian beliefs; Catholic	Fundamentalist messianism	Secular; Catholic	Mixed with recurrent episodes of messianism
Particularity	No land ownership; consumption-debt enslaving workers, decimation of Indio population	Slave economy; coexistence of very unequal ties within a single property (*fazenda*)	No slavery but feudal system, banditry, emigration and religiosity as "escape" strategies from social inequity	Subsistence economy, not export-oriented, more horizontal societal tradition	Different bottom-up experiences of horizontal societal organization

Source: Based on Ribeiro (1995).

processes of equal access to socioeconomic rights (Barrientos, 2013; Skidmore, 2002). But key historical developments have resulted in subnational differences in terms of ethnic mixing and prevalent economic structure, with regional histories almost developing in parallel until the twentieth century (Leff, 1997; Reis, 2014; Torres et al., 2020).

The north has mainly experienced "extractive" colonial rule and importation of slaves (Acemoglu and Robinson, 2013; Musacchio et al., 2014; Naritomi et al., 2012). In fact, two Brazilian ports, Salvador and Rio de Janeiro, sadly historically qualify among the nine biggest slave import markets of the world (Nunn, 2008). In the south, however, this was paralleled by state-sponsored immigration of Europeans, which peaked between the 1880 s and the 1920 s, and is thought to have introduced to the country additional civic traditions, cultural elements, and preferences for spending on education (Carvalho Filho and Monasterio, 2012; Rocha et al., 2017). Much in line with Engerman and Sokoloff (2002), the initial geographical and settlement differences appear to have led to further indirect effects on public spending patterns (Musacchio et al., 2014), human capital accumulation (Musacchio et al., 2014; Rocha et al., 2017), land inequality, local institutional quality (Naritomi et al., 2012), and concentration of economic power (Carvalho Filho and Monasterio, 2012; Naritomi et al., 2012).

Ribeiro (1995) describes in great detail how different cultural protocells emerged at a great territorial distance within Brazil (see Table 1). The northeast developed as plantation economy, characterized by extensive land property, intensive monoculture of sugar cane and cotton (Leff, 1997), with the importation of slaves accounting for about 70% of export revenue (Ribeiro, 1995: 259). The region declined with the end of slavery, and, because its types of land were less suited for coffee production, which became the economic driver in the nineteenth century (Leff, 1997). The slave-plantation complex profoundly shaped a prevalent, patriarchal family structure (Freyre in Skidmore, 2002:10) within a context of marked social inequality (Naritomi et al., 2012: 399).

The northern Amazon grew as its export-oriented, extractive economy centered on primary produce from the forest (e.g., spices and latex), which implied decimation of the enslaved indigenous population. Later, with the surge of the latex boom at the turn of the nineteenth century, poor, landless, *Nordestinos* (from the Northeast and Center-West regions), immigrated, commonly ending up in slavelike conditions because they became indebted to their employers, which were also local monopolists in necessary consumption goods (Ribeiro, 1995: 278).

In the vast and desolate pasture plains of the Center region (*Cerrado*, savanna), different migration waves introduced poor workers who engaged first in pastoral activities and later in the cultivation of cotton (*mocó*). Social organization became strictly hierarchical, with cattle/landowners maintaining a high concentration of land, capital, and technology, preventing the working poor from obtaining skills or prospects for improvement (Ribeiro, 1995: 320–321), lastly through the growth of capital-intensive agriculture, which turned most of the ancient pastures into soil for exported monocultures, for example, soy.

The first Neobrazilian societies populating the Southeast region were more horizontal, with an economy oriented toward subsistence, not exports.[12] Immigration to previously sparsely populated areas spurred during the gold rush (Naritomi et al., 2012) and led to a new urban and ethnically mixed society, characterized by abundant resources, thriving arts and architecture, and economic diversification oriented toward the local domestic market. Though it was the birthplace of the Republican thought in view of "freeing" the extraction-centered economy from colonial taxes (Naritomi et al., 2012: 401), the area declined after the Portuguese crown suppressed incipient requests for industrialization (Ribeiro, 1995: 342). Many emigrated or returned to subsistence agriculture, whereas a small portion of the previous elite found "refuge" in public administration. During the export-oriented coffee boom, landowners pushed for maintaining an elastic labor supply and preferred European immigrants to local subsistence farmers and to freed Northeastern slaves as workforce (Leff, 1997; Petrone, 1982; Rocha et al., 2017; Skidmore, 2002). This nascent rich class of coffee barons became an oligarchy, assuming control over trade of their produce while also taking over important political positions. This later allowed them to use formal institutions to secure wealth (Leff, 1997), for example, through control of the real exchange rate, which granted export profits while impoverishing the masses through inflation.

The Southern pampas developed by slowly integrating different peoples (Ribeiro, 1995: 369–376): pastoral "Gauchos"[13] who spoke guarani and adapted to nature for their subsistence, relying on flocks living freely on no-man's-land; the "Matutos," which are Portuguese migrants and soldiers intentionally translated to the Southern coast by the crown to occupy the territory contested by the Spanish; and "Gringos," European workers immigrated on state-sponsored settlements that established themselves as small landowners (Rocha et al., 2017).

Despite the remoteness of these historical processes, they are likely to echo to the present and to leave traces on subnational institutional landscapes. Carvalho Filho and Monasterio (2012) describe continuity, for example, among Protestant immigrants pursuing human capital accumulation and equity, whereas Catholics consistently preferred cohabitation of diverse generations. They also suggest proximity in cultural diffusion inasmuch as offspring "dispersed in the agricultural frontier" (p. 799). Musacchio et al. (2014) show that in regions where the share of slaves in the population was large during the empire, education investment and outcomes were still lower at the turn of the nineteenth century. In contrast, Rocha et al. (2017) find that in areas with intense voluntary European migration, requests for public schooling were successful.

Torres and Dessen (2008) investigate the link between the mixed ethnic-cultural composition of the Brazilian population driven by different regional historical patterns and the current Brazilian family structure. They find that the North and Northeast regions have larger families compared to the Southeast region. Further, they observe differences in the internal functioning of families (e.g.,

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[12] Ribeiro describes the "creation of the Brazilian people" as originating in *cunhadismo*, which is exemplified by Indios giving their women to Portuguese colonizers, thereby allowing strangers to become part of their tribe (1995: p. 72). The infiltration facilitated recruitment of the workforce among Indio relatives.

[13] Prevalent in the wider cultural-ecological area comprising Argentina, Uruguay, Paraguay, and the South in Brazil.

hierarchical structure, division of labor, type of affective link between spouses, and between parents and their children). According to Torres and Dessen, this is particularly relevant in the Brazilian society, in which the family—particularly in the poorest areas—substitutes for some of the state's responsibilities in terms of social protection and inclusion. Furthermore, the meta-analysis conducted by Torres et al. (2015) suggests that the Southern and Southeastern regions—which experienced subsidized immigration—score higher on values related to autonomy/self-direction. The Northeast region, with its past rooted in the plantation economy, scores the highest on embeddedness and hierarchy, which, according to Schwartz, are juxtaposed with autonomy and egalitarianism inasmuch as preservation of the social order is a key value (Licht et al., 2007; Schwartz, 1992, 2004, 2006).

It is not our intention to neatly characterize the Brazilian cultural ecosystems in terms of their individual components; rather, we seek to capture the differences in their "gestalt" (Pryor, 2007: 822), which can be attributed to historical processes (Alesina et al., 2013; Cao et al., 2021; Nisbett and Cohen, 1996; Nunn, 2012) and the indirect effects of geographic endowments (Engerman and Sokoloff, 2002). The reconstruction of subnational historical processes, and the documented heterogeneity across regions in terms of having an individualistic attitude, perceived distance to power, and family ties (Hofstede et al., 2010; Torres et al., 2015; Torres and Dessen, 2008; Van Horn et al., 2010), is likely to affect the development of formal institutions (Marè et al., 2020; Pitlick and Rode, 2017) and, accordingly, their relation to informal institutions. We next focus on the differences in institutional interdependence patterns that can be observed in the different macroregions.

5. Data and methods

We start by not measuring culture explicitly but by taking for granted that the five Brazilian macroregions represent separate cultural ecosystems due to their historical past. In a separate robustness analysis reported in the Online Appendix, however, we find empirical evidence confirming that the five Brazilian macroregions are statistically significantly different systems in terms of two latent factors that we estimate using principal component analysis (PCA). We run our estimation with a set of municipal-level variables that reflect the historically driven, collective experience forging cultural mindsets (see Section 1).[14] Our first latent factor mainly captures ethnic composition and the share of illiterates in Brazilian municipalities; the second one is mostly correlated with religious composition. Interestingly, we find that macroregions are always different in both the factors —confirmed by specific statistical tests of any possible pair— but that states (a lower level of aggregation) are not, because some of them overlap in at least one of the two factors. Therefore, we find this test useful for further validating our choice to distinguish cultural ecosystems at the level of administrative macroregions.

5.1. Variables included in the network computation

As our empirical analysis extends the work by Jacobi (2018), we also use the mesolevel dataset (Jacobi, 2018) comprising the universe of Brazilian municipalities. It combines census data (2010) with a municipality survey (*Perfil dos Municipios,* IBGE) and their public accounts data (*FAZENDADATA,* IBGE) for the same year. Measuring institutional factors at the municipality level guarantees the large number of observations required by correlation network analysis. However, this choice also implies lower aggregation than usual in measuring institutions. In the Brazilian federal system, the municipal level is the lowest level of governance at which formal institutions can emerge*,* as it includes the competence of legislation. Municipalities belong to their respective states (e.g. Bahia, Amazonas, Minas Gerais), which are themselves part of administrative macroregions (see Table 2).

Municipal governance is therefore clearly embedded within higher-level governance structures, specifically the state of belonging and the Federal Union which is the Brazilian national government, whose respective constitutions municipal law cannot contradict. So, although this level of governance is the closest to the citizen, it allows for only a limited typology of institutional factors that can be captured. According to the Brazilian constitution (1988), municipalities elect a mayor and 9–55 council members, depending on the size of the population. Their key municipal functions are legislation on matters of public interest, the institution and collection of taxes under their jurisdiction, planning, public initiatives, organizing and rendering public services, maintaining preschool and primary education, as well as health care, in cooperation with the Federal Union and the state of belonging (Art. 30). Municipalities retain a fixed proportion of the federal taxes that they collect, between 25% and 50% (depending on the specific tax) (Art. 158). They may institute additional taxes (Art. 30). The fiscal variables that we consider characterize the administrative capacities/quality of the local institutional environment in line with literature on state effectiveness (Besley and Persson, 2011; Pritchett and Werker, 2012) and state capability (Sarker, 2006).

Among our measures of formal institutions, we therefore include the number of taxes collected and the share of taxes in total municipal income (Cummings et al., 2009; Gründler and Köllner, 2020; Marè et al., 2020). We also include a measure of public income diversification, namely, a Herfindahl Index over five public revenue sources to proxy for sound fiscal management (Carroll et al., 2003); and two measures of public spending: on public goods (Burns and Keswell, 2015; Touré, 2021) and on health (de la Maisonneuve et al., 2017).

At the municipality level, we also register the presence and strength of participatory councils, an innovative institution in which citizens codetermine municipal decision-making and can therefore engage in democratic practice (Avritzer, 2009; Galletta, 2021; Wampler, 2012).

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[14] The variables we include in PCA are shares observed in the municipal populations, of, e.g., ethnic belonging, religious affiliation, and illiteracy (see online Appendix for details). These shares reflect cumulative collective outcomes in line with our conception of culture as a historically shaped, shared mindset.

Table 2

Brazilian municipalities nested in states and macroregions.

Macroregion	North	Northeast	Center West	Southeast	South	**Brazil**
No. of states	7	9	3	4	3	26
No. of municipalities	449	1794	465	1668	1188	5564

Source: IBGE, 2010.

Note: The mesolevel dataset does not include the capital city Distrito Federal, which is contemporarily a state and a municipality.

Our measures of informal institutions proxy for expectations of interpersonal interactions, which affect attitudes: toward women, youth, family, the economy, conventions, and political competition. Therefore, we include female labor market participation and the female wage gap as proxies for women's position in society (Cavapozzi et al., 2021; Inglehart and Baker, 2000), the inverse of the age of the mayor to proxy for openness toward young people (Inglehart and Baker, 2000), the share of extended families that have cohabitation with parents and relatives (Alesina and Giuliano, 2015; Maré et al., 2020), the ratio between indirect taxes and factor gross domestic product to proxy for the prevalence of the informal economy (Godfrey, 2011; Zoogah et al., 2015); the number of art groups to proxy for (unproductive) entrepreneurship (Baumol, 1996), which implies some collective motivations for challenging contemporary conventions (Lindqvist, 2011; Rindova et al., 2009); and the number of candidates in municipal elections to proxy for local democratic attitude and electoral competition (Banerjee and Iyer, 2008). In a country where local governments are at least partially autonomous in terms of budgetary decisions and in which legislators are chosen by an open-list proportional representation system,[15] Arvate (2013), for example, finds that having a higher number of candidates significantly reduces the rents of incumbents and, therefore, increases the supply (and the efficiency) of public goods.

Apart from estimating direct relationships between formal and informal institutions, we also note indirect and concatenated effects in our computed networks. They can be seen as paths that link factors by "passing through" other variables. Therefore, we also include some control variables:

- economic characteristics (GDP per capita, Gini index, the share of industry in municipal GDP, the number of public employees in the total workforce);
- sociodemographic characteristics (population density, share of residents older than 60/with income below 70 reais (approximately 40 USD), share of illiterate adults, ethnic fractionalization index,[16] and the exponential share of Catholics in the municipal population);[17]
- variables that capture the remoteness of the municipality from economic activity (density of transportation services, share of population living in rural areas, and the number of municipal collaborations with other municipalities/governance levels across themes to proxy for institutional permeability).[18]

The last group of controls includes proxies for social capital and trust. Unlike some papers (e.g. Williamson, 2009) that consider social capital an informal institution, we separate social capital variables from the institutional domain (Voigt, 2018) and use them as control variables that potentially affect institutional connections (Pitlik and Rode, 2017).[19] We separate infrastructure for social aggregation typically provided by public spending— such as libraries, museums, and stadiums—from other gatherings that foster social capital, including cultural centers, and community radios and associations. These are noncompulsory social venues that emerge on the request of citizens (Touré, 2021; Uslaner and Conley, 2003). Lastly, we include the likeliness of missing communication (Jacobi, 2018), which captures a type of educational fractionalization (Bossert et al., 2011; Jones and Zhan, 2020): here this implies that different groups have different educational backgrounds - specifically, different shares of adult illiterates. The groups are defined by age-class and ethnic belonging in line with categories used in the Census. Our measure computes all differences in the share of adult illiterates across different age and ethnic groups. As these differences can imply a lower probability in jointly discussing public issues we use this indicator as a proxy for the lack of trust. All count variables are scaled per capita or per 1000 inhabitants, and to make distributions more normal, we use log or exponential transformations. Table 3 outlines the pool of variables included in the analysis.

5.2. Patterns of Institutional Interdependencies

To calculate the asymmetric symbiotic relationships, we apply correlation network analyses (Horvath, 2011; Jacobi, 2018; Jacobi and Amendolagine, 2023). In correlation networks, the "adjacency matrix is constructed on the base of pairwise correlations between numeric vectors" (Horvath, 2011: 91). In our analysis, our pool of formal and informal institutions and control factors become nodes

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[15] This allows for at least partial influence on the order in which a party's candidates are elected by the voters.

[16] See Alesina and La Ferrara, 2005 for ELF – fractionalization of the population in terms of linguistic and ethnic belonging.

[17] Exponential transformation is necessary to adjust distribution to a quasi-normal shape.

[18] See Jacobi (2018) and Reis (2014) on the role of transportation costs in Brazilian economic development.

[19] Following a suggestion by an anonymous referee, we implement a robustness analysis in which we drop social capital variables from the network (see the online Appendix). The main results of our analysis, presented in Section 5, are confirmed.

Table 3

Descriptive statistics of the variables included in the analysis.

Variable	North	Northeast	Center west	Southeast	South
INSTITUTIONS					
Informal institutions, Mean (St. Dev.)					
femlbmktpart	0.37 (0.03)	0.38 (0.04)	0.38 (0.03)	0.40 (0.03)	0.43 (0.03)
femwagegap	0.72 (0.09)	0.76 (0.08)	0.65 (0.07)	0.71 (0.08)	0.72 (0.08)
mayoryouth	0.61 (0.14)	0.60 (0.15)	0.60 (0.12)	0.56 (0.15)	0.58 (0.13)
Extendfam	0.38 (0.11)	0.33 (0.08)	0.25 (0.05)	0.25 (0.05)	0.22 (0.04)
econformal	0.04 (0.03)	0.04 (0.03)	0.06 (0.04)	0.06 (0.05)	0.06 (0.05)
artgroups[a]	0.30 (0.32)	0.43 (0.39)	0.45 (0.42)	0.54 (0.55)	0.64 (0.61)
candidates[a]	0.31 (0.31)	0.24 (0.21)	0.37 (0.35)	0.32 (0.31)	0.38 (0.31)
Formal institutions, Mean (St. Dev.)					
participnr[a]	0.38 (0.51)	0.26 (0.23)	0.55 (0.50)	0.49 (0.49)	0.68 (0.59)
participforce	1.19 (0.73)	1.17 (0.68)	1.48 (0.73)	1.57 (0.73)	1.53 (0.73)
taxesnr[a]	0.20 (0.25)	0.15 (0.20)	0.29 (0.34)	0.39 (0.44)	0.53 (0.48)
Taxessh	0.06 (0.07)	0.04 (0.03)	0.07 (0.05)	0.07 (0.06)	0.06 (0.05)
Pubincdiv	0.16 (0.11)	0.12 (0.09)	0.24 (0.12)	0.25 (0.15)	0.25 (0.14)
publicgood	0.13 (0.08)	0.12 (0.06)	0.15 (0.07)	0.17 (0.06)	0.18 (0.07)
healthspend	139 (55.4)	136 (62.3)	160 (71.6)	113 (62.1)	115 (57.5)
CONTROLS					
Social Capital and Trust, Mean (St. Dev.)					
socagginfra[a]	0.19 (0.21)	0.17 (0.18)	0.31 (0.28)	0.29 (0.28)	0.40 (0.34)
socgather[a]	0.08 (0.10)	0.10 (0.12)	0.14 (0.16)	0.15 (0.18)	0.22 (0.22)
miss_comm	0.37 (0.21)	0.39 (0.17)	0.24 (0.15)	0.17 (0.11)	0.14 (0.11)
Economic, Mean (St. Dev.)					
gdp_pc[b]	1.24 (0.57)	0.83 (0.43)	1.83 (0.52)	1.73 (0.64)	1.97 (0.40)
Gini	0.58 (0.06)	0.53 (0.05)	0.51 (0.06)	0.47 (0.06)	0.47 (0.06)
industry[b]	0.12 (0.10)	0.12 (0.09)	0.14 (0.12)	0.18 (0.14)	0.17 (0.14)
pubemp[a,b]	0.08 (0.03)	0.08 (0.03)	0.08 (0.04)	0.07 (0.03)	0.07 (0.03)
Remotenness, Mean (St. Dev.)					
instpermea[a]	0.29 (0.46)	0.25 (0.39)	0.59 (0.76)	0.44 (0.60)	0.72 (0.92)
Transport	0.20 (0.32)	1.03 (1.43)	0.23 (0.43)	0.87 (2.48)	0.77 (0.83)
Rural	43.3 (19.7)	45.1 (19.5)	28.2 (17.2)	25.8 (18.9)	39.6 (23.8)
Sociodemographic, Mean (St. Dev.)					
catholic[c]	0.67 (0.12)	0.81 (0.12)	0.66 (0.09)	0.73 (0.14)	0.78 (0.13)
popdensity	22.3 (142)	89.9 (417)	28.4 (158)	194.9 (912)	77.4 (265)
pop60plus	7.7 (2.23)	11.4 (2.39)	10.6 (3.12)	13.0 (2.73)	14.1 (3.38)
Sharepoor	2.74 (0.64)	3.08 (0.45)	1.34 (0.61)	1.26 (0.77)	1.14 (0.66)
Illiteracy	17.3 (6.67)	27.3 (6.64)	12.3 (4.09)	10.9 (5.81)	7.9 (3.86)
Elf	0.47 (0.09)	0.50 (0.06)	0.55 (0.04)	0.49 (0.09)	0.33 (0.14)

Source: Based on the Mesolevel dataset, 2010.

[a] Variable scaled by 1000 inhabitants.

[b] Variables in logarithm

[c] Exponential variable

that are connected by correlation. For an introduction to the calculation of symmetric correlation networks and to an enhancement based on two-way quantile regression networks, see Jacobi (2018, 2022). The calculation of asymmetric symbiotic relationships requires the extension of the simple correlation network approach and working bidirectionally for each relation, connecting a pair of institutional factors. In what follows, we provide technical details and refinements that enable us to calculate directed weighted networks.

Quantile regressions enable us to determine the relevance of predictors at different points of the response distribution. For example, female labor market participation might be a predictor of democratic attitudes but only in municipalities with relatively high levels of democratic attitudes—for example, at the 80th quantile (higher end) of the distribution, though not for those located at the 20th quantile (lower end). Quantile regressions calculate several different regression curves in correspondence to different percentage points of the distribution (in our analysis at p20, p35, p50, p65, p80). For each variable introduced (*y*), we estimate five quantile regression models for which the *p*th conditional quantile given x_i is

$$Q^{(p)}(y_i \mid x_i) = \alpha^{(p)} + \beta_{x_i}^{(p)} + \varepsilon_i^{(p)}$$

where the *p*th quantile of the error term is zero.[20] Looping through the entire list of variables, ten quantile regressions are calculated for each possible pair of variables, because dependent and independent variables are switched within each relation. We restrict our

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[20] Error terms at different quantiles are not necessarily i.i.d. (Hao and Naimann, 2007).

Table 4

Example of a derivation of a symbiotic relationship in which the "share of taxes" is a symbiont on the host "female wage gap".

y	x	q20	q35	q50	q65	q80	percentage delta	No. of significant coefficients
Tax share	female wage gap	-.0214 *	-.0322 *	-.0470 *	-.0786 *	-.1320 *	5.17	5
Female wage gap	taxes share	-.6006 *	-.5541 *	-.6027 *	-.6049 *	-.5833 *	-0.03	5

Source: Based on Mesolevel dataset, 2010, Northeastern macroregion.

Notes: The upper part of the table reports the coefficients of quantile regressions with the tax share as the dependent variable and the female wage gap as the independent variable. The lower part of the table reports the coefficients of quantile regressions with the female wage gap as the dependent variable and the tax share as the independent variable. The table also shows the delta differences in the two directions between the coefficients related to the maximum and minimum percentiles with 5% statistical significance.

selection and maintain a relationship in the network only if the beta coefficient is statistically significant ($p < = 0.10$) in at least three of the five regressions that we run on each dependent variable.[21]

In Jacobi (2018), an asymmetric symbiotic relationship is determined using the following logic: the magnitude of beta coefficients proxy for the relative importance of the independent variable in explaining the dependent variable. In each of the five estimated quantile regressions, we compare the estimations in which y is the dependent factor with those of the regression in which x is the dependent factor. If we observe a greater increase in the slope coefficient in one direction than when switched, the independent variable (x) is more relevant for explaining the dependent variable y (at higher moments of its distribution). Such asymmetry, if detected, is quantified by comparing the respective percentage change (delta) in the slope coefficient along quantiles for each direction. The difference in these deltas between one direction and another become the weight of the arc in our directed network.[22] Although such arcs do not demonstrate causality, they indicate the directionality of the numerical relation that we observe among factors. Within a framework inspired by symbiosis, each arc in the network represents an asymmetric symbiotic relationship in which the factor from which the arc originates is a host and the factor at which the head of the arc terminates is a symbiont that "feeds" on that host. In the calculation of our weighted directed network, we retain only pairs of variables for which we detect these asymmetric symbiotic relationships.

We include 30 variables, therefore, each of our weighted directed networks graphically summarizes $(30*29)*5 = 4350$ bivariate regressions. These regressions are calculated separately for each of the five macroregions. Every single relation could benefit from its own specification of the regression model and the inclusion of control factors. However, in a correlation network, the intrinsic goal is to obtain a more systemic view of the totality of relations among the factors included in the analysis. Therefore, it needs to treat them in a way that makes them equivalent, to some extent, although that leads to a preference for bivariate over multivariate specifications.

Table 4 gives an example of how the calculation of a two-way quantile regression estimates ten coefficients and leads to the identification of an asymmetric symbiotic relationship. At higher levels of the distribution of our (formal) institutional variable "share of taxes in municipal revenues" (Θ), the female wage gap (Π) acquires greater explanatory power in the bivariate regression. Coefficients are statistically significant at p20, p35, p50, p65, and p80. When we swap the dependent and independent variable, the explanatory power of taxes on the female wage gap slightly decreases at higher moments of the female wage gap. So, we compare the percentage deltas in both directions between the coefficients related to the maximum and minimum percentiles with statistical significance.

Taxes are more "dependent" or "feed" more on the female wage gap, not the other way around. Therefore, a directed arc connects the female wage gap (host) to the share of taxes (symbiont). The weight of this arrow is 5.14.

$$w_{\Pi\Theta} = \left| \left[\frac{|\beta_{\Pi}^{(pMAX)}| - |\beta_{\Pi}^{(pMIN)}|}{|\beta_{\Pi}^{(pMIN)}|} \right] \right| - \left| \left[\frac{|\beta_{\Theta}^{(pMAX)}| - |\beta_{\Theta}^{(pMIN)}|}{|\beta_{\Theta}^{(pMIN)}|} \right] \right|$$

After we calculate the five weighted directed networks, we can apply the tools of network analysis. We focus on in-degree and out-degree centrality measures (Opsahl et al., 2010) to capture centrality in symbiont positions and in host positions, respectively. Nodes with multiple inward-facing arcs are dependent on a variety of hosts. These nodes are associated with more volatile institutions, which are affected by multiple institutional sources of change. However, nodes with multiple outward-facing arcs have systemic relevance because they serve as hosts for many other factors. These nodes represent institutions whose change might affect many other symbiotically dependent institutions.

6. Results

6.1. Institutional Interdependence in the five ecosystems

Fig. 1a-1e show the complete weighted directed networks calculated for the five Brazilian administrative macroregions. Nodes in Fig. 1a-1e are labeled as formal and informal institutions and a series of controls, which include social capital, economic factors,

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[21] *P*-values of 0.10 are not uncommon in investigations of slowly changing, structural features such as institutions. We provide a detailed robustness analysis in the online Appendix, in which we compare findings calculated at 10% significance with those obtained with 5% significance. Our results are robust to these tests and confirm our main findings.

[22] To work on a smaller scale, we calculate percentage deltas without multiplying by 100. Cf. the arrow weight formula in this section. This implies that an asymmetry of 5 stands for 500% difference.

a. **North**
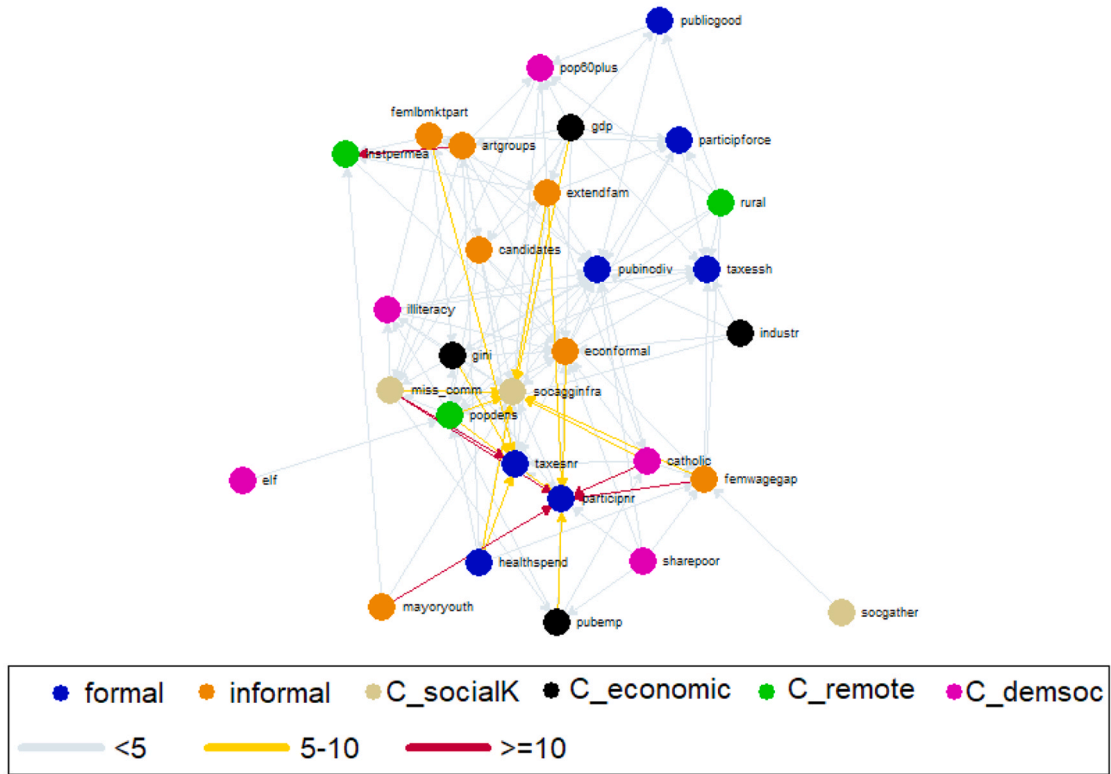
b. **Northeast**
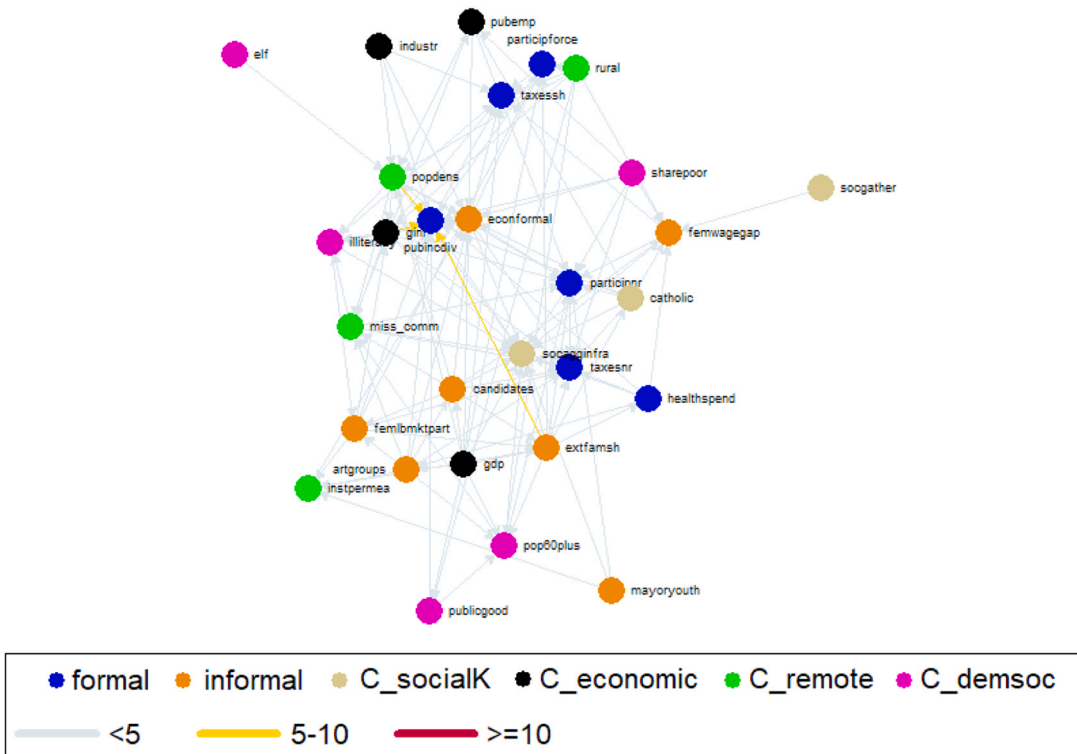
Fig. 1. Directed weighted network of symbiotic relationships. *Notes*: Blue nodes are variables for formal institutions, orange nodes informal institutions, gray nodes social capital controls, black nodes economic controls, green nodes remoteness controls, pink nodes demographic and social controls. The arcs indicate asymmetric symbiotic relationships and take a light-blue color if asymmetry is less than 5 (difference between the two percentage deltas), yellow if asymmetry is between 5 and 10, and red if asymmetry is 10 or more.
Source: Mesolevel dataset.

remoteness, and demographic and social characteristics. Arcs that tie the nodes together are asymmetric symbiotic relationships, graduated in colour by the weight of their asymmetry: each head of the arc points to a symbiont that feeds on a host.

The five directed networks are comparable in size, as seen in Table 5, in which some topological features are reported for the entire, weighted network and for the subnetwork, composed only of stronger arcs ($> =5$). For each (sub-) network, Table 5 reports the number of nodes, the number of asymmetric relationships (arcs), the minimum and maximum value of the weight of arcs, measuring the strength of the asymmetry, and the network density. In the full networks, the number of variables involved in symbiotic relationships is similar across the five regions. However, the number of asymmetric connections and the density is lower in the Northern regions. In the subnetworks with only symbiotic relationships and stronger asymmetry, network density across the five regions is more similar.

The network visualization of interdependence confirms dense relationships that are asymmetric to different degrees.[23] Formal and informal institutions are interdependent in many ways. Despite their similarities, the five networks display differences in terms of the centrality of specific factors and the weight of specific asymmetric relations. Within our five networks, different nodes take a highly central position: the formal institution of participatory councils in the North and public income diversification and the share of taxes on municipal revenues in the Northeast. In the Center West, two structural factors proxy remoteness, whereas in the Southeast it is social capital enhancing gatherings. In the South, taxes and participatory councils are very central.

6.2. Symbiotic relationships between formal and informal institutions

We now focus on institutional factors and on their position within specific relationships and the network overall. Table 6 reports symbiotic relationships in which a formal or informal institution is involved as symbiont or host. We do not include relations with control factors here. In Table 6, it is clear that the most common pattern in a symbiotic relationship tends to be one in which a formal institution is a symbiont or an informal institution is a host. Formal institutions more often tend to depend on other factors to thrive. In contrast, informal institutions tend to be less dependent and more often are involved in relations in which they provide habitat for others.

The lower portion of the table goes into the details of formal-informal institutional relations and shows that they are distributed across four categories: from informal (host) to formal symbiont, from formal to formal institution, from informal to informal institution, and from formal (host) to informal symbiont.

The most commonly observed typology goes from informal to formal institutions (confirming Maseland, 2013; Pryor, 2007; Williamson, 2009), more so in the north than in the south. In the two southern macroregions, symbiotic relationships in which formal institutions are tied to one another are more common. This smaller "role" of informal institutions is further reflected in the larger share of relationships in which formal institutions serve as hosts for informal institutions. In the northern regions, symbiotic relationships in which formal institutions act as hosts are less frequent; instead, informal institutions feeding on other informal institutions are more prevalent (especially in the remotest areas in the north, but also in the Center-West). The Center region sits between the two different institutional landscapes characterizing the North and the South.[24]

Which formal and informal institutions within the five networks are the most important? Those with the highest centrality. We distinguish between in-degree centrality, in which a factor "receives" many heads of arcs (a "multiple symbiont"), and out-degree centrality, in which many arcs depart from the same node (a "multiple host"). Across all macroregions, the in-degree of formal institutions tends to be higher, whereas informal institutions tend to have more out-degree centrality, but the pattern is less clear in the South and Southeast. Fig. 2 illustrates this pattern in the two most dissimilar regions: the North and the Southeast. These findings imply that formal institutions not only tend to be symbionts more frequently but they do so in a multidimensional way, by feeding on multiple other factors. Informal institutions tend to be hosts to multiple other factors.

Table 7 has a more fine-grained view and reports which institutional factors are among the ten most connected nodes in terms of in- or out-degree centrality. Among our informal measures with high out-degree centrality, gender parity seems to be important in different parts of the country, whereas the systemic role of family ties is limited to the northern macroregions. In the southern areas, the attitude toward young people emerges as important. The incidence of art groups, our proxy for (unproductive) entrepreneurship, is central in different networks, though at different strengths.

Formal institutions that act as multiple hosts spend on public goods in the Northeast and the Southeast, public income diversification in the Center-West and Southeast, and public spending on health in the South.

Among the formal measures that have high in-degree centrality—that is, multiply dependent on other factors—taxes and participatory councils emerge in all regions. We note greater regional homogeneity among the most central formal institutions than among the most central informal institutions. Informal measures with high in-degree centrality imply that they depend more on other

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[23] Although we do not report symmetric networks that are based on statistically significant correlation coefficients, they are much denser than our asymmetric networks focused on here.

[24] Appendix Table A8 lists the strongest asymmetric relationships between formal and informal institutions in the five macroregions.

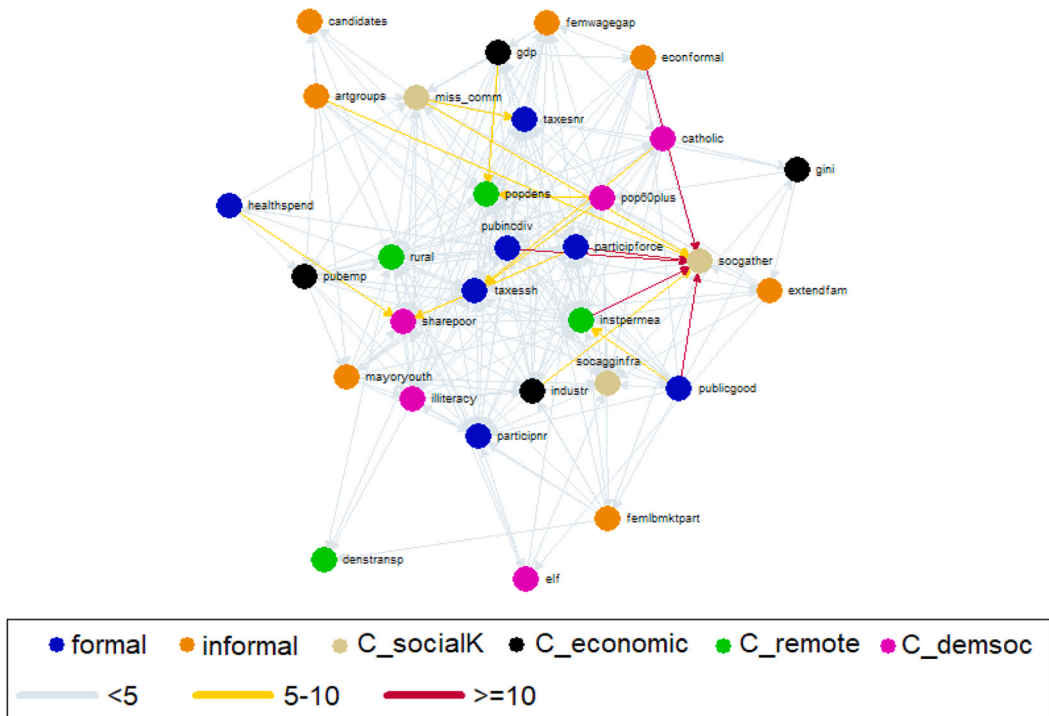### c. Center West
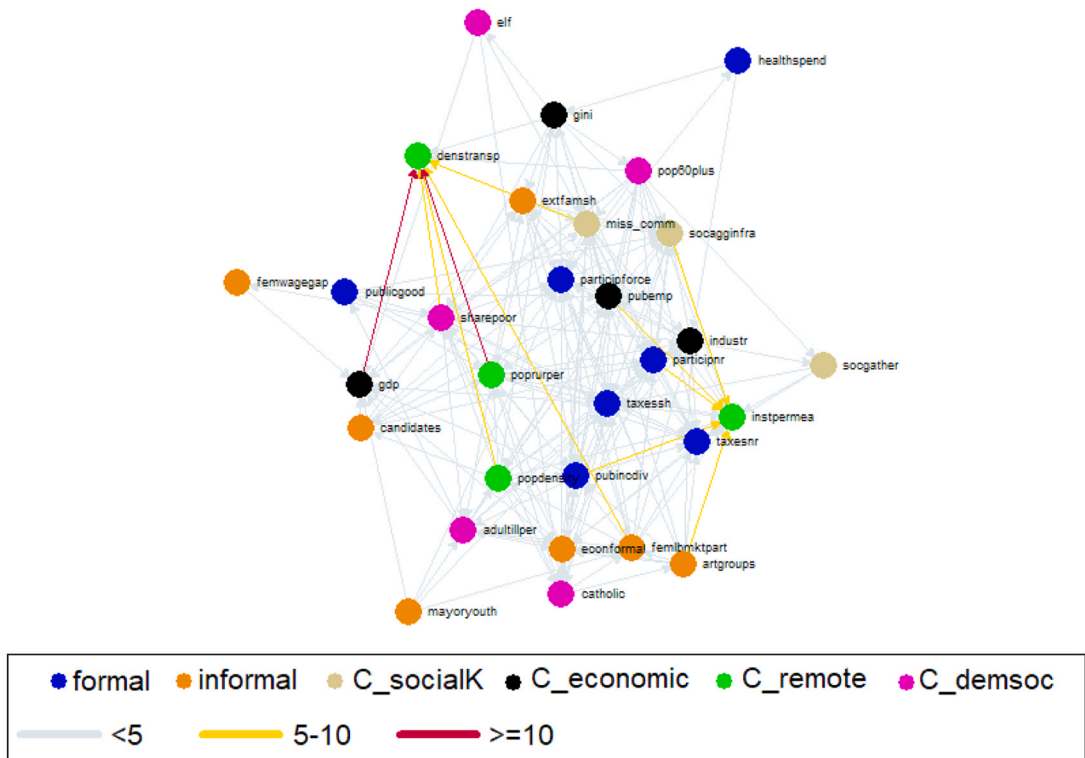
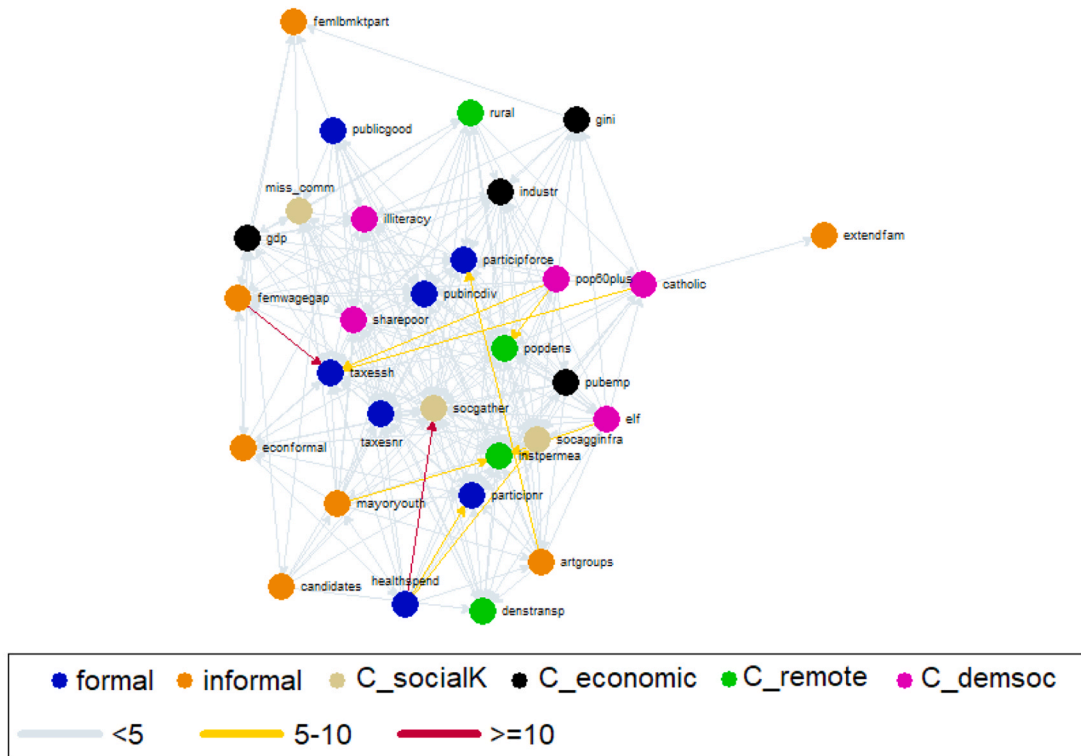### d. Southeast

Fig. 1. (*continued*)

e. South

Fig. 1. (*continued*)

Table 5
Compared network characteristics, five Brazilian macroregions.

	North		Northeast		Center West		Southeast		South	
Network	all	> 5	all	> 5	all	> 5	all	> 5	all	> 5
Nodes	29	17	29	9	30	13	30	17	30	14
Arcs	125	20	89	8	194	11	218	16	233	10
Min arc weight	0	5.5	0	5.1	0	5.3	0	5.1	0	5.0 5
Max arc weight	27.9	27.9	10.2	10.2	12.4	12.4	26.4	26.4	24.5	24.5
Density	0.154	0.074	0.11	0.111	0.223	0.071	0.251	0.059	0.268	0.055

Source: Mesolevel dataset.
Notes: For each region—for both the full network and the subnetwork composed of arcs with stronger asymmetry, namely 5 or larger (difference between the two percentage deltas), the table reports the number of nodes in the network, the number of arcs connecting the nodes, the minimum and maximum weight of the arcs, and the density of the network.

factors, which could make them potentially more malleable for policy makers: in the northern regions, for example, the formality of the economy and the female wage gap.

Our results seem to corroborate that informal institutions have a highly relevant function in the institutional landscape (Acemoglu and Jackson, 2017; Maseland, 2013; Williamson, 2009). We next discuss this finding and triangulate it with differences across cultural ecosystems.

6.3. Triangulating culture and informal and formal institutions

Our results so far suggest that formal institutions tend to be the factors that feed on other hosts the most, whereas informal institutions tend to be hosts for other factors. We now turn to the question of whether different cultural ecosystems lead to different patterns of institutional interdependence. In Tables 6 and 7, the northern regions show patterns in which informal institutions have greater relevance as hosts of both formal and other, informal institutions. In the southern regions, however, informal institutions have a less important role, and formal institutions more often act as hosts, not only as symbionts.

We read this pattern as follows: the history previously described suggests that the Brazilian Northeast, with its slave-intensive plantation economy, tended to rely on extractive institutions, in which few public services were extended, first, to slaves and, later, to

Table 6
Formal and informal institutions within symbiotic relationships.

	North		Northeast		Center West		Southeast		South	
Total no. of symbiotic relationships	125		89		194		218		233	
	No.	%	No.	%	No.	%	No.	%	No.	%
(i) Symbiont = formal	52	41.6	44	49.44	67	34.54	70	32.11	73	31.33
(ii) Symbiont = informal	27	21.6	10	11.24	24	12.37	20	9.17	25	10.73
Host = formal	13	10.4	13	14.61	29	14.95	47	21.56	53	22.75
Host = informal	43	34.4	27	31.46	48	24.74	55	25.23	46	19.74
	No.	%	No.	%	No.	%	No.	%	No.	%
(i) Symbiont = Formal & Host = Informal	19	36.54	13	29.55	18	26.87	14	20	17	23.29
(i) Symbiont = Formal & Host = Formal	6	11.54	8	18.18	11	16.42	14	20	15	20.55
(ii) Symbiont = Informal & Host = Informal	8	29.63	2	20	6	25	3	15	5	20
(ii) Symbiont = Informal & Host = Formal	2	7.41	1	10	1	4.17	6	30	5	20

Source: Mesolevel dataset.

Notes: For each region-based network, the upper part of the table reports: the number and the share of formal and informal factors being a symbiont in an asymmetric relationships; the number and the share of formal and informal factors being a host in an asymmetric relationships. Intended as breakdown of (i) and (ii) of the upper part, the lower part of the table reports the number and the share of formal and informal factors being the host of the arcs having, respectively, formal and informal symbionts.
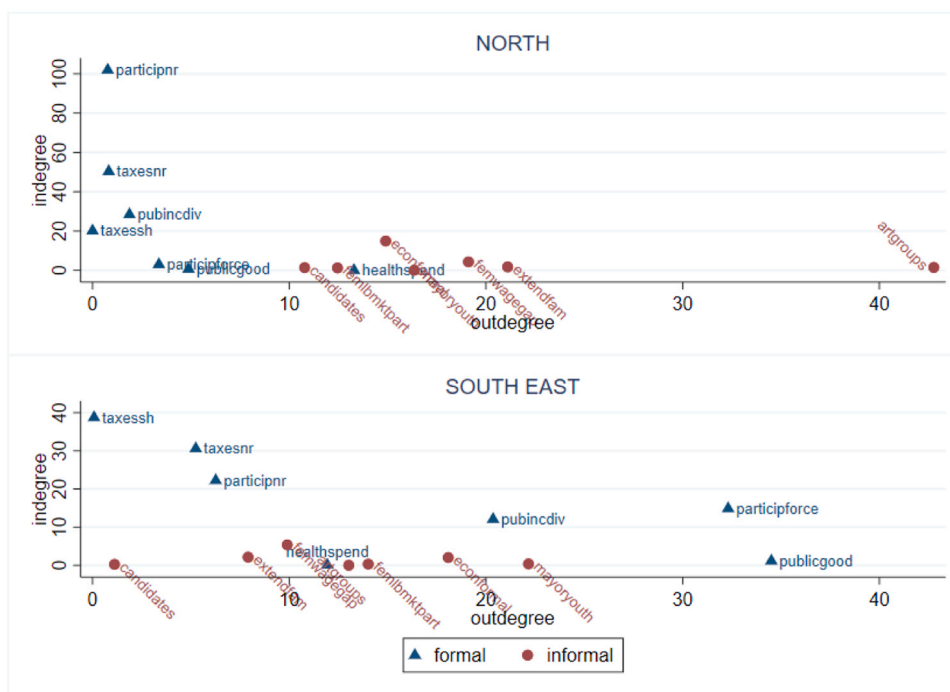

Fig. 2. Comparison of in-degree and out-degree centrality of institutional factors in two regions. Note: The figure reports the out-degree centrality computed over outward-facing arcs (identifying multiple hosts) and the in-degree centrality computed over inward-facing arcs (identifying multiple symbionts) statistics for formal and informal institutions in the North and Southeast regions.
Source: Mesolevel dataset.

their free descendants (Musacchio et al., 2014; Reis, 2014). Similarly, poor workers who migrated to the North experienced slavelike conditions (Ribeiro, 1995). In the two southern regions, with massive subsidized immigration of Europeans, the design and functioning of formal institutions was characterized by much more dialogue and involvement with inhabitants. Immigrants there received assistance in starting up activities and they obtained schooling for their offspring (which they had requested) (Rocha et al., 2017). We read the southern history as having been more inclusive than that of the North.

It is likely that this (un)successful "societal struggle" (Pritchett, 2013) left long-term marks on the institutional landscape. We can mention supporting empirical evidence from prior authors. Torres and Dessen (2008) explicitly relate past historical events to current family structures, explaining them using Banfield's (1958) view that familism became an (informal) alternative to (formal) state provision of certain services. In their study, families in the North and Northeast are larger than those in the Southeast. Further, they observe that families' internal functioning (e.g., hierarchical structure, division of labor, type of affective link between spouses and between parents and their children) differ between these areas of the country. Torres et al. (2015) find similar results, namely that the Northeast is characterized by higher embeddedness and hierarchy (Schwartz, 2004). These two empirical works are consistent with

Table 7
Institutional factors among the ten nodes with highest (in-/out-) degree centrality in the five macroregional networks.

	Out-degree (multiple host)				In-degree (multiple symbiont)			
	Informal institution	Ntwk stat	Formal institution	Ntwk stat	Informal institution	Ntwk stat	Formal institution	Ntwk stat
North	artgroups	42.77			econformal	14.89	participnr	101.98
	extendfam	21.12			femwagegap	4.25	Taxesnr	50.34
	Femwagegap	19.11					pubincdiv	28.42
	mayoryouth	16.35					Taxessh	20.12
	econformal	14.91						
Northeast	fewwagegap	27.56	publicgood	15.19	econformal	6.62	taxessh	55.38
	femlbmktpart	14.04					pubincdiv	32.48
	econformal	6.73					participforce	21.72
	extendfam	6.33						
Center West	femlbmktpart	24.08	pubincdiv	15.92			taxesnr	26.16
	artgroups	12.81					participnr	19.38
							taxessh	17.13
							participforce	16.03
							pubincdiv	7.03
Southeast	mayoryouth	22.16	publicgood	34.51			taxessh	38.75
	econformal	18.08	participforce	32.31			taxesnr	30.60
			pubincdiv	20.36			participnr	22.26
							participforce	14.88
South	mayoryouth	34.65	healthspend	48.76			taxessh	50.48
	femwagegap	23.42					participnr	29.26
	artgroups	20.70					participforce	21.91
							pubincdiv	12.98
							taxesnr	12.35

Source: Mesolevel dataset.
Notes: For each regional network, the table reports only those formal and informal institutional factors that classify among the ten nodes of the network with, respectively, highest out-degree and highest in-degree centrality values. Out-degree centrality computes a node's centrality over outward-facing arcs, while in-degree centrality computes the centrality of a node over its inward-facing arcs.

our finding that informal institutions are more relevant in the Northern regions, which have a more extractive past. In the southern regions, in which family ties are weaker than in the northern regions, the same empirical research confirms greater autonomy/self-direction (Torres et al., 2015), low perceived distance to power, and greater self-reliance (Van Horn et al., 1995). The evidence reported suggests that regional history is linked to different shared mindsets that, in other papers, are related to a more (or less) positive collective perception of formal institutions—for example, the perceived degree to which institutions act in the interest of their citizens (Miller and Listhaug, 1990; Kaasa and Andriani, 2022). In the South, state-sponsored European immigration is likely to have induced a perception of empowerment and opportunity, which evolved into requests granted for public investment (Rocha et al., 2017). However, the cumulative lack of investment in public goods in areas with a high proportion of slaves and their descendants (Musacchio et al., 2014; Reis, 2014) might have led to a disempowering perception that formal institutions are less friendly and supportive.

The empirical evidence presented by Torres and Dessen (2008), Torres et al. (2015), and by Van Horn et al. (1995) seems to suggest that these perceptions have cumulatively consolidated, for example, in the prevalent values held in the different macro-regions. The differences in values they report may explain the different levels of trust in formal institutions. Kaasa and Andriani (2022) find evidence of reduced institutional trust in areas in which power distance (Hofstede, 2001), or acceptance of inequality, is greater. Our findings suggest that historically extractive processes may be "psychologically meaningful" situations (Oyserman et al., 2009) that cumulatively lead to a perception of disempowerment in which formal institutions are less friendly and supportive. In such cultural contexts, trust is likely to be lower, and reflexive cognitive processes may subsequently rely on informal more than on formal norms. This interpretation is consistent with Pritchett (2013), who sees formal institutions as consolidations/formalizations of a successful social struggle.

Therefore, our evidence suggests that when areas have a history in which institutions have traditionally been more extractive, even now informal institutions there play a more relevant role. However, in areas where social struggles were successful in shaping more inclusive institutions, formal institutions still appear to be more independent from informal institutions and also become fruitful grounds for other institutions.

7. Research implications and conclusion

This paper set out to give greater "plasticity" to the study of interdependence between formal and informal institutions. We adopt a symbiotic lens on institutional interconnections in order to grasp multiple, asymmetric relationships (Jacobi, 2018; Jacobi and

Amendolagine, 2023). We treat culture as an ecosystem, which acknowledges its multidimensional, not fully deterministic nature (Pickett and Cadenasso, 2002; Pryor, 2007). In reconstructing diverse subnational historical trajectories, we "situated" (Huebner, 2013; Oyserman et al., 2009; Schwartz, 2004) the analysis of institutional interdependence in cultural contexts that we describe as shaped by specific histories (Alesina et al., 2013; Michalopoulos and Papaioannou, 2014; Nunn, 2012). Using Brazilian subnational data, we identify five statistically significantly different cultural ecosystems. Using correlation network analysis tools, we calculate weighted directed networks and find that informal institutions tend to be hosts that provide a foundation for formal institutions, because the latter are more often symbionts or dependent on the former; this asymmetry is more pronounced where political processes have historically been less inclusive.

Our approach has some limitations—for example, the challenge of measuring formal and informal institutions (cf. Voigt, 2013, 2018) and culture at the appropriate level (Na et al., 2010). Nonetheless, our findings emerge from a new perspective, which leads to some research implications.

In general, we suggest that a complexity- and ecology-inspired approach to the study of institutional interdependence is promising. First, we confirm that asymmetric relations among local institutional factors are massive, recalling the need to understand multiple simultaneous relations (Jacobi, 2018; Kuran, 2009; Voigt, 2013). Within the static exercise that we perform, we momentarily separate culture from institutions. Although this choice has some limitations because culture is dynamically endogenous (see McCloskey, 2016; Mokyr, 2016), our findings suggest that this approach also has some advantages: the contextualizing relevance of culture can be seen more easily when we look at the relationships between different institutional factors, instead of looking at single institutional factors. According to our ecosystems perspective, shared mindsets shape entire institutional landscapes, rather than affecting single, specific factors, confirming Pryor (2007).

With regard to the two emergent properties that we detect in our comparative analysis, we propose, first, that the relative "dominance" of informal institutions over formal ones (Maseland, 2013; Mathers and Williamson, 2011; Williamson, 2009) may be tied to their slow-moving nature. Williamson (2000) suggests that different types of norms change at different speeds: culture and tradition take about a thousand years to change, in contrast to governance implemented by public policy, which could change in approximately 10 years. Within ecosystems, and complex adaptive systems in general, slower levels dominate those that move more rapidly (Allen and Starr, 1982; Holling, 1995; O'Neill et al., 1986;). In our analysis, informal institutions dominate because they tend to be hosts to formal institutions. Although our arcs only reflect numerical relations that can be observed statistically, the emergent property that we detect in the five macroregional networks suggests that causality might go from informal to formal institutions. Lock-in effects between formal and informal institutions have been described before (Acemoglu and Jackson, 2017; Belloc and Bowles, 2013; Grosjean, 2011), however, our complexity-informed view helps ground such directionality with greater detail.

Second, with regard to our systemic comparison across macroregions, historically more-inclusive political processes (Boranby and Guerriero, 2019) seem to be associated with formal institutions becoming nurturing terrain, as if they had acquired a certain level of "maturity." Our triangulation efforts suggest that this maturity may be tied to shared mindsets in which a more positive collective perception of formal institutions accumulated (see Kaasa and Andriani, 2022). Our results suggest that when formal institutions result from an inclusive process, their hold on society is likely to be stronger. By contrast, when processes are less inclusive, inhabitants might develop resentment because they feel vulnerable and powerless in the face of government decisions (Grimmelikhuijsen and Porumbescu, 2013). Based on our analysis of Brazilian data, when formal institutions emerge from a history of extraction and subjugation, informal institutions remain more relevant to the system. Therefore, we suggest that symbiotic relationships represent a promising, alternative, interpretation of weakness vs. strength in institutional factors, corroborating that mismatches between formal and informal institutions are detrimental to economic development (cf. Graafland, 2020; Hodgson, 2006; Williamson, 2009).

Our findings have potential policy relevance, as greater knowledge of the relationships that tie formal and informal institutions can help policy makers in (1) contextualizing institutional settings at the subnational level, (2) targeting institutional factors with potentially systemic effects, and (3) identifying which institutional factors need to be targeted jointly. The distinction between formal and informal institutions adopted here (based on the locus of enforcement, see Voigt, 2018) can be useful because policy makers have different degrees of control over them. When informal institutions "feed" formal ones, policy makers may need to focus on specific social attitudes before changing laws. In this sense, our results hint that the Brazilian (formal) institutional innovation of participatory councils could be an interesting game changer in Brazilian social struggles: this type of increased public participation in decision-making (Avritzer, 2009; Galletta, 2021; Wampler, 2012) can itself act as a host for other formal institutions across diverse cultural ecosystems.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ecosys.2023.101092.

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