



What feeds on what? Networks of interdependencies between culture and institutions

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Received: 23 December 2021 / Accepted: 17 January 2023 / Published online: 23 February 2023
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Abstract

Culture and institutions both matter in shaping trajectories for socioeconomic progress. As the debate on causal directionalities between culture and institutions is still ongoing, we recast its perspective: a complex network of symbiotic relationships ties a multitude of cultural and institutional factors together. We blend the institutional complementarities literature with symbiosis theory, and place it into the context of a data-driven approach that extends correlation network analyses. We frame each single interdependence between a cultural and an institutional factor as an asymmetric symbiotic relationship in which a ‘host’ feeds a ‘symbiont’: the latter is more dependent on the former. In our computed network, each relation locates within a broader context of pathways and network constellations. We apply our approach to Brazilian municipal data. Our results confirm high complexity in the coevolution of culture and institutions and suggest an emerging pattern in which cultural factors are more likely to be hosts than institutions or social capital. In the Brazilian municipal reality, the institutional innovation of participatory councils bears the potential of game-changer in the system, while tax collection strongly depends on cultural factors i.e. the (in)formality of the economy and family ties.

Keywords Culture · Informal institutions · Formal institutions · Symbiosis · Correlation network analysis · Weighted directed network · Brazil

JEL Classification O17 · Z13 · C40 · O21 · K4 · R580

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1 Introduction

For the last decades, international efforts have sought to promote economic development throughout the globe, often by promoting better institutions. While much success has been achieved in some parts of the world, other areas are subject to backlash also due to their cultural embedding. Afghanistan or the Mafia-ridden Italian South are just illustrative examples of a wide array of economies, in which cultural elements play a crucial role for progress (Guiso et al., 2016; Putnam, 1993; Touré, 2021). The relationship between culture and institutions is therefore a topical issue within economics, and still strongly debated (Alesina & Giuliano, 2015).

Cultural norms, that tend to include informal institutions, are socially enforced and can be distinguished from formal rules, which are legally stipulated and enforced through state power (Acemoglu & Robinson, 2019; Hodgson, 2001; Mathers & Williamson, 2011; Voigt, 2018). Understanding the interaction between the two dimensions is crucial to assess the eco-systemic conditions that can shape socioeconomic progress (Belloc & Bowles, 2013; Williamson, 2009; Touré, 2021).

The extant literature has advanced arguments and empirical evidence on the complementarity between cultural and formal institutional factors, sometimes without assessing any direction in such relationship, framing it as co-evolving (Belloc & Bowles, 2013; Gelfand et al., 2011; Tabellini, 2008). Another strand of the literature, has tried to isolate the causal effects of specific institutional or cultural factors, yet there is no consensus on the directionality of such effects (Acemoglu & Jackson, 2017; Licht et al., 2005; Marè et al., 2020; Maseland, 2013; Putnam, 1993; Williamson, 2009).

In this paper, we seek to advance clarity on the relationship between culture and institutions, and propose an innovative methodological approach to recast the perspective on it. We put into question the attempt to reduce investigations to a specific relation between isolated factors. In fact, isolating specific effects is likely to be affected by institutions often playing a complementary role to other factors, such as human capital (Glaeser et al., 2004), culture itself (Guiso et al., 2009; Gutmann & Voigt, 2020; Tabellini, 2010), market structure (Aoki, 2001), corporate governance (Pagano & Rowthorn, 1994; Vatiero, 2017), or other formal institutions (Amable, 2016; Bruszt & Campos, 2019; Pagano & Vatiero, 2015), and geography (Gelfand et al., 2011; Gneezy et al., 2016). Moreover, the tendency to use cross-sectional analysis within this area of research allows for a series of confounding factors to concur in influencing both culture and institutions (Alesina & Giuliano, 2015).

Our contribution is threefold: first, we set our analysis at the sub-national level in order to keep a series of important confounding factors like official language, colonizing power, and national institutional frameworks constant (Guiso et al., 2009; Hofstede et al., 2010; Naritomi et al., 2012; Putnam, 1993; Tabellini, 2010). Second, within the same country, we adopt a systemic view (Kuran, 2009), which pays attention to complexity (Arthur, 1989) and the emergent properties of a system of relations (Anderson, 1972; Hodgson, 2007; Lewes, 1875). We therefore do not focus on a specific relation, but instead opt for working with a pool of cultural, institutional and other socioeconomic control factors. We propose a data-driven methodological

approach in which such factors are allowed to interact, and through which it is possible to empirically map multiple relationships between institutional and cultural factors in a network.

Third, as a conceptual framing for the multiple relationships we detect, we build on the literature on institutional complementarities and on a research tradition that uses ecology and biology as an inspiration for the study of institutions (Richerson et al., 2010; Auyang (1998) and Hoover (1995) in Hodgson, 2004; Jacobi, 2018; Nelson & Winter, 1982; Vatiery, 2017). More specifically, we characterize the relations between cultural and institutional factors as interdependencies and refer to symbiosis theory (Margulis, 1984; Watkins, 1998). We distinguish between ‘hosts’ that nurture other factors by providing a specific habitat or service (Cain et al., 2011), and ‘symbionts’ (Overstreet & Lotz, 2016) that reversely ‘feed’ on other factors and thereby are more dependent on them. We follow Jacobi (2018), and focus specifically on asymmetric symbiotic relations, yet we extend her work by focussing on different node-typologies (cultural, institutional, socio-economic control) and by identifying motifs and clustering (Fagiolo, 2007; Onnela et al., 2005) in the network.

Our investigation focuses on Brazil, which can be considered an ideal laboratory for sub-national level analysis (Gneezy et al., 2016; Hofstede et al., 2010; Musacchio et al., 2014; Naritomi et al., 2012). First, it is one of the biggest countries in the world: more than 200 million people live on a surface covering almost half of Latin America. It is part of the BRICS, therefore resembling a successful instance of national socioeconomic development. Second, it experienced very diversified subnational historical paths, which reflects in subnational differences in terms of cultural values (Hofstede et al., 2010; Torres et al., 2015) and institutions (Naritomi et al., 2012; Musacchio et al., 2014). Of particular relevance in Brazilian history is a diversified settlement experience that saw the North of the country experiencing widespread influx of forced labour (slaves) against subsidized (voluntary) immigration in the South. Brazilian subnational historical differences, therefore, represent a relevant case study as they combine the experience of extractive vs. inclusive institutions (Robinson & Acemoglu, 2012) within the same country-setting. Such variety justifies an in-depth investigation of a single country that can potentially provide insights for other contexts affected by more (or less) extractive institutions. Third, Brazil is characterized by a multi-level governance structure: the municipality level, that we take as unit of analysis, is the most local level of autonomous governance, which is embedded within other governance structures, specifically the state and the Federal Union. We include data on the Brazilian universe of 5565 municipalities.

Our computation of multiple relationships within a weighted directed network produces new insights on the role that cultural vs. institutional factors play, in as much as their position—and embeddedness in the network is studied with greater depth. At the Brazilian municipal level, we detect an emerging pattern for cultural factors tending to be hosts, confirming authors such as Williamson (2009) or Maseland (2013) who stress a relatively more exogenous role of culture with respect to institutions. Our finding emerges from a manifold and articulated interdependency structure we observe among multiple cultural, institutional and control factors. We also find that institutions and social capital are more often symbionts and middlemen, but the trend is less evident than our first finding. Our analysis also produces

some policy implications for the Brazilian local level. It suggests that the inclusive institution of participatory councils bears the potential of game-changer, as it simultaneously serves as host for other formal institutions and for social capital. Such evidence is of particular relevance given the diverse historical background the Brazilian sub-regions experienced. We therefore recommend continued attention and monitoring of such institutional innovation (Avritzer, 2009; Galletta, 2021; Wampler, 2012) as it could significantly improve state-society relations. Our findings also inform on which factors need to be targeted jointly in order to modify a symbiotic factor, and which factors are likely to trigger most important—but also less foreseeable—systemic effects.

The paper is structured as follows: Sect. 2 places our contribution within the relevant literature and introduces our interpretation of asymmetric symbiotic relationships between cultural and institutional factors. We then introduce our empirical strategy to construct a weighted, directed network that maps asymmetric interdependencies and uses network statistics to quantify the different embedding of the factors we study (Sect. 3). In Sect. 4, we introduce our pool of institutional, cultural and structural control variables and Sect. 5 presents our results: our concluding section outlines key research implications.

2 A systemic view that draws on symbiosis

Within the economic literature, one strand provides arguments and empirical evidence on the complementarity between cultural and formal institutional variables, without assessing any direction in such relationships. The existence of certain cultural values can shape the formal institutional setting which, in turn, can make the survival of specific values easier. Institutions and cultural norms interact, possibly forming multiple equilibria defined by different self-reinforcing matches between legal norms and values. In Tabellini (2008), the complementarity between cultural values and quality of institutions (measured as effectiveness of law enforcement) can explain long-term patterns in terms of cultural, institutional and economic development. Strong law enforcement gives incentives to transmit moral values over generations, while societies with weaker morality are more likely to tolerate deviations from legal rules (Gelfand et al., 2011). Belloc and Bowles (2013) discuss the complementarity between cultural and legal norms and conclude that Pareto-inferior cultural-institutional conventions can persist over time when the cost of transition to a Pareto-superior convention is high and the population has a large size. Guiso et al. (2016) empirically investigate the long-term persistence of the effects of the free city experience on the accumulation of civic capital over subsequent centuries in Italy. In this case, towns that were free city states in the Middle Ages developed higher self-efficacy values over time that, in turn, nurtured local civic capital and institutions in the following centuries.

Another strand of the literature, however, has tried to isolate the causal effects of specific institutional or cultural factors, not yet finding a consensus on the directionality of such effects. Some works stress the role of informal norms and culture in guaranteeing enforcement of formal institutions. The seminal work of Putnam

(1993) argues that free cities in the Middle Ages generated long-term cultural changes towards stronger cooperation values in Italy. In turn, differences in such historical experience motivate gaps in institutional functioning at the local level. Licht et al. (2005) run a cross-country empirical analysis of the relationship between cultural values and legal rights of corporate investors: they conclude that culture can work as an obstacle to reforms of the corporate governance systems. Acemoglu and Jackson (2017) theoretically show that the enforcement of laws becomes more difficult if laws conflict with social norms, that is when private agents have less incentives to cooperate with the aim to enforce the law. Marè et al. (2020) explore the effects of family ties on the functioning of public institutions. They show that stronger family ties, by reducing social capital, negatively affect trust in the public sector, leading to lower tax morale and a larger size of the underground economy.

Other investigations instead find evidence for the opposite direction, with formal institutions feeding culture. In an experiment involving fifteen small pre-industrial societies located in different countries, Henrich et al. (2001) show that different types of economic organization and, in particular, different degrees of market integration lead to different propensity to cooperate within the studied societies. Alesina and Fuchs-Schündeln (2007) find that living under communism has shaped people's attitudes: they predict a convergence (within two generations) between Western and Eastern Germans in their preferences for the role the state should play in the economy. Herrmann et al. (2008) undertake an experiment in sixteen cities in different parts of the world, showing that cooperation is more likely to occur in places with stronger rule of law and greater institutional transparency. Grosjean (2011) estimates a cultural gravity model, finding that distance in social trust across countries is lower for those that have shared common institutions for longer time, e.g. having belonged to the Ottoman empire. (Gneezy et al., 2016) use field experiments in Brazilian fishermen villages to investigate the link between work organization and cooperation norms. They find that at the Sea, where fishermen work in teams they also have a larger propensity to cooperate in other areas. Contrarily, those living in villages close to lakes are more likely to work individually and are less cooperative.

With respect to the literature presented, this study adopts a more systemic view, and therefore maps many of the relations here described within a unified system of interdependencies. As we shall see, the conceptual framework adopted allows directionalities between cultural and institutional factors, yet by opting for a data-driven empirical investigation, we do not set such directionality *ex ante*.

2.1 Key features of an ecological perspective

A series of studies have proposed analogies between the coevolution of social structures and living organisms, for example applying the institutional complementarity logic to the development of the human brain (Battistini & Pagano, 2008); or to explain the variety in corporate governance models (Vatiero, 2017). Richerson et al. (2010) show how cultural innovations like agriculture had an effect similar to environmental conditions on the evolution of genes. Boyer and Petersen (2013) outline how context-specific adaptations have generated co-evolutionary patterns

between culture and institutions. According to our knowledge, Jacobi (2018) is the only empirical investigation of symbiotic relationships among social structures. We therefore follow Jacobi (2018) and characterize the interdependencies among cultural and institutional factors—and other controls—as symbiotic relationships. Symbiosis offers two key advantages for a systemic view (Kuran, 2009) on culture and institutions. First, a systemic view requires us to widen the perspective from pairs of factors to manifold connections co-existing at the same time. Within an ecological perspective, such intrinsic complexity is rather obvious: no organism exists in isolation from others or from its environment (Margulis, 1984; Odum & Copeland, 1972). Note that a symbiotic view therefore stresses going beyond atomism, which e.g. characterizes Darwinian approaches (Watkins, 1998).

Second, ecological perspectives avoid the ‘functional fallacy’ (Amable, 2000) according to which social structures are functional for the promotion of economic efficiency. Culture and institutions are both likely to co-evolve within specific environments (Richerson et al., 2010). Social structures that consolidate in such process may interlock and form ‘conventions’ that may as well be sub-optimal for economic functioning (Belloc & Bowles, 2013). Symbiosis, which can be interpreted as the ‘living together’ of unlike organisms (De Bary, 1879) is a compatible concept, because it implies functional neutrality. Symbiotic relationships are indeed highly specific and open to the myriad of possible combinations with which living organisms can exchange (Watkins, 1998). Examples of such combinations are mutualism, commensalism or parasitism, which describe different patterns of exchange within a symbiotic relationship (Cain et al., 2011).

In what follows we apply such a systemic perspective inspired by symbiosis to the study of interdependencies between culture and institutions. In line with Overstreet and Lotz (2016), we simplify the pluralism in symbiosis by characterizing it as a ‘host-symbiont’ relationship. The host provides habitat (or resources, or services) for the symbiont, but is not necessarily itself dependent on the latter. The symbiont uses other organisms as habitat and is dependent on its host.¹ We restrict the focus of our analysis to asymmetric symbiotic relationships, in which the symbiont is more dependent on the host than vice versa. We therefore exclude strict mutualism, which is symmetric (Cain et al., 2011), and instead study relationships in which a symbiont feeds on some habitat/resource/service provided by a host. Within our complex network, our institutional, cultural and socioeconomic control factors may all potentially assume the role of the host or of the symbiont; or both roles, given that multiple relationships coexist at the same time.

Complexity-inspired views are natural within ecological investigation (Taylor, 2010), but they also have some tradition in economics (Debreu, 1970) and surely recently captured more attention, in as much as socioeconomic progress is more and more identified as an emergent property of a system (Barder, 2012; Beinhocker, 2006), that can not easily be engineered with a linear, top-down (best) policy logic, but that instead requires capacity to adapt and to select the policy-solution most fit

¹ Note that other authors refer to both organisms engaged in a symbiotic relationship as symbionts (e.g. Margulis, 1991 in Watkins (1998)).

for the (complex) surrounding context (Barder, 2012; Ramalingam, 2013). Complexity theory has inspired economics and the social sciences, lately, by inspiring research on self-organization, emergent properties, path dependence and hysteresis (Boschma & Frenken, 2009; Dolphin et al., 2012; Martin & Sunley, 2006, 2015). With respect to such recent developments, our study contributes with an empirical strategy that computes complex systems using structural indicators. In this way, it constructs an empirically-grounded complex system as these strands of literature advocate. By producing a weighted directed network, the approach here proposed opens the doors to applications of graph theory, such as directed acyclic graphs (Pearl & Verma, 1987; Imbens, 2020). This represents a key innovation for the quantitative, empirical investigations of culture and institutions.

2.2 Asymmetric symbiotic relationships between social structures

We next propose an interpretation of how asymmetric symbiotic relationships between two different social structures, whether cultural or institutional, may emerge. Within the existing literature on institutional complementarities, interdependencies may evolve across separate domains (e.g. the market vs. public policy vs. family structure). Each domain resembles an institutional environment within which individuals or groups of agents seek for the maximization of payoffs. Within such environment, the ‘payoffs of agents in one domain may be affected by the institutions prevailing in other domains’ (Aoki, 2001, p.225). This means that endogenous rules emerging in an environment can represent exogenous factors for another environment.

The factors we allow to engage in a symbiotic relationship are conceived at a collective level, being either formal/informal rules belonging to a specific domain, or structural (e.g. demographic, geographic, economic) features of the environment. Such collective structures result from choice-processes endorsed by a sufficient amount of members of society. In as much as choice within one domain is affected by exogenous factors emerging from another domain, a structural interdependence across the two institutional domains is likely to develop. Our symbiotic relationships are meant to capture such structural interdependence.²

We depart from an exploratory point of view according to which any cultural and institutional factor could potentially be interdependent with other institutional/structural factors—and the directionality of such interdependence may not be known *ex ante*—in line with our data-driven empirical strategy (see Sect. 3). By not defining *ex ante* the directionality, we contemporaneously test multiple hypotheses, namely that culture may be feeding upon institutions, that institutions may be feeding on culture or that the relationship may be mainly symmetric, without any causal directionality. In what follows, we describe a single asymmetric symbiotic relationship

² On including geographical or demographic features as controls, we expect these to represent exogenous factors to the institutional environment in which a specific rule develops (Aoki, 2001; Gelfand et al., 2011), and to result from migration choices, i.e. moving from the mountains to the plain, or to reach an urban area.

between a cultural and an institutional factor. We purposefully select two social structures that may—or may not be interdependent.

Two sets of agents, M and N (which may or may not overlap—see Aoki (2001), make choices in different institutional environments (or domains), namely C (Culture) and I (Institutions). For simplicity, the consequence functions—or payoffs (u in C and v in I) are structured in the same way in both domains: both define that the return to an agent's choice in one domain, is conditional on the simultaneous choices being made in the other domain. In line with (Aoki, 2001, p.225), these are interdependent payoffs: the cumulative, collective outcome of choices leads to the institutionalization of an endogenous rule in one domain, which becomes an exogenous parameter to the other domain.³ In our treatment, agents can choose between two different rules in each domain: Σ^* or Σ^{**} (in the case of C) and Λ^* or Λ^{**} (in the case of I). For illustrative purpose, let's assume that the two rules in C refer to equal treatment of male and female offspring, e.g. equal investing in their education (Σ^*) or a conservative view in which girls are expected to commit to housework and child rearing only (Σ^{**}). Whereas within domain I , the two rules refer to acceptance of progressive taxation (Λ^*) or its rejection (Λ^{**}) see Table 1.

Equations 1 and 2 combine the two payoff functions in a situation in which increasing differences (Topkis, 1978, 2011; Milgrom & Roberts, 1990)⁴ exist between the domains C and I : in domain C , payoff associated to choosing Σ^* is greater in presence of Λ^* than in presence of Λ^{**} . Within domain I , the payoff associated to choosing Λ^* over Λ^{**} is similarly greater in presence of Σ^* , which resembles a complementarity between Σ^* and Λ^* .

$$[u(\Sigma^*; \Lambda^*) - u(\Sigma^{**}; \Lambda^*)] - [u(\Sigma^*; \Lambda^{**}) - u(\Sigma^{**}; \Lambda^{**})] = \alpha \quad (1)$$

$$[v(\Lambda^*; \Sigma^*) - v(\Lambda^{**}; \Sigma^*)] - [v(\Lambda^*; \Sigma^{**}) - v(\Lambda^{**}; \Sigma^{**})] = \beta \quad (2)$$

with α and β larger than zero.

Potentially, the relationship between domain C and domain I could be symmetrical, not displaying any particular dependence of one on the other. Yet, our investigation restricts the focus on detecting asymmetric relationships, in which one structural factor feeds (depends) upon another—more than vice versa.

CASE A: Institutional rule “feeding on” a cultural rule

In case the institutional rule were a symbiont on a cultural rule (cf. Maseland, 2013; Mathers & Williamson, 2011; Tabellini, 2010), payoffs for accepting progressive taxation increase more in presence of liberal views on women's role in society than vice versa. This would imply that as Λ is dependent on Σ more than vice versa, α is smaller than β (see Table 1). Λ then is a symbiont on Σ .⁵ This asymmetry

³ Aoki (2001, p.226) introduces the payoff functions as follows: $u_i = u(i \in M)$ and $v_j = v(j \in N)$, defined on binary choice sets of their own, with another set as the set of parameters.

⁴ The asymmetric relations we describe resemble strategic complementarities as studied by the same authors.

⁵ We do not expand on this here, but the asymmetry described can also be expressed in terms of supermodularity conditions (Aoki, 2001; Topkis, 1978, 2011; Milgrom & Roberts, 1990).

Table 1 Culture and institutions as interdependent domains within which actors choose

	Domain C (culture)	Domain I (institutions)
Individual–context interaction	Value attributed to girls' position in society	Position towards progressive taxation
Choice	Σ^*	Λ^*
Implying specific shared intentionalities	Σ^{***} Equal investing in male and female offspring's education	Λ^{**} Accepting progressive taxation
Preferred payoff increases in presence of	Λ^* A conservative view: girls should commit to housework and to child rearing only	Σ^* Rejecting progressive taxation
Relational possibilities	Case A—asymmetry: institution feeds on culture $0 < \alpha < \beta$ Case B—asymmetry: culture feeds on institution $\alpha > \beta > 0$ Symmetry: independence $\alpha = \beta = 0$	

emerges because in domain I , Λ^* is the more convenient choice of rule whenever the rule Σ^* prevails.

In terms of our framework, case A resembles a situation in which Σ^* provides a habitat for the unfolding of Λ^* . While choices in domain C may or may not reversely be affected by choices in domain I , in case A the role of the cultural environment C as host is greater than the potential role as host of the institutional environment I ; and ($0 < \alpha < \beta$).

CASE B: Cultural rule “feeding on” an institutional rule

In case B, we outline the inverse argument in which a cultural rule depends on an institutional rule (cf. Bisin & Verdier, 2017; Grosjean, 2011). In this case, choices regarding progressive taxation affect the payoffs derived from attitudes towards women more than vice versa.

In terms of symbiotic relationships, case B resembles a situation in which the acceptance of progressive taxation serves as host for liberal attitudes towards women’s role in society: in this case, it is Σ that depends more on Λ than vice versa, so β is smaller than α . In case B, it is Σ that is a symbiont on Λ .

Note we just delineated two cases with opposite directionality of the asymmetry: we purposefully selected an example in which rules could—or could not—engage in an asymmetric relationship. Furthermore, the directionality is not necessarily clear *ex ante*.⁶ As we shall see in what follows, the systemic view we propose puts each asymmetric relationship (within or) across domains into a broader context—namely a complex network within which pathways and other motifs, such as triplets, can form specific constellations of interdependencies between cultural and institutional factors.

3 Mapping multiple interdependencies

We next describe our empirical, data-driven strategy that allows computing asymmetric symbiotic relationships among a pool of factors. Our analysis adopts an exploratory view in which all factors included in the analysis may—or may not—engage in such relationships, as either hosts and/or symbionts. The methodology is here used for studying interdependencies among social structures, e.g. culture and institutions, but it can potentially also be used in other fields.

3.1 Mapping host-symbiont relations in correlation networks: two-way quantile regressions

The logic of our empirical analysis constructs upon correlation network analysis, a method used in medical research to identify most centrally located genes, that through co-expression kick-off certain diseases. Instead of genes, we study a pool of

⁶ Marè et al. (2020) and Gründler and Köllner (2020) have studied the link between family attitude and taxes. In line with such literature, we can expect case A to be more likely than case B.

cultural, institutional and socioeconomic variables—all measured at a given level of analysis, here the Brazilian municipality level. When analyzing institutional factors, we may identify most centrally located social structures that—jointly with others—shape institutional landscapes and e.g. facilitate or block the adoption of policies that seek for systemic change (cf. *Institutional Hysteresis* in Boschma and Frenken, 2009).

To represent asymmetric symbiotic relationships, we construct a directed network that reflects directions of feeding-flows between nodes. This requires the construction of a network based on regression models (Horvath, 2011). We rely upon a computation strategy based on the use of two-way quantile regressions (Jacobi, 2018). Quantile regressions can be understood as extensions to linear regression. While the regression curve gives ‘a grand summary for the averages of the distributions corresponding to the set of x s’, quantile regressions compute several different regression curves in correspondence to different percentage points of the distribution and thus get a more complete picture of the set. ‘Just as the mean gives an incomplete picture of a single distribution, so the regression curve gives a correspondingly incomplete picture for a set of distributions’ (Mosteller and Tukey, 1977 in Koenker, 2005, p.3).

Quantile regressions therefore allow focusing on noncentral locations on the response distribution. The *quantile* is to be understood as a generalizing term for the more specific *quartiles*, *quintiles*, *deciles* and *percentiles*: ‘the p th quantile denotes that value of the response below which the proportion of the population is p ’ (Hao and Naiman, 2007, p.3). This is in line with a cumulative density function F_y that for each value of y provides us with the proportion of the population for which $Y \leq y$ (Hao and Naiman, 2007, p.7). We compute the following quantile regression for each variable included in our pool:

$$y_i = \alpha^{(p)} + \beta^{(p)}x_i + \epsilon_i^{(p)} \quad (3)$$

where the quantiles p are the values $p20$; $p35$; $p50$; $p65$; $p80$ along the distribution of the y variable: and y_i and x_i represent any variable of our pool of factors for municipality i . Every single relation could benefit from an own specification of the regression model and the inclusion of control factors. However, different specifications would make the comparison across relations more difficult, which is exactly the intrinsic goal of a correlation network: it implies a more systemic view on the totality of relations and therefore needs to treat them in a way that makes them equivalent, to some extent—although that leads to preferring bivariate over multivariate specifications. A second argument against specifying each relation singularly relates to computational costs given the high amount of regressions to specify ($(29 \times 28) = 812$). For each y , we estimate five quantile regression models for which the p th conditional *quantile* given x_i is

$$Q^{(p)}(y_i|x_i) = \alpha^{(p)} + \beta^{(p)}x_i + \epsilon_i^{(p)} \quad (4)$$

where the p th quantile of the error term is zero.⁷ We loop through the entire list of variables included in the analysis (Table 4 in the Appendix), and compute ten

⁷ In line with Hao and Naiman (2007, p.29). Error terms at different quantiles are not necessarily i.i.d.

quantile regressions for each possible pair of variables: five regressions—one per quantile—in which one of the variables is the dependent variable; and five more in which we switch dependent and independent variable. We keep a relationship only if in at least three out of the five regressions we run on each dependent variable the β coefficient is statistically significant with a p-value of $p \leq 0.10$.⁸ The magnitude of coefficients proxy the relative importance of the independent variable in explaining the dependent one. To investigate the asymmetric character of the pairwise relations, we compare the estimations of the quantile regression coefficients in which y is the dependent factor with those of the regression in which x is the dependent factor. We derive a measure of asymmetry by comparing the respective percentage change in the slope coefficient along quantiles for each direction (see 7). The logic is that a greater increase in the slope coefficient in one direction stands for greater relevance of the independent variable in explaining the dependent one (at higher moments of its distribution), than when switched (Jacobi, 2018). The difference between such percentage changes between one direction and the other becomes the weight of the arc in our directed network. While such arcs do not claim causality, they indicate the directionality of a numerical relation that we observe among factors.

In line with our illustrative example, let’s imagine a situation in which attitude towards progressive taxation (Λ) is a symbiont on attitude towards women’s role in society (Σ), as described in case A. We first take the five estimated coefficients of equation 4 when $\Sigma = x$ and $\Lambda = y$, namely:

$$\beta_{\Sigma}^{(p20)}; \beta_{\Sigma}^{(p35)}; \beta_{\Sigma}^{(p50)}; \beta_{\Sigma}^{(p65)}; \beta_{\Sigma}^{(p80)} \tag{5}$$

where each coefficient describes how factor Σ explains variability in the dependent variable Λ at a specific moment of its distribution (the quantiles $p20, p35, p50, p65, p80$). We then take the five estimated coefficients of equation 4 when $\Lambda = x$ and $\Sigma = y$, namely:

$$\beta_{\Lambda}^{(p20)}; \beta_{\Lambda}^{(p35)}; \beta_{\Lambda}^{(p50)}; \beta_{\Lambda}^{(p65)}; \beta_{\Lambda}^{(p80)} \tag{6}$$

where, in a specular fashion, each coefficient describes how factor Λ explains variability in the dependent variable Σ at a specific moment of its distribution. We claim that Λ is a symbiont (feeding) on its host Σ if:

- $|\beta_{\Sigma}^{(p20)}| \leq |\beta_{\Sigma}^{(p35)}| \leq |\beta_{\Sigma}^{(p50)}| \leq |\beta_{\Sigma}^{(p65)}| \leq |\beta_{\Sigma}^{(p80)}|$ and $|\beta_{\Sigma}^{(p20)}| < |\beta_{\Sigma}^{(p80)}|$
- $|\beta_{\Lambda}^{(p20)}| \leq |\beta_{\Lambda}^{(p35)}| \leq |\beta_{\Lambda}^{(p50)}| \leq |\beta_{\Lambda}^{(p65)}| \leq |\beta_{\Lambda}^{(p80)}|$ and $|\beta_{\Lambda}^{(p20)}| < |\beta_{\Lambda}^{(p80)}|$
- $\{|\beta_{1\Sigma}^{(p80)} - |\beta_{1\Sigma}^{(p20)}|\} > \{|\beta_{1\Lambda}^{(p80)}| - |\beta_{1\Lambda}^{(p20)}|\}$ ⁹

In such case, we observe that at higher levels of Λ (higher moments of its distribution), Σ is more and more relevant: else said, at higher levels of Λ , Λ is more

⁸ Indeed, for more than 85% of the pairs of variables we test we find that all the ten β coefficients we estimate are significant with a p-value of $p \leq 0.05$.

⁹ In case the coefficients at p20 or p80 were not significant, we consider the min/max significant coefficients among the three lowest/highest estimated quantiles, respectively.

dependent on Σ . Yet, at higher levels of Σ , Σ is not equally more dependent on Λ . We therefore observe an asymmetric relationship in which Λ is a symbiont feeding on the habitat provided by the host Σ . We quantify the asymmetry as difference in the percentage change in the two directions as specified in (7), which determines the weight of an arc departing from Σ and heading towards Λ .

$$[(|\beta_{1\Sigma}^{(p80)}| - |\beta_{1\Sigma}^{(p20)}|)/|\beta_{1\Sigma}^{(p20)}|] - [(|\beta_{1\Lambda}^{(p80)}| - |\beta_{1\Lambda}^{(p20)}|)/|\beta_{1\Lambda}^{(p20)}|] = w_{\Sigma\Lambda} \tag{7}$$

In the directed network, we therefore compute arrows going from hosts towards symbionts. The arrow’s weight reflects the degree of asymmetry (dependence) of the relationship.

3.2 Detecting direct and indirect feeding in directed networks

The directionalities our methodology plots in a directed weighted network can provide some orientation for policy-makers that seek to modify the existing economic-institutional system. The detailed view our analysis provides gives some guidance with respect to i) which factors may require joint/coupled targeted policies to be addressed ii) which indirect (and possibly undesired) effects such policies may be triggering. We next introduce network analysis tools that allow qualifying what feeds on what by going into greater detail of direct and indirect interdependencies. While direct interdependencies represent asymmetric complementarities, indirect links show concatenated interdependencies that can undermine a linear engineering logic of policy-making. In our analysis, we proceed by working through three layers—the overall network topology, the topology of nodes, the topology of edges.

Network topology To better describe our network, we look at motifs, which are a ‘set of topologically equivalent subgraphs of a network’ (Fagiolo, 2007, p.8), such as the non-frustrated triangle (a closed triplet with circular directions) or a path of two (two sides of a triplet in Onnela et al., 2005). Clustering coefficients quantify the tendency of certain motifs to appear and of certain nodes to assume specific positions within them (Clemente & Grassi, 2018; Onnela et al., 2005). Within our framework, motifs reflect the tendency for nodes to assume the role of multiple symbionts (contemporaneously feeding on different other nodes), multiple hosts (contemporaneously feeding different other nodes), or of the mediator that forwards an indirect effect lying on a path linking two other nodes, or by assuming a so-called middleman position, in which the indirect effect parallels a direct effect between two other factors.

In Fig. 1, our formal institutional variable (Λ) assumes three different positions within the triplet. In panel a the acceptance of progressive taxation (Λ) is subject to in-clustering: it is a multiple symbiont, feeding on both the attitude towards women’s role in society (Σ) and trust (Θ). In this case, our institutional variable depends on factors rooted in culture and trust, and is likely to change only when these, latter factors vary. In panel b, the situation is opposite, as the institutional variable is subject to out-clustering: it is now itself a host for both the cultural variable (Σ) and trust (Θ). In such set-up, we can imagine e.g. the positive experience of progressive

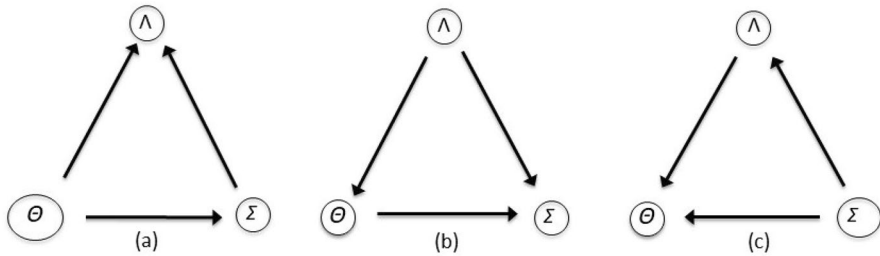


Fig. 1 In- and out-clustering patterns, middleman. Adapted from Fagiolo (2007)

taxation to represent a fertile ground for a cultural change in which traditional gender discriminatory practices are abandoned in favour of greater equality, and—contemporaneously—favouring the development of generalized trust. Finally, in panel c the acceptance of progressive taxation assumes the role of the middleman: it serves as host for trust, but feeds itself on the attitude towards women. It therefore acts as mediator within a triplet in which a direct interdependence (of Θ on Σ) is paralleled by an indirect one. In such a scenario, the institutional variable is only partially able to mitigate the prevalent role of culture, which affects both, formal institutions and trust. When we look at our network topology, we are able to identify the prevalence of such clustering patterns, which can inform on the relative (in)dependence of formal institutions vis-a-vis cultural factors. If in-clustering among formal institutions is prevalent, these appear to be systemically more dependent on cultural and social factors. Whereas greater out-clustering among formal institutions indicates greater 'maturity' of formal institutions in as much as they provide habitat for other factors. High middleman clustering of formal institutions within a network would stress their partial (in)dependence, which however leaves space for introducing change via policies, in as much as a middle-man position implies mediating indirect effects.

Node topology Our analysis can also shed light on the specific role that single nodes assume within the network. When computing clustering coefficients, we obtain the tendency of each single factor to being involved in a position of e.g. in- or out-clustering, or of the middleman (Fagiolo, 2007).¹⁰ In addition, we use in- and outdegree centrality, which is computed as the weighted sum of inward or outward-facing arcs, respectively. A factor with high indegree centrality in our framework is a multiple symbiont, feeding on many other factors. Nodes with high outdegree are hosts that provide habitat to a multitude of other factors. Furthermore, we make use of the hubs and authorities statistics: these are recursive measures in which hubs emerge if they point to high-quality authorities. Authorities emerge in as much as their predecessors are hubs of high-quality (Gómez, 2019).

¹⁰ Fagiolo (2007) builds upon Onnela et al. (2005) and Milo et al. (2002). We use *nwcc* (Joyez, 2017) in STATA to compute clustering coefficients as the ratio between the number of triangles in the network graph having i as vertex taking part in the specific subgraph (triangle type) and the number of all possible triangles that i could have formed.

We synthesize such statistics by computing some net scores (outdegree minus indegree, outclustering minus inclustering, hub score minus authority score) for each factor. This allows us to estimate for each cultural/institutional factor whether it is a relative host or a relative symbiont within the network (cf. Fang & Huang, 2013). We suggest to use such measures to evaluate whether a specific node may be more or less viable for policy change. In our view, greater indegree/inclustering of a node makes a factor potentially more viable for change because systemic and unexpected consequences may be smaller. Where a node displays a greater outward and mediating profile, it may kick-off a series of unforeseeable effects in the system when it changes (McKelvey, 1997).

Edge topology First, we describe the asymmetric symbiotic relations we identify through our two-way quantile regression loops in terms of their asymmetry weight and in terms of the precise nodes involved in them. Stronger weight of an arc indicates a greater asymmetry hinting that the dependency—or “feeding effect”—is stronger. To quantify relational patterns even more, we use discrete assortative mixing (Newman, 2003),¹¹ which allows us to observe whether formal institutions tend to feed on other formal institutions (displaying assortativity) or whether some other, repeated, matching pattern can be observed among our factors $i \in C, I, Z$ where C and I represent our pool of cultural and institutional variables, respectively, and Z comprises socio-economic control variables (see Sect. 4). If feeding tends to occur across domains C, I, Z our network displays disassortative mixing. Networks representing systems are more likely to be disassortative due to complementarities between different node types (Newman, 2003).¹² In our analysis, disassortativity stands for complementarity between institutions and cultural factors, whereas greater assortativity hints for cultural and institutional factors being more isolated (and independent) from each other, as they would tend to associate more among themselves.

4 Data

For our empirical analysis, we work with a pool of factors i that seek to capture social structures within the domains of culture (C), institutions (I) and socio-economic development (Z). Any variable $i \in C, I, Z$ is measured at the municipality level, in order to capture within-country variation as much as possible, and in order to grant the numerosity of observations required by our network computation methodology. In the Brazilian federal system, the municipality is the lowest level of governance (or state-power) which includes legislation. It is the lowest administrative level at which formal institutions can emerge. At such level, no statistically representative value-surveys exist so far (Hofstede et al., 2010).¹³ We therefore rely

¹¹ We use *nwassortativity* an extension to *nwANND* (Joyez, 2022).

¹² Whereas social networks tend to be assortative, displaying *homophily*.

¹³ These are typically used to measure culture (Guiso et al., 2009; Tabellini, 2010).

on administrative data and other secondary sources for all of our variables i , which allows us to work with the universe of the 5565 Brazilian municipalities. More specifically, we use a Meso-level dataset (Jacobi, 2018),¹⁴ which combines census data with a municipality-survey (Perfil dos Municípios, IBGE) and their public accounts data (FAZENDADATA, IBGE) of the same year (2010).

In line with the requirements of our methodology, we prefer continuous variables over discrete ones, and make use of some simple data transformation in order to produce variables i that assume a quasi-normal distribution. This is a necessary condition in order for the quantile regression loops to rely on a significantly numerous sample at any p th computation. For example, when original distributions are right(left)-skewed, we use log-transformation (the exponential). Further, all of our count variables i are divided by 1000 inhabitants (in what follows, these are ‰ measures) in order to clean our proxies from a mere scale effect.

Measures of Formal Institutions We consider our proxies for formal institutions to refer to legally stipulated rules (Hodgson, 2001). The locus of their enforcement lies in state power (Acemoglu & Robinson, 2019; Voigt, 2018). Municipalities in Brazil elect a mayor and 9–55 councilmen, depending on their population size. Key municipal functions are planning, public initiative, legislation on matters of public interest, the institution and collection of taxes under their jurisdiction, organizing and rendering public services; maintaining—in cooperation with the Republic and the state, pre-school and primary educational, as well as health services (Brazilian Constitution, Art. 30). Municipalities collect Federal taxes from which they retain a fixed proportion that ranges between 25% and 50% depending on the specific tax (Brazilian Constitution, Art. 158). They may institute additional taxes in line with Art. 30. We include some fiscal variables into our pool of factors in order to characterize the administrative capacities/quality of the local institutional environment in line with literature on state effectiveness (Besley & Persson, 2011; Pritchett, 2012) and state capability (Sarker, 2006). Taxes have been found to relate to a series of other economic behaviours and cultural factors (Marè et al., 2020; Gründler & Köllner, 2020). Specifically, we use

- the ‰ number of taxes collected (*taxesnr*) and
- their share within municipal revenues (*taxessh*) and
- public income diversification (*pubincdiv*), measured as Herfindahl index over five sources of public revenues (taxes, social contributions, income from the economy, capital goods and transfers).

While all potentially proxy institutional quality (Cummings et al., 2009), we single out the latter as particularly relevant in as much as the variable serves as proxy for sound fiscal management (Carroll, 2005; Carroll et al., 2003). We further include

¹⁴ This is a collection of secondary data which are publicly available. The dataset is available upon request.

- per capita public expenditure on health (*healthspend*) (de la Maisonneuve et al., 2017) and;
- the share of municipal spending on public goods (*publicgood*) (Touré, 2021);

which are both related to democratic performance (Galletta, 2021) and to social ties, specifically to the polarization of society (Burns & Keswell, 2015).

The municipality in Brazil is also the level at which *participatory councils* are active, an innovative institution in which public administration and citizens jointly decide on policies and budget allocation. Participatory councils represent a key instance in which citizens can exert democratic practice (Avritzer, 2009; Galletta, 2021). Specifically, we look at the

- % quantity of participatory councils (*participnr*), where different councils treat separate topics such as education, human rights, gender issues, etc.
- decisional strength of participatory councils (*participforce*), which may range from being merely consultative to deciding upon budget. Our measure computes the mean strength over potentially 12 thematically different councils

The Brazilian *Conselhos Partecipativos* may proxy state-society interactions (Wampler, 2012) and can be expected to significantly relate to public spending (Galletta, 2021).

Measures of cultural factors Culture comprises many aspects such as diet or religion, but also socially accepted expectations regarding social interaction (Opp, 1982). These reflect in common dispositions that are enforced internally by society (Acemoglu & Robinson, 2019; Voigt, 2018; Gutmann & Voigt, 2020). Not many of such factors are tangible/easily measurable. We select a series of proxies through which we seek to be capturing prevalent shared mental models (cf. (Denzau & Douglass, 1994; Roy & Denzau, 2020), such as attitude towards women or towards youth; towards family, the economy, conventions and political competition; and religious belief. The use of aggregate measures at the municipality level is in line with social psychology findings that suggest culture cannot be reduced to the individual level (Na et al., 2010). For example, local contexts in which female labour market participation is lower and in which the female wage gap is higher maintain less egalitarian views on women's position in society. To proxy women's position in society as studied by Cavapozzi et al. (2021), Inglehart and Baker (2000), Gangadharan et al. (2019), we use:

- female labour market participation (*femlbmktpart*) and;
- the female wage gap (*femwagegap*);

To partially capture conservative attitudes (Inglehart & Baker, 2000), we further consider:

- the inverse of the mayor's age (*mayoryouth*) to capture attitude towards youth, as more conservative local contexts are less likely to elect a young mayor;
- the prevalence of *catholic* believers, measured as exponential share of Catholics over the municipal population. Catholic belief relates to a series of other eco-

conomic behaviours (Benjamin et al., 2016; Lewer & Van den Berg, 2007), trust (Guiso et al., 2009) and to family ties (Marè et al., 2020);

- the share of extended families (*extendfam*) to proxy family ties, which characterize more traditional societies (Inglehart & Baker, 2000) and tend to associate with lower generalized trust (Alesina & Giuliano, 2015) and greater tax evasion (Marè et al., 2020);
- the ‰ number of art groups on the municipal population (*artgroups*), through which we seek to proxy an unproductive (Baumol, 1996) type of entrepreneurship that reflects the collective motivation to challenge contemporary conventions and norms and that is embedded in social ties (Lindqvist, 2011; Rindova et al., 2009);

To capture the collective attitude through which the local society positions itself with respect to the market and the state, we use:

- the prevalence of the informal economy (*econformal*), proxied as ratio between indirect taxes and factor GDP which captures the formality of aggregate demand and has been studied e.g. by Godfrey (2011) and Zoogah et al. (2015);
- the per capita number of candidates that stood for municipal elections (*candidates*) to proxy local democratic attitude and electoral competition (cf. Banerjee and Iyer, 2008), which could reflect a more deeply ingrained democratic attitude at the local level, likely to promote/reinforce inclusive institutions (Acemoglu & Robinson, 2019).

Measures of socio-economic development Within the domain of socio-economic development, we include a series of structural control factors $i \in Z$ that we organize within four subcategories, to grant greater interpretational clarity during the analysis. Our subcategories are the following: economic structure and performance, social capital and trust, degree of remoteness from economic activity, and demographic and human capital features of the municipality. Such elements have been found to be interdependent with institutional and cultural factors (Alesina & Giuliano, 2015; Batinti et al., 2019; Glaeser et al., 2004; Sachs, 2003).

To track economic performance and structure we use the following measures:

- log of municipal GDP per capita (*gdppcap*);
- the Gini index (*gini*);
- the log share of industry in municipal GDP (*industry*); and
- the share of public sector employment on total workforce (*pubemp*).

Such measures seek to capture, broadly, market development and industrialization, as well as the more or less equal distribution of economic benefits.

To proxy social capital and trust, we use

- the % number of infrastructure facilitating social aggregation (*socagginfra*) such as museums, theatres, stadiums, etc., which are typically provided through public expenditure;
- the % number of cultural centres, community radios and clubs/associations (*socgather*), which we interpret as non-compulsory municipal venues that emerge by request on behalf of citizens, and that can become a vehicle for exerting pressure on institutions (Touré, 2021), and for the unfolding of particularized versus generalized trust (Uslaner & Conley, 2003);
- the likeliness of missing communication (*misscomm*), which we measure as educational fractionalization (Bossert et al., 2011) that compounds distances between different groups' illiteracy shares, where groups are defined by age and ethnicity, e.g. young white, young Indio, elderly black, etc.

The measure treats such distances as potential “gaps” in communication, and computes the compounded “gaps” between all groups in the municipality. Missing communication is likely to imply reduced trust and cooperation (Jacobi, 2018; Jones & Zhan, 2020; Kolo, 2012).

We further control for the degree of remoteness of an area from economic activity, for which we include

- the % number of municipal collaborations with other governmental levels or municipalities (*instpermea*), which we see as proxy for institutional permeability to the extent that a greater amount of collaborations is likely to increase the degree to which local institutions learn/are influenced by other governance experiences;
- the density of transportation services per km^2 in the municipal area (*transport*);
- the share of population living in rural areas (*rural*).

More remote and isolated areas may display different institutional patterns than more connected ones (Gelfand et al., 2011; Gneezy et al., 2016).

Lastly, we also control for the demographic structure and human capital features of the municipality:

- population density (*popdensity*);
- the share of residents aged older than 60 (*pop60plus*);
- the share of residents with monthly income below 70 reais¹⁵ (*sharepoor*);
- the adult illiteracy rate (*illiteracy*); and
- an ethnic fractionalization index (Alesina & Ferrara, 2004) over the five ethnicities officially recorded in the Census (*elf*).

Table 4 in the Appendix reports the main descriptive statistics of the variables used in the analysis. In what follows, we present results on the interdependencies, so the

¹⁵ National absolute poverty line below which social transfers are guaranteed no matter the exact family composition.

relations we identify between municipality-level measures belonging to the domains *C*, *I* and *Z*.

5 Results

Figure 2 represents the directed weighted network we compute: nodes are coloured according to their thematic belonging, labels correspond to variable names. Arcs depict an interdependency in which the node from which an arc originates is a ‘host’, feeding the node reached by the arc, which is a ‘symbiont’. Strongest arcs are darker and represent greater asymmetry.

5.1 Network topology

Our network comprises 30 nodes and 212 arcs. Table 5 in the Appendix summarizes key characteristics, hinting for the network to having a low density within a single modular structure. The network is disassortative, suggesting that highly central nodes tend to pair up with less central nodes. The majority of arcs has a low asymmetry weight, and only few arcs assume a much stronger weight. Indegree centralization is higher than outdegree centralization, hinting that some multiple symbionts assume a highly central position within the network. Clustering of 35% shows there is a tendency for closed triplets to form. We observe that closed triplets are less common when two arcs are inward facing than when two arcs are outward directed. This suggests for the network to be characterized by some, systemic nodes that have greater relevance in serving as hosts for multiple other factors (that are themselves connected). The most common clustering pattern within closed triplets we identify, however, is the middleman pattern, which confirms that indirect feeding is very common, and that many nodes in this way exert a mediating role. This echos the high betweenness centrality of the network (see Table 5), confirming a consistent presence of indirect feeding mediated by factors that lie in between. Figure 3 summarizes the key motifs/triads we identify. Of all potential triplets that could form within our network, 1487 assume the motif of the single arc. In line with the network’s higher indegree centralization, motifs in which there is a multiple symbiont (two inward-facing arcs) are much more frequent than those in which there is a multiple host. Mediation of indirect effects appears to be rather common in our network, while cyclic triplets are rather rare.¹⁶ Our network therefore displays complex and multi-faceted interdependency patterns in which direct and indirect feeding is present. We next seek to unfold the relative role of cultural and institutional factors within such feeding.

¹⁶ We do not dwell on cyclic triplets here.

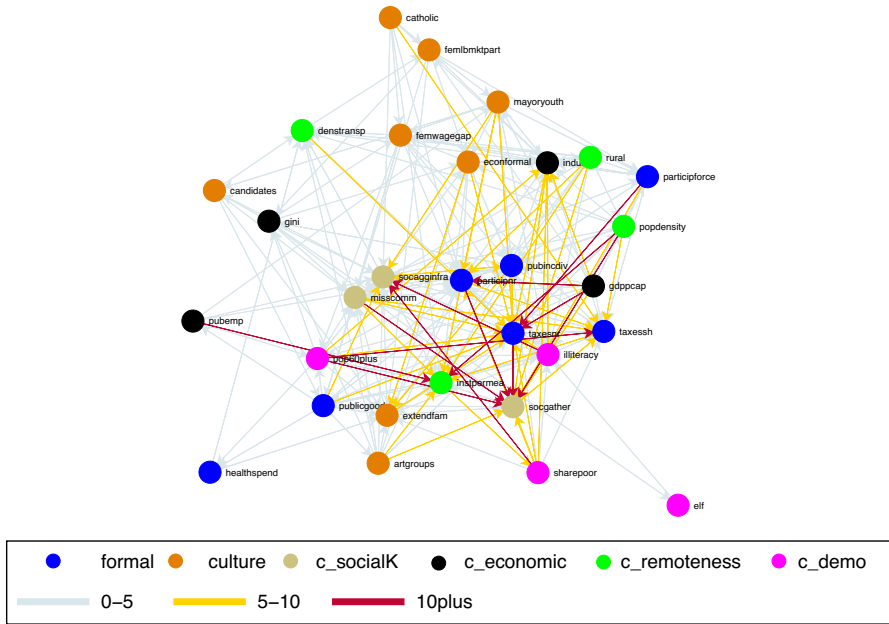


Fig. 2 Directed weighted network summarizing computed asymmetric relationships

5.2 Node topology: hosts, symbionts, mediators

We find nodes display higher indegree than outdegree values, in line with network topology. The most central factors in terms of indegree are our two tax-variables (*taxesn* and *taxessh*) and the number of participatory councils (*participnr*) within the domain of institutions *I*; two proxies of social capital (*socgather*; *socagginfra*); and our measure of institutional permeability (*instpermea*), all $\in Z$. The most central nodes in terms of outward facing arcs are GDP per capita (*gdppcap*), population age (*pop60plus*) and density (*popdensity*), all $\in Z$.

We next use net scores of single nodes to observe which cultural, institutional and social capital factors tend to be hosts and which tend to be symbionts. In Figs. 4, 5, 6, 7, 8, net scores are positive when the outward-sensitive statistics of a node is greater than the respective inward-sensitive statistics. Positive values hint the node tends to be more host than symbiont. In Fig. 4, we observe that among institutions, the landscape is variegated, but our two tax-variables (*taxesn*, *taxessh*) and the number of participatory councils (*participnr*) are clear net symbionts. Among our cultural factors, the prevalent net role is the one of the host, although our measure for family ties (*extendfam*) stands out as an exception. Our social capital measures (*socgather*, *socagginfra*, *misscomm*) display a similarly variegated pattern as nodes $\in I$. The incidence of cultural centres, community radios and clubs/associations (*socgather*) however stands out as key net symbiont.

Nodes that form closed triplets more often engage in outclustering than in including (Fig. 5, and Table A2). Among our institutional factors, spending for health

Type of triad	Graph	Interpretation	Frequency
empty		no asym. relations	669
single arc	$i \longrightarrow j$	single asymmetric relation	1487
two inward-facing arcs	$i \xrightarrow{k} j$	multiple symbiont	559
two outward-facing arcs	$i \xleftarrow{k} j$	multiple host	245
path	$i \longrightarrow j \longrightarrow k$	mediation	459
middleman	$i \xrightarrow{k} j$	amplification: double (direct and indirect) effect	608
non-frustrated triangle	$i \xrightarrow{k} j$	cyclically reinforcing	33

Fig. 3 Motifs and their frequency in our weighted directed network *Source:* Authors’ elaboration based on *Meso-level* dataset, 2010

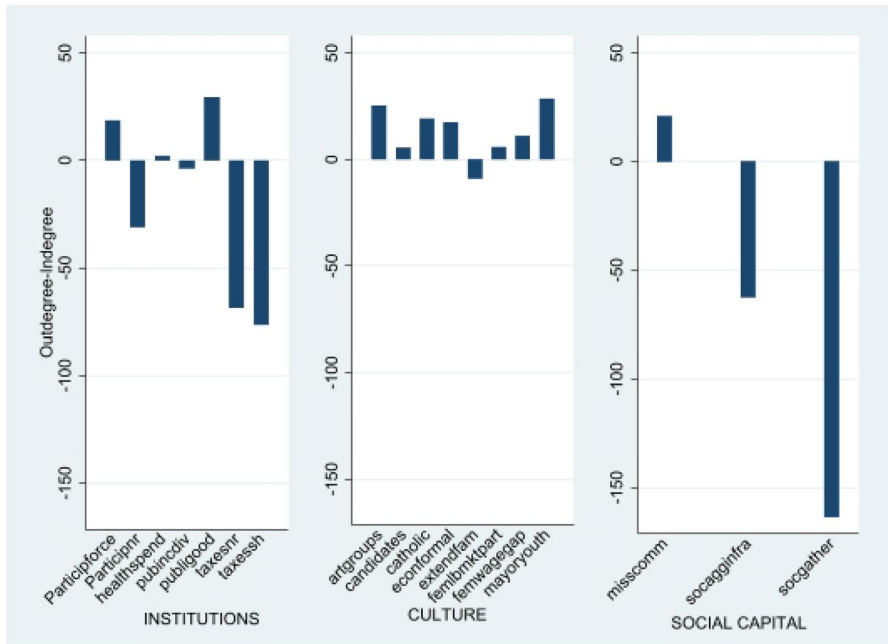


Fig. 4 Outdegree-Indegree (Net Score) of institutional, cultural and social capital factors *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

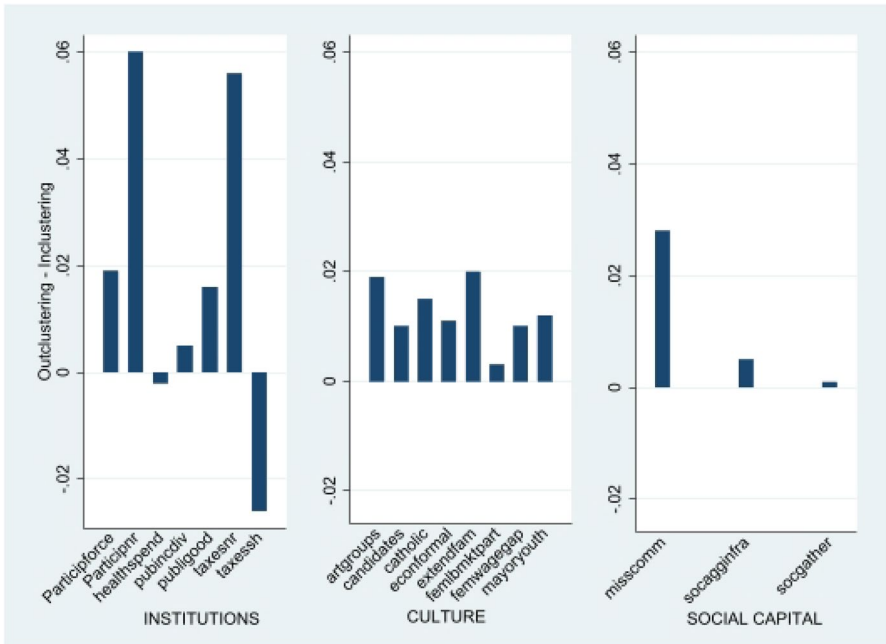


Fig. 5 Outclustering-Inclustering (Net Score) of institutional, cultural and social capital factors *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

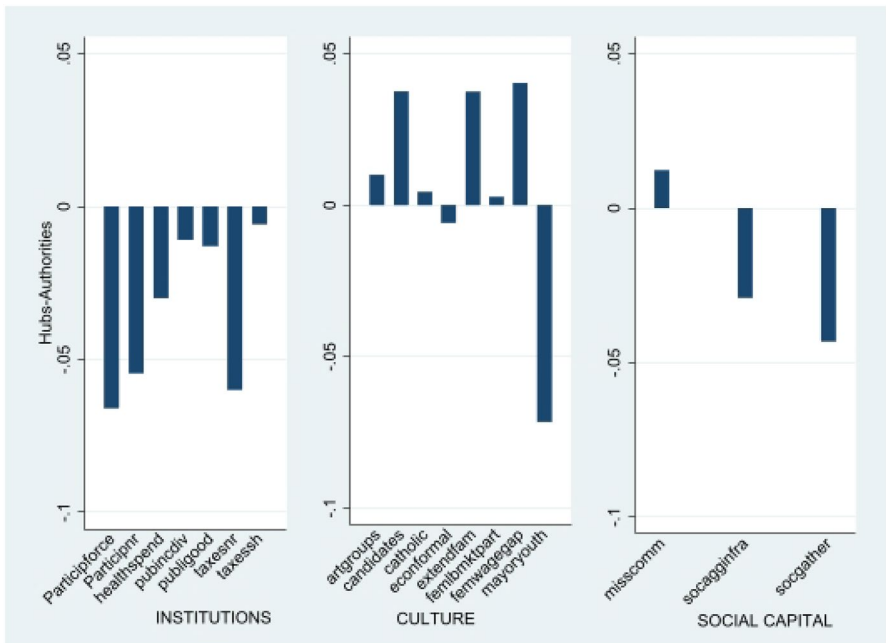


Fig. 6 Hub-Authority (Net Score) of institutional, cultural and social capital factors *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

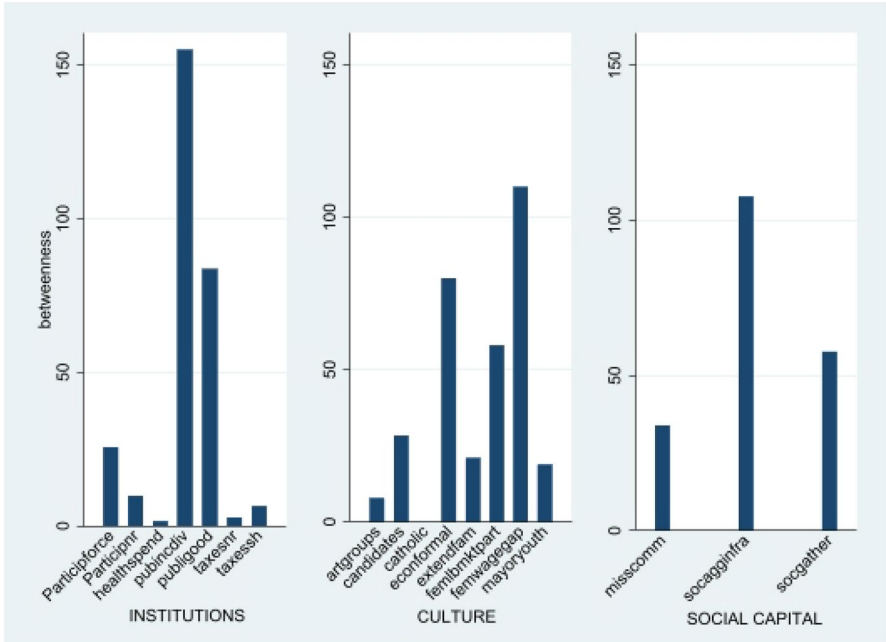


Fig. 7 Betweenness centrality of institutional, cultural and social capital factors Source: Elaboration by the authors based on *Meso-level* dataset, 2010

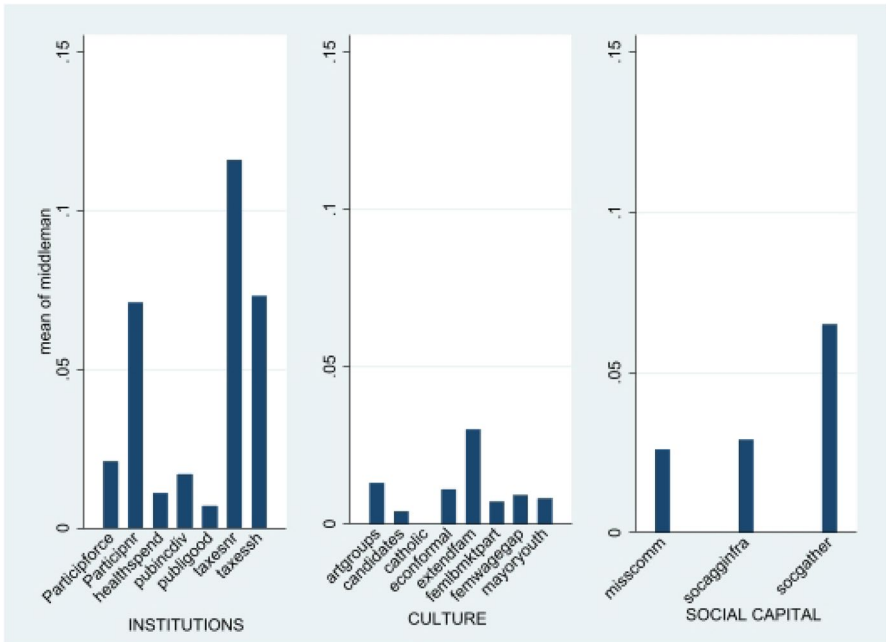


Fig. 8 Middleman clustering of institutional, cultural and social capital factors Source: Elaboration by the authors based on *Meso-level* dataset, 2010

(*healthspend*) and the share of taxes within municipal incomes (*taxessh*) are net symbionts having greater inclustering than outclustering coefficients. Participatory councils (*participnr*) and the number of taxes collected (*taxesnr*), contrarily, display high net positive outclustering. In overall, we observe a rather varied landscape among our nodes $\in I$. Our cultural factors, on the contrary, display greater homogeneity, with outclustering always prevailing over inclustering. Our social capital measures behave similarly.

In Fig. 6, institutional factors all tend to be relative authorities, while cultural factors are more often hubs. Among our social capital proxies, there is variety: our measure of likeliness for missing communication (*misscomm*) is a hub, whereas infrastructure facilitating social aggregation (*socagginfra*) such as museums, theaters, stadiums, etc. and more informal social gatherings (*socgather*) are authorities. A key outlier within domain C is the age of the mayor (*mayoryouth*), which is a net authority in the network.

In overall we observe a general trend for cultural factors to assume net roles as hosts, more than institutions. Nodes within domain I display heterogeneous patterns. Consistent multiple symbionts are taxes and participatory councils, yet these factors also serve as hosts for other factors—as is evident in their net outdegree (*participforce*) and their net outclustering (*participforce*, *participnr*, *taxesnr*). An institutional variable that displays a relevant role as host is spending for public goods (*publicgood*)—yet it is an authority, like all other nodes $\in I$, and not a hub as most nodes $\in C$. Our proxies for social capital display a profile that somehow locates midway between the domains I and C . While the likeliness of missing communication (*misscomm*) engages in ties in a similar way to cultural factors, infrastructure (*socagginfra*) and informal groups (*socgather*) that foster social interactions assume positions that are similar to institutional factors.

We next focus on mediator nodes (Figs. 7 and 8). Betweenness centrality (Freeman, 1977) measures the number of shortest paths on which a node is located, so high values of betweenness identify factors through which feeding among two other nodes has to pass. Nodes with high betweenness have certain power in the network, in as much as they mediate indirect effects (see Fig. 3). We find our proxy for institutional quality (*pubin divid*) to be the most relevant mediator in our network, together with spending for public goods (*publicgood*) $\in I$; female wage gap (*femwagegap*) and labour market participation (*femlbmktpart*), and the formality of the economy (*econformal*) $\in C$; and facilitators of social aggregation (*socagginfra* and *socgather*) $\in Z$. Other control factors with high betweenness (see Table 6 in the Appendix) are the gini coefficient, and our two measures of institutional (*instpermea*) and geographical (*transport*) remoteness.

Nodes with high betweenness centrality can potentially trigger systemic effects because of their key role as mediators in the network: improvements in public income diversification (*pubin divid*) and fighting income inequality at the Brazilian local level therefore emerges as a relevant priority, given the high values of betweenness of *gini* and of *femwagegap*.

In Fig. 8, the key middlemen in our network are taxes (*taxesnr*, *taxessh*) and participatory councils (*participnr*) $\in I$, social gatherings (*socgather*) $\in Z$ and family ties (*extendfam*) $\in C$. These nodes form closed triplets in which they receive an arc

Table 2 Institutions and culture as host: which factors do they feed? *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

Host type	Symbiont type	# Relations	<i>Asymmetric relations > 5%</i>		
			Host	Symbiont	Asymmetry strength
Institutions	Institutions	13	participforce	taxesnr	10.887
			publicgood	taxesnr	6.853
			pubinclud	taxesnr	6.753
			participnr	taxessh	5.551
	Culture	5	pubinclud	extendfam	7.283
			Social capital	7	taxesnr
	participnr	socgather	36.261		
	participforce	socgather	8.761		
	publicgood	socagginfra	5.709		
	Economic structure	4	n.a.	n.a.	n.a.
	Remoteness	4	taxessh	instpermea	7.958
	Demography	3	n.a.	n.a.	n.a.
	Total	36			
Culture	Institutions	19	econformal	taxesnr	7.505
			mayoryouth	taxesnr	5.847
			catholic	taxessh	5.717
			mayoryouth	participnr	5.360
			extendfamily	taxesnr	5.256
	Culture	13	econformal	extendfam	5.862
	Social capital	12	mayoryouth	socagginfra	6.061
			artgroups	socgather	5.781
	Economic structure	7	n.a.	n.a.	n.a.
	Remoteness	10	mayoryouth	instpermea	5.424
			artgroups	instpermea	5.082
	Demography	4	n.a.	n.a.	n.a.
	Total	65			

(act as symbiont) and simultaneously forward an arc (act as host) to another node that already is a symbiont on the original node (see panel c in Figs. 1, and 3).

In our network, some of the most central nodes are multiple symbionts: if policy-makers seek to alter e.g. taxes or the incidence of participatory councils, they should be aware of the need to design policies that jointly target the factors these depend upon. However, as many of our key symbionts also engage in outclustering motifs, and act as middleman, any change to them induced by policy-making is likely to trigger some indirect effect on the rest of the network. The greater the outdegree/outclustering of a node, the more a policy-induced change may trigger a maximum of (unexpected/undesired) effects. This is a

Table 3 Institutions and culture as symbionts: which factors feed them? *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

Symbiont type	Host type	# Relations	<i>Asymmetric relations > 5%</i>		
			Host	Symbiont	Asymmetry weight
Institutions	Culture	19	econformal	taxesnr	7.505
			mayoryouth	taxesnr	5.847
			catholic	taxessh	5.717
			mayoryouth	participnr	5.360
			extendfam	taxesnr	5.256
	Social capital	10	socgather	taxessh	8.882
			socagginfra	pubincdiv	5.557
			misscomm	taxesnr	5.418
			misscomm	taxessh	5.055
	Economic structure	10	gdppcap	taxesnr	25.294
			gdppcap	participnr	23.403
			industry	taxesnr	6.724
	Remoteness	11	transport	taxesnr	7.981
			popdensity	taxessh	5.251
			rural	participnr	5.146
	Demography	12	pop60plusper	taxessh	32.110
			sharepoor	participnr	9.262
			illiteracy	taxesnr	7.795
			sharepoor	taxesnr	7.210
			pop60plus	taxesnr	5.149
Culture	Total	62			
	Institutions	5	pubincdiv	extendfamily	7.282887
	Culture	13	econformal	extendfamily	5.862
	Social capital	1	n.a	n.a	n.a.
	Economic structure	6	n.a	n.a	n.a.
	Remoteness	4	n.a	n.a	n.a.
	Demography	3	n.a	n.a	n.a.
	Total	32			

double-edged sword: while systemic change is more likely to be triggered by targeting multiple hosts and middlemen, the degree of unpredictability of the overall effect is also greater (McKelvey, 1997).

5.3 Edge topology: asymmetric relations

Tables 2 and 3 report details about asymmetric relations in which institutions and culture act as, respectively, hosts and symbionts. They also report all relations where the asymmetry is larger than five. In Table 2, institutions are less often

hosts in stronger asymmetric (36) relations, compared to cultural factors (65 relations). When they are hosts, institutional factors tend to feed other institutions, mainly. Yet, cultural factors also mainly tend to feed institutional factors. Where institutions serve as hosts for other formal institutions, we see that institutional quality (*pubin divid*, *publicgood*), including their democratic declinations (*participnr*, *participforce*) play a key role as habitat for tax collection. Noteworthy is that spending on public goods (*publicgood*) and the quality/strength of participatory councils (*participforce*), which are not among our key institutional symbionts, acquire greater relevance among the hosts $\in I$. These factors, and taxes, also feed social capital (*socgather*, *socagginfra*). Only one relationship in which an institutional factor serves as host for a cultural one qualifies as strong enough in Table 2, namely institutional quality (*pubin divid*) feeding family ties (*extendfam*).

The most frequent type of relationship in which a cultural factor serves as host is one in which an institutional factor is a symbiont (19 relations). Yet, cultural factors also feed other cultural factors (13 relations) and social capital proxies (12 relations), but they tend to do so with weaker arcs. In the strongest symbiotic relationships between culture (host) and institutions (symbiont), cultural hosts are the (in)formality of the economy (*econformal*), the youth of the elected mayor (*mayoryouth*), the prevalence of Catholics (*catholic*) and family ties (*extendfam*) feeding taxes (*taxesnr*, *taxessh*) and participatory institutions (*participnr*). In our strongest culture-culture relation family ties (*extendfam*) feed on the informality of the economy (*econformal*). Social capital feeds on the youth of the mayor (*mayoryouth*) and on the incidence of art groups (*artgroups*).

Table 3 confirms that institutions are prevalently engaged in relationships in which they are symbionts (62 relations), most often feeding on cultural factors (19). Key symbiont institutions involved in stronger asymmetric relations are: our tax-variables (*taxesnr*, *taxessh*), number of participatory councils (*participnr*), and public income diversification (*pubin divid*). When institutions feed on control factors, we find the following hosts: share of residents aged older than 60 (*pop60plus*), GDP per capita (*gdppcap*), share of poor residents (*sharepoor*), and the incidence of social gatherings proxying social capital (*socgather*). We only detect 32 relationships in which cultural factors are symbionts, and only two of these have an arc weight above 5 percentage points: family ties (*extendfam*) are the symbiont in both, feeding upon the (in)formality of the economy (*econformal*) $\in C$, and on institutional quality (*pubin divid*) $\in I$. Cultural factors mainly feed upon other cultural factors, but with weak ties.

When focusing on the prevalent directionality between culture and institution, we find that the prevalent matching pattern across node domains is one in which a cultural factor serves as host for an institutional symbiont (see Table 7 in the Appendix). Symbiotic relationships within the domains C and I are also frequent, while relations in which an institutional factor feeds a cultural one are the least frequent. Table 8 reports our results on assortative mixing: we find that across the domains C , I and Z , our network is slightly disassortative. Nodes have a tendency to engage in symbiotic relations with nodes that belong to other domains.

Such disassortativity slightly increases when we restrict the network to relations $\in I \vee C$. In contrast, our computations return assortative patterns when we restrict the network to relations $\in I \vee Z$ or to relations $\in C \vee Z$. Such results confirm that despite a tendency of cultural factors to feed on other cultural factors, and despite institutions tending to feed other institutional factors, there is a slightly stronger tendency for relations to form in which one cultural factor engages with an institutional factor. Tables 2, 3 and 7 in the Appendix show that while 19 relations in our network tie a cultural host to an institutional symbiont, only 5 relations tie an institutional host to a cultural symbiont.

We therefore summarize few, emergent patterns in our network: cultural factors are more likely to engage in outward facing arcs than in inward facing arcs, so they tend to be net hosts in the system. Institutions display a variegated landscape: beyond a slight tendency for them to being net symbionts in the system, they also act as middlemen and hosts, somehow blurring any clear emergent pattern. Among our control factors, we have paid particular attention to social capital proxies—and find they behave somewhat in between of institutions and culture: they assume a particular role as mediators of indirect effects, which implies being simultaneously both, host and symbiont. We find there is a tendency for cultural factors to feed institutional factors, but this is clearly not the only type of matching observed in our network: cultural factors depend on other cultural factors, but the weight of arcs in such relations is smaller. Institutions tend to feed other institutional factors, and our socio-economic controls also engage in some important symbiotic relations, as expected.

6 Summary and outlook

As extant literature has stressed, culture and institutions co-evolve. In the long term, directionalities among cultural and institutional factors may not be constant but may switch—e.g. institutions feeding on culture first, and culture later feeding on institutions in return. The approach here presented takes a snapshot of what feeds on what in a given moment of time. Such short term horizon in which we place the analysis is compatible with that of policy making.

Our results show that the relative dominance of culture over institutions (Belloc & Bowles, 2013; Mathers & Williamson, 2011; Maseland, 2013; Williamson, 2009) may be profoundly tied to their slow-moving nature (Williamson, 2000). Within ecosystems, and complex adaptive systems in general, slower levels control faster-moving ones (Allen and Starr, 1982, O'Neill et al., 1986 in Holling et al., 1995). In our symbiotic framework this translates into cultural factors being hosts that provide habitat for formal institutions, which makes the former more difficult to modify through policies.

We suggest that our analysis provides some guidance in identifying promising policy-targets: we find that taxes, which have been emphasized as key for economic development (Besley & Persson, 2011; Litina & Palivos, 2016; Marè et al., 2020; Cummings et al., 2009), are in fact highly central in the local Brazilian

economic-institutional system. Taxes are important mediators, forwarding feeding provided by economic growth. Yet, their embedding as prevalent symbionts suggests that targeting them directly is unlikely to change the institutional landscape. Alternative targets of policies are institutions that serve as hosts for other formal institutions: in the Brazilian local reality, we see that institutional quality, and its democratic declinations in the form of participatory councils play a key role as hosts for e.g. tax collection. Thus, the strengthening of local fiscal management (Carroll, 2005; Carroll et al., 2003), and of participatory governance (Avritzer, 2009; Galletta, 2021; Wampler, 2012) bears much greater potential in (also) improving tax collection. Various of our network statistics confirm the potential that the innovative Brazilian participatory councils bear in becoming game-changers for the institutional landscape.

A second group of potential policy-targets are relevant mediators in the system: apart from institutional quality and spending for public goods, inequality, remoteness, and places and gatherings that facilitate social capital are important mediators that deserve attention by policy-making in as much as they can potentially unblock or amplify other dependencies. This confirms the key role of social capital for economic development (Batinti et al., 2019; Putnam, 1993; Sabatini, 2008). We also find that cultural key mediators are gender parity, and the formality of the economy.

Any policy-target is embedded in a slow-moving, less modifiable cultural context (Williamson, 2000): in our local Brazilian system, the relative (in)formality of the economy, the youth of the elected mayor, the prevalence of Catholics and family ties are hosts in the strongest symbiotic relationships between culture (host) and institutions (symbiont). We find taxes and participatory institutions to be the symbionts in such strongest relations. This means that factors such as family ties and religion (Benjamin et al., 2016; Gründler & Köllner, 2020; Inglehart & Baker, 2000; Marè et al., 2020; Sabatini, 2008), but also the attitude towards youth (voting a younger mayor) and the tendency to pursue informal economic transactions (Godfrey, 2011; Zoogah et al., 2015) matter in setting the habitat for formal institutions.

Our empirical strategy based on municipality level data has some drawbacks. For example, it is not possible to comprise the most traditional measures of institutions (constitutional elements, property rights) or of culture (values preferred in the education of own children). Our analysis captures institutional and cultural aspects that are relevant (and vary) at the municipal level. Their numerosity allow reconstructing that economic-institutional system of relations prevalent within a country. Shifting the analysis of institutions and culture to a within-country perspective implies that typical confounding factors like official language, colonizing power, and national institutional frameworks are constant and therefore under better control (Hofstede et al., 2010; Naritomi et al., 2012).

While our results are specific for Brazil, we suggest that the new perspective that can be gained from a systemic view on interdependencies is helpful for the research tradition investigating culture and institutions and their respective role for socioeconomic development (Alesina & Giuliano, 2015; Bisin & Verdier, 2017; Guiso et al., 2009; Gutmann & Voigt, 2020; Marè et al., 2020; Maseland, 2013; Pitlik & Rode, 2017; Tabellini, 2010; Touré, 2021).

As the Nobel Laureate Giorgio Parisi puts it “each complex system is complex in its own particular way”, which makes it difficult to extrapolate any clear external validity from our findings. On questioning him regarding the adequacy of comparing complex systems with similar root data, he encouraged such endeavour because despite some noise specific to the particular system, eventually some emerging patterns common to different systems will be found (Parisi, 2022). We expect our approach to be replicable and of particular interest to large countries in which multilevel governance coexists with subnational cultural variety, for example Italy, Germany, China or the United States.

At the current state of analysis, we suggest the external validity of our findings to be limited to the following insights: interdependencies between institutional and cultural factors are highly complex, so the quest to disentangle unique and unidirectional causalities is likely to result in oversimplifications. In terms of the relative position that institutions assume vis-a-vis cultural and structural factors, our analysis suggests that because of their centrality, institutional factors tend to be highly interconnected—which also makes them more inter-dependent. In contrast, cultural factors tend to assume a greater role as hosts providing habitat for other factors. As any culture-institutional relation is embedded in a broader net of relations, such embedding needs to be understood to fine-shape policy-making. If policy-makers seek to alter e.g. taxes or local democratic governance, they should be aware of the need to design policies that jointly target their hosts. We further highlight our findings seem to confirm that cultural factors form cultural systems (Pryor, 2008) because they feed each other, and other factors. We also suggest further research on the distinction between culture and social capital/trust is desirable (cf. (Pitlik & Rode, 2017; Voigt, 2018)), as social capital may be similarly dependent as formal institutions, hence much less solidly grounded as cultural norms appear to be.

Appendix: Tables

See Tables 4, 5, 6, 7 and 8.

Table 4 Variables included in the analysis. *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

Variable	Type	N.Obs.	Mean	SD	Min	Max	Transformation
taxesnr	Institution	5563	0.316	0.394	0.000	3.403	% _o
taxessh	Institution	5212	0.057	0.055	0.000	0.692	
pubincdiv	Institution	5211	0.205	0.138	0.010	0.765	
healthspend	Institution	5211	126.558	63.278	0.000	813.857	pcap
publicgood	Institution	5212	0.154	0.069	0.000	0.628	
participnr	Institution	5563	0.452	0.480	0.000	4.908	% _o
participforce	Institution	5566	1.395	0.738	0.000	4.833	
femlbmktpart	Culture	5565	0.397	0.039	0.223	0.503	
femwagegap	Culture	5564	0.722	0.084	0.332	1.120	
mayoryouth	Culture	5546	0.584	0.144	0.000	1.000	
catholic	Culture	5563	2.149	0.275	1.081	2.696	exp
extendfam	Culture	5564	0.278	0.086	0.081	0.995	
econformal	Culture	5560	-3.2763	0.719	-6.050	-0.244	log
artgroups	Culture	5209	-1.008	0.926	-6.620	1.611	log; % _o
candidates	Culture	5544	-1.601	1.035	-6.931	1.316	log
gdppcap	Economic structure	5562	1.463	0.696	0.014	4.886	log
gini	Economic structure	5565	0.503	0.066	0.284	0.808	
industry	Economic structure	5564	-2.133	0.654	-4.735	-0.115	log
pubemp	Economic structure	5553	-2.671	0.413	-5.251	-0.916	log
socagginfra	Social capital	5563	0.271	0.274	0.000	2.484	% _o
socgather	Social capital	5563	0.145	0.173	0.000	2.484	% _o
misscomm	Social capital	5565	0.255	0.180	0.000	1.000	norm
intpermea	Remoteness	5563	0.439	0.659	0.000	8.874	% _o
transport	Remoteness	5564	0.008	0.017	0.000	0.833	
rural	Remoteness	5495	36.632	21.803	0.000	95.800	
popdensity	Demography	5562	3.211	1.422	-2.030	9.475	log
pop60plus	Demography	5564	12.094	3.276	2.600	29.400	
sharepoor	Demography	5557	1.946	1.085	0.000	4.018	
illiteracy	Demography	5563	16.169	9.840	1.000	44.400	
elf	Demography	5563	0.465	0.119	0.017	0.707	

Appendix: Example triplets and what to learn from complexity for policy-design

In what follows, we select few specific triplets extrapolated from the entire network. We use these as examples in which institutions work either as multiple symbionts (Fig. 9), multiple hosts (Fig. 10), or as mediators (Figs. 11 and 12). The examples resume some of the findings described and seek to elucidate some policy implications of our analysis. Figure 9 shows how taxes (*taxesnr*) are multiple symbionts, mainly because family ties (*extendfam*) act as middleman that

Table 5 Network topology
Source: Elaboration by the authors based on *Meso-level* dataset, 2010

Network topology	
nr of nodes	30
nr of arrows	212
Min arrow value	0
Max arrow value	48.09
Arrow weight average	3.85
Arrow weight median	2.13
Arrow standard deviation	6.15
Arrow skewness	3.928
nr of paths	870
Average (shortest) path length	1.531
Density	0.244
Degree centralization	0.613
Indegree centralization (valued)	5.39
Outdegree centralization (valued)	2.26
Average eigenvector centrality	0.17
Average closeness centrality	0.66
Average betweenness centrality	40.2
Transitivity	1.048
Overall clustering (nb triads/possible triads)	0.350
Overall inward weighted clustering coefficient	0.015
Overall outward weighted clustering coefficient	0.020
Overall middleman weighted clustering coefficient	0.030
Overall cycle weighted clustering coefficient	0.005
Outward weighted degree assortativity coefficient	- 0.126
Outward strength assortativity coefficient	- 0.069
Inward weighted degree assortativity coefficient	- 0.387
Inward strength assortativity coefficient	- 0.366

forwards an indirect effect of taxes feeding on (left) institutional quality (*pubincdiv*), and (right) on the (in)formality of the economy (*econformal*). In this restricted example, any intended change in the number of taxes collected at the Brazilian municipality level, will have to consider local institutional quality, the extent of the informal sector, and the role of family ties in mediating between the (in)formal market, and the willingness to pay taxes.

Figure 10 depicts how the quality of participatory councils (*participforce*) acts as a multiple host (two outward facing arcs) at the Brazilian local level. Higher quality of participatory councils foresees for example that citizens can co-determine budget allocation on specific issues governed by the council within their municipality. The triplet shows that participatory councils that promote stronger state-society relations have the potential to becoming game-changers within the Brazilian local institutional landscape, as they provide habitat for formal

Table 6 Network statistics for single nodes. *Source:* Author's elaboration based on Fagiolo (2007). *Meso-Level* dataset, 2010

Variable	Type	Joint Centrality	Indegree	Outdegree	Inclustering	Outclustering	Middleman	Betweenness
pubincediv	Institution	43.704	23.655	20.049	0.010	0.015	0.017	154.900
publigood	Institution	30.690	0.615	30.075	0.000	0.016	0.007	83.539
Participforce	Institution	28.673	5.011	23.662	0.006	0.025	0.021	25.590
Participnr	Institution	123.966	77.481	46.485	0.010	0.070	0.071	9.744
taxessh	Institution	92.518	84.560	7.958	0.026	0.000	0.073	6.416
taxesnr	Institution	166.909	117.794	49.116	0.023	0.079	0.116	2.710
healthspend	Institution	4.476	1.249	3.227	0.002	0.000	0.011	1.500
femwagegap	Culture	18.423	3.690	14.733	0.002	0.012	0.009	109.874
econformal	Culture	24.204	3.344	20.860	0.004	0.015	0.011	79.952
femibmktipart	Culture	8.870	1.493	7.377	0.000	0.003	0.007	57.929
candidates	Culture	5.748	0.152	5.596	0.000	0.010	0.004	28.279
extendfam	Culture	41.838	25.373	16.465	0.004	0.024	0.030	20.861
mayoryouth	Culture	29.469	0.439	29.030	0.001	0.013	0.008	18.702
artgroups	Culture	25.578	0.113	25.465	0.000	0.019	0.013	7.686
catholic	Culture	19.262	0.000	19.262	0.000	0.015	0.000	0.000
socagginfra	Social capital	103.171	82.824	20.347	0.008	0.013	0.029	107.675
socgather	Social capital	193.036	178.348	14.688	0.039	0.040	0.065	57.729
misscomm	Social capital	46.980	13.083	33.897	0.004	0.032	0.026	33.922
gini	Economic structure	8.376	0.604	7.772	0.000	0.004	0.006	133.356
industry	Economic structure	63.539	47.950	15.589	0.006	0.053	0.053	4.257
pubemp	Economic structure	28.444	0.054	28.389	0.000	0.021	0.013	3.560
gdppcap	Economic structure	90.509	0.000	90.509	0.000	0.025	0.000	0.000
inpermea	Remoteness	115.748	105.607	10.141	0.022	0.015	0.017	80.519
transport	Remoteness	31.649	16.289	15.359	0.007	0.023	0.024	62.294
rural	Remoteness	26.330	0.163	26.166	0.000	0.014	0.009	24.417

Table 6 (continued)

Variable	Type	Joint Centrality	Indegree	Outdegree	Inclustering	Outclustering	Middleman	Betweenness
illiteracy	Demography	63.465	11.863	51.602	0.004	0.025	0.022	49.935
pop60plus	Demography	76.189	4.232	71.958	0.001	0.026	0.029	22.162
sharepoor	Demography	53.836	5.094	48.742	0.000	0.034	0.009	14.738
popdensity	Demography	65.240	4.721	60.519	0.000	0.026	0.041	3.506
elf	Demography	1.823	0.530	1.293	0.000	0.000	0.000	0.250
Avg (total)								

Table 7 Network topology of inter-domain sub-networks
Source: Elaboration by the authors based on *Meso-level* dataset, 2010

	I-I	C-C	I-C	C-I
nr of arcs	13	13	5	19
Average weight	3.23	0.99	2.61	2.97
Median weight	1.31	0.46	1.54	2.66
Standard deviation	3.41	1.57	2.8	2.18
Skewness	0.95	2.55	1.05	0.48

Table 8 Assortative mixing across domains C, I and Z
Source: Elaboration by the authors based on *Meso-level* dataset, 2010

Domains	Assortativity
C, I, Z	- 0.026
C, I	- 0.048
I, Z	0.046
C, Z	0.202

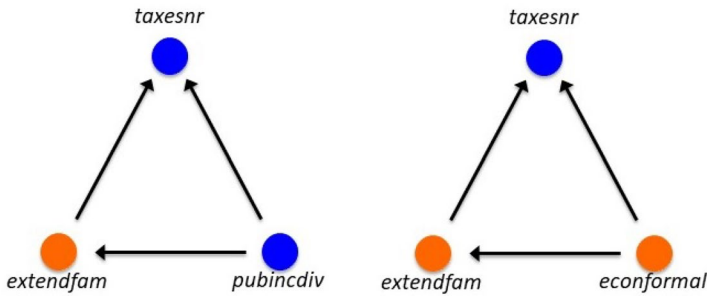
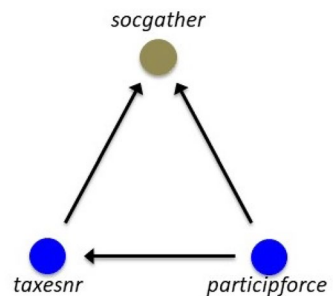


Fig. 9 Taxes as symbionts *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010

Fig. 10 Participatory councils as multiple hosts *Source:* Elaboration by the authors based on *Meso-level* dataset, 2010



institutions (*taxesnr*) and for social capital (*socgather*). Formal institutions with such a profile in the network surely deserve increased attention and monitoring in view of their advantageous position to kick-off a change in the system.

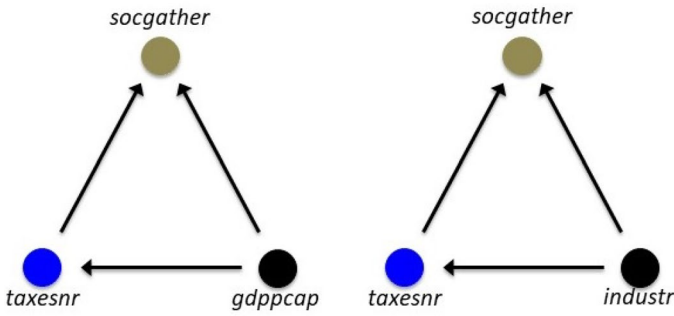


Fig. 11 Taxes as middleman Source: Elaboration by the authors based on *Meso-level* dataset, 2010

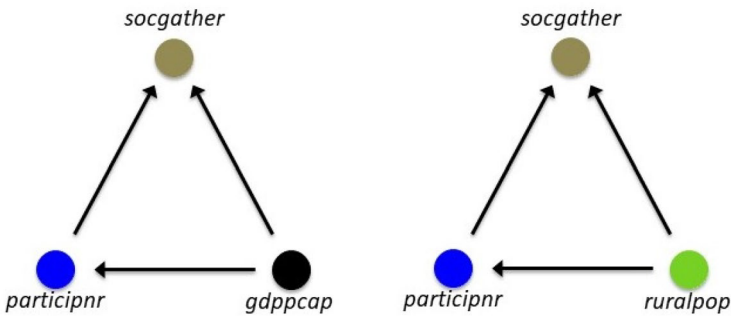


Fig. 12 Participatory councils as middleman Source: Elaboration by the authors based on *Meso-level* dataset, 2010

In Fig. 11, the number of taxes collected (*taxesnr*) is the middleman for an indirect effect that sees two economic control factors, GDP per capita (*gdppcap*, left) and industrialization (*industry*, right) feeding local social capital (*socgather*). Both triplets seem to summarize how at the Brazilian local level, economic development can affect social capital and that institutions mediate such process. In a similar fashion, in Fig. 12 the number of participatory councils (*participnr*) assumes a middleman position: the participatory institution channels feeding for social gatherings which comes from GDP per capita (*gdppcap*, left), and from the share of rural population (*ruralpop*, right). For policy-making it can be relevant to acknowledge such kind of configurations. The first example stresses that changes in taxes may have direct and indirect effects on society that are not easy to predict. The second example confirms the potential of participatory councils as system-changers, as they depend upon—and connect to—diverse structural features of the local Brazilian society.

Funding Open access funding provided by Università degli Studi di Trento within the CRUI-CARE Agreement.

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