Società Italiana
di Economia dello Sviluppo

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June 2022

SITES Working Paper No. 11

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Abstract

We propose a methodology inspired by ecology to map the complex interdependencies between cultural and institutional factors - controlling for other socioeconomic and structural characteristics. We characterize interdependencies as asymmetric symbiotic relations, distinguishing between 'hosts' that nurture other factors and 'symbionts' that reversely feed on the former. We use correlation network analysis to compute a map of multiple such interdependencies for Brazil, which has a vast territory, internally diversified historical paths and a multilevel governance structure. We set the empirical analysis at the municipality level and find that institutional factors tend to be symbionts, whereas cultural factors tend to be hosts. However, our results also show that institutions assume multiple roles within a complex network of interdependencies, often becoming themselves habitat for others or transmittors of indirect effects.

JEL codes: O17; O43; C18; D02; H70

Keywords: institutions; culture; symbiosis; correlation network analysis; Brazil

*Corresponding author: nadia.vonjacobi@unitn.it. We gratefully acknowledge financial support from the University of Foggia (InnovaPuglia PSR Puglia). We thank Massimiliano Vatiero, Roberto Tamborini and Luigi Bonatti for very helpful comments on previous drafts, and Leonardo Weller and the entire Economia Politica research group of the Fundação Getulho Vargas for important comments and suggestions.

1 Introduction

The relationship between institutions and socioeconomic development is a complex one. Institutions often play a complementary role with respect to other factors, such as human capital (Glaeser et al., 2004), culture (Guiso et al. (2009); Gutmann and Voigt (2020) Tabellini (2010); Williamson (2009)), market structure (Aoki, 2001), or other institutions (Amable (2016); Pagano and Rowthorn (1994); Pagano and Vatiero (2015)). Therefore, it is a challenge to isolate specific institutional effects, and there is ongoing debate about the directionality of such effects.

The relationship between culture and institutions in particular has been much investigated, especially to unfold which kinds of norms tend to prevail on the others in shaping trajectories for socioeconomic progress (Belloc and Bowles (2013); Williamson (2009); Touré (2021)). 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 and Robinson (2019); (Hodgson, 2001) (Voigt, 2018)). Some authors have stressed the role of informal norms in guaranteeing enforcement of formal institutions (Acemoglu and Jackson (2017); Marè et al. (2020)), yet others have underlined how formal institutions contribute to shaping culture (Grosjean, 2011). In this paper, we adopt a systemic view (Kuran, 2009) and propose a methodological approach through which it is possible to map multiple interdependencies between institutions and other cultural, institutional, and socioeconomic factors. We characterize interdependencies as asymmetric symbiotic relations (Jacobi, 2018), which are special cases of institutional complementarity (Amable (2000); Aoki (2001)). Our approach delivers a map of multiple and simultaneous dependencies - like a complex network.

We apply our methodology to the case of Brazil, which has a vast territory, a multilevel governance structure and substantial subnational cultural differences, due to diverse

historical development paths (Leff (1997); Hofstede et al. (2010); Musacchio et al. (2014); Naritomi et al. (2012)). Therefore, we set our analysis at the sub-national level (Putnam (1993); Tabellini (2010)), and study Brazil's 5565 municipalities, which represent the country's lowest level of governance including legislature. We prefer focussing on a single country as this makes the relationships that tie culture to institutions less subject to confounding factors that plague cross-sectional analysis. We implement correlation network analyses (Horvath (2011); Jacobi (2018)) to acquire a microscopic-type view on relations that are usually investigated at the macro level. By plotting multiple relationships within an overall network we are able to identify institutional factors that are most 'central' within our web of asymmetric interdependencies. In line with a symbiotic view, we distinguish between 'hosts' that nurture other factors by providing a specific habitat or service (Cain et al., 2011), and symbionts (Overstreet and Lotz, 2016) that reversely 'feed' on other factors and thereby are more dependent on them.

Our results suggest that institutional factors tend to be symbionts, whereas cultural factors tend to be hosts, confirming authors such as Williamson (2000) or Maseland (2013) stressing a relatively more exogenous role of culture with respect to institutions. Our results however also show that institutions assume multiple roles within a complex network of interdependencies, often becoming themselves habitat for others or transmittors of indirect effects. Within our results, the proxies of social capital we insert as control factors stand out as highly central and as key transmittors within the overall network.

The paper first introduces our theoretical framework (section 2), in particular a perspective in which different institutional and structural factors engage in asymmetric symbiotic relationships. We then introduce correlation network analysis and our empirical strategy to construct a directed weighted network that maps asymmetric interdependencies (section 3). Section 4 introduces network statistics derived from graph theory to study the different embedding the factors we study. In section 5 we introduce

our pool of institutional, cultural and structural control variables and section 6 presents our results. Our concluding section outlines some key research implications.

2 A Systemic View that Draws on Symbiosis

The literature centred on institutional complementarities has proposed a co-evolutionary perspective in which institutions interlock with social norms and economic specialization in specific ways (e.g. Aoki (2001); Pagano and Rowthorn (1994)). A series of analogies between the coevolution of social structures and living organisms have been proposed (Battistini and Pagano (2008); Richerson et al. (2010); Boyer and Petersen (2013); Jacobi (2018)). We follow Jacobi (2018) and characterize the interdependencies among institutional factors and other factors of cultural, institutional or socioeconomic nature as symbiotic relationships.

2.1 Key features of an ecological perspective

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.

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 and Bowles, 2013). Symbiosis, which can be interpreted as the 'living together' of unlike organisms (De Bary, 1879) implies functional neutrality because relationships are highly

specific and open to the myriad of possible combinations with which living organisms can exchange. 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 institutional interdependencies. 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 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 threfore exclude strict mutualism, which is symmetric (Cain et al., 2011). Our interdependencies are therefore relationships in which a symbiont feeds on the habitat provided by the host. Our institutional, cultural and socioeconomic control factors may all potentially assume the role of host or symbiont.

2.2 Theoretical Framework

We next propose a formal treatment of asymmetric symbiotic relationships. In a similar fashion to existing literature on institutional complementarities, we are interested in the interdependencies that exist between 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. Studying the interdependencies between different domains requires a theoretical framework in which the ''payoffs of agents in one domain may be affected by the institutions prevailing in other domains'' (Aoki, 2001, p.225). The endogenous rules that result in the different environments can represent exogenous factors for another environment.

[1] Note that other authors refer to both organisms engaged in a symbiotic relationship as symbionts.

The factors we imagine to be engaged 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. Institutional rules can be re-conduced to an underlying choice process based on strategic interactions (Aoki (2001); Witt (1989)). Although not as easily linked to choice processes, we also include structural features as controls in our pool of factors. We assume our treatment to be compatible with such inclusion: on the one hand, control factors such as geographical or demographic factors represent exogeneous factors to the institutional environment in which a specific rule develops (Aoki, 2001). On the other hand, migration choices, at least at the local level (such as moving from the mountains to the plain, or leaving a rural village to reach urban areas), can contribute to the environmental features that surround people.

We depart from an exploratory point of view according to which all institutional factors 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 section 3). In what follows, we formalize a single asymmetric symbiotic relationship between two institutional factors.

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). The cumulative, collective outcome of such choices leads to the institutionalization of an endogenous rule. Agents can choose between two different rules, 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^{**}). Payoff functions (u in C and v in I) are assumed to be identical within each

domain.

We delineate two cases in which we invert the argument and therefore the directionality of the asymmetry: in case A an institutional rule is a symbiont depending on a cultural rule (cf. Maseland (2013); Tabellini (2010)). In case B a cultural rule is a symbiont depending on an institutional rule (cf. (Bisin and Verdier, 2017) Grosjean (2011)). Equations 1 and 2 summarize an asymmetric relationship in which increasing differences (Topkis (1978); Topkis (2011); Milgrom and Roberts (1990)),[2] 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^{**}.

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

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

with α and β larger than zero. Within domain I, the payoff associated to chosing Λ^* over Λ^{**} is similarly greater in presence of Σ^*, which resembles a complementarity between Σ^* and Λ^*.

CASE A: Institutional rule "feeding on" a cultural rule Equation 3 stresses an asymmetry according to which payoffs for liberal views on women's role in society increase more in presence of progressive taxation than vice versa.[3]

$$0 < \alpha < \beta \tag{3}$$

In terms of our framework based on symbiosis, as Λ is dependent on Σ more than vice versa, α is smaller than β. Λ then is a symbiont on Σ. Note that such asymmetry can

[2] The asymmetric relations we describe resemble strategic complementarities as studied by the same authors.

[3] We exclude the case in which $\alpha = 0$ as this would have implications of independence.

also be expressed in terms of supermodularity conditions (Aoki (2001); Topkis (1978); Topkis (2011); Milgrom and Roberts (1990)). According to 4 and 5, choices in domain I are more dependent on choices made in domain C than vice versa. In particular, in domain I, Λ^* is the more convenient choice of rule whenever the rule Σ^* prevails.

$$u(\Sigma^*;\Lambda^*) - u(\Sigma^{**};\Lambda^*) \geq u(\Sigma^*;\Lambda^{**}) - u(\Sigma^{**};\Lambda^{**}) \tag{4}$$

$$v(\Lambda^*;\Sigma^*) - v(\Lambda^{**};\Sigma^*) > v(\Lambda^*;\Sigma^{**}) - (\Lambda^{**};\Sigma^{**}) \tag{5}$$

In this case, Σ^* resembles an exogenous factor favouring the development of the endogeneous rule Λ^*. In light of our example, more liberal views on women's role in society would favour acceptance of progressive taxation (as e.g. studied by Gründler and Köllner (2020)). In terms of our framework, in case A the acceptance of progressive taxation is a symbiont on liberal attitudes towards women. This implies an asymmetric relationship between Λ^* and Σ^* in which Λ^* depends upon Σ^* or else said, 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 (as in 3).

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. In this case, choices regarding progressive taxation affect the payoffs derived from attitudes towards women more than vice versa. In a specular fashion to case A and in line with 1 and 2, we formalize the asymmetric relationship between Λ and Σ in case B as:[4]

$$\alpha > \beta > 0 \tag{6}$$

[4]For the reason explained in the previous footnote, we exclude the case in which $\beta = 0$.

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.

In terms of supermodularity conditions, in case B more liberal views on women are more likely to occur in the domain C in presence of acceptance of progressive taxation (7). While choices in the domain C may or may not reversely act as 'exogeneous' factor promoting progressive taxation, the directionality of such positive effect, if present, is smaller than vice versa (as in 6).

$$u(\Sigma^*;\Lambda^*) - u(\Sigma^{**};\Lambda^*) > u(\Sigma^*;\Lambda^{**}) - u(\Sigma^{**};\Lambda^{**}) \tag{7}$$

$$v(\Lambda^*;\Sigma^*) - v(\Lambda^{**};\Sigma^*) \geq v(\Lambda^*;\Sigma^{**}) - v(\Lambda^{**};\Sigma^{**}) \tag{8}$$

By presenting the two inverted arguments of cases A and B we stress that our framing potentially allows any factor to be a symbiont on another, without setting the directionality of interdependence ex ante. Our illustrative example has focussed on two rather specific cultural and institutional factors. Marè et al. (2020) and Gründler and Köllner (2020) have studied the link between family attitude and taxes finding empirical evidence for an interdependence between the two domains. In line with such literature, we expect case A to be more likely than case B. Furthermore, authors of such studies show that the relationship between the attitude towards women's role in society and towards taxation may be reinforced by a further - indirect - relationship that could be mediated by a third factor, e.g. the value attributed to family ties (Marè et al., 2020).

As we shall see in what follows, the systemic view we propose puts each asymmetric relationship between two institutional factors into a broader context - namely the other relationships that tie such factors to other, further institutional or structural features. Each relationship we measure is therefore part of a broader, 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

3.1 Correlation Networks

The construction of a correlation network can be subdivided into three main phases, two of data preparation and one of analysis. We first build a dedicated dataset (phase 1), which collects cultural, institutional and socioeconomic variables at a given level of analysis, here municipalities in Brazil. In phase 2, we calculate pairwise correlations among all variables included in our pool of factors in order to construct a relational dataset (so-called *edgelist*) to which network statistics can be applied. The unit of analysis of an edgelist is the single relation (*edge*) between two factors (*nodes*): here it is the correlation coefficient computed over the available observations (5565 municipalities in our Brazilian dataset). We apply restrictions using a Pearson test in order to preserve only correlation coefficients with statistical significance at the 5% level. In phase 3 we reshape the dataset: we eliminate the original variables and transform columns reporting correlation coefficients into observations (rows).

This first computation delivers a weighted, undirected network that maps symmetric relationships, which are quantified through the absolute value of the correlation coefficient. At this point it is possible to apply network statistics to the obtained edgelist. A series of different software packages is today able to compute standard network statistics on weighted networks.[5]

[5] We have made use of the package *netsis* (Miura, 2012) designed for STATA. For its application to correlation networks, however, it is necessary to use the inverse of the correlation coefficient in all network statistics that make use of the concept of *paths*, such as the closeness or betweenness degree (Freeman, 1977). The plots included in this article have been designed using *nwcommands* (Grund et al. 2015).

3.2 Mapping Host-Symbiont Relations in Correlation Networks: Two-Way Quantile Regressions

To represent symbiotic relationships with asymmetric character, we construct a directed network that reflects directions of habitat-provision between nodes. This requires refinement of the computation of the correlation network, in particular the construction of a network based on regression models (Horvath, 2011, ch.13). Our strategy to capture asymmetric symbiotic relationships is based on the use of two-way quantile regressions.

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 xs", 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 pth 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 funcion 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:

$$y_i = \alpha^{(p)} + \beta^{(p)} x_i + \epsilon_i^{(p)} \tag{9}$$

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 $((29 * 28) = 812)$. For each y, we estimate five quantile regression models for which the pth conditional *quantile* given x_i is

$$Q^{(p)}(y_i|x_i) = \alpha^{(p)} + \beta^{(p)}x_i + \epsilon_i^{(p)} \tag{10}$$

where the pth quantile of the error term is zero[6]. We loop through the entire list of variables included in the analysis, and compute ten quantile regressions for each possible pair of variables. We run five regressions - one per quantile - for one of the two variables, taking it as dependent variable; then we switch dependent and independent variable and run the other five regressions. We keep only pairs of variables for which we detect a symbiotic relationship. We restrict our selection by keeping 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 $p <= 0.10$.[7] 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 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 increase in the slope coefficient along quantiles for each direction. The logic is that a greater increase in the slope coefficient

[6] In line with (Hao and Naiman, 2007, p.29)). Error terms at different quantiles are not neccesarily i.i.d.

[7] Indeed, for more than 85% of the pair of variables we test we find that all the ten β coefficients we estimate are significant with a p-value of $p <= 0.05$.

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 in percentage points of such increase 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 previous 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 10 when $\Sigma = x$ and $\Lambda = y$, namely:

$$\beta_{\Sigma}^{(p20)}; \beta_{\Sigma}^{(p35)}; \beta_{\Sigma}^{(p50)}; \beta_{\Sigma}^{(p65)}; \beta_{\Sigma}^{(p80)} \tag{11}$$

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 10 when $\Lambda = x$ and $\Sigma = y$, namely:

$$\beta_{\Lambda}^{(p20)}; \beta_{\Lambda}^{(p35)}; \beta_{\Lambda}^{(p50)}; \beta_{\Lambda}^{(p65)}; \beta_{\Lambda}^{(p80)} \tag{12}$$

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 permit detection of an asymmetric symbiotic relationship between Λ and Σ if at least three of the five coefficients in both (11) and (12) are statistically significant. 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 $|\beta_{\Lambda}^{(p20)}| < |\beta_{\Lambda}^{(p80)}|$

- $\{|\beta_{1\Sigma}^{(p80)} - |\beta_{1\Sigma}^{(p20)}|\} > \{|\beta_{1\Lambda}^{(p80)}| - |\beta_{1\Lambda}^{(p20)}|\}$ [8]

In such case, we observe a situation in which 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 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 13, which determines the weight of an arc departing from Σ and heading towards Λ.

$$[(|\beta_{1\Sigma}^{(p80)}| - |\beta_{1\Sigma}^{(p20)}|)/|\beta_{1\Sigma}^{(p20)}|] - [(|\beta_{1\Lambda}^{(p80)}| - |\beta_{1\Lambda}^{(p20)}|)/|\beta_{1\Lambda}^{(p20)}]| = w_{\Sigma\Lambda} \tag{13}$$

The directed network we obtain is far less dense than the initial correlation network.[9] Arrows go from habitat-nodes (hosts) towards symbionts.

4 Centrality and Motifs in Directed Networks

In analogy to undirected networks, it is possible to compute statistics in weighted directed networks, which resembles the detection of clustering (Clemente and Grassi, 2018). Clusterings reflect the local configuration of specific network motifs, such as triangles (Onnela et al., 2005) and allow observing flux intensities with particular attention to the position that certain nodes assume in such patterns. A motif is 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 (Onnela et al., 2005). Recent extensions in the computation of clustering coefficients to

[8] 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.

[9] The reduced density of the directed network may in part be due to the restrictions we impose: only converging estimates and relations in which at least three out of five of computed coefficients were significant at the 10% level have been included. Including a control factor further reduces the amount of converging estimations due to the limitation of sub-samples for each of the estimated quintiles.

weighted directed networks have improved our ability to capture subgraph intensities within the overall complex network, allowing us to better understand network architecture.

Within our directed networks, we are interested in some specific positions that institutional factors may assume: to capture indegree centrality we compute the weighted sum of inward-facing arcs. Nodes with high in-degree are multiple symbionts, meaning they depend on multiple habitat-nodes. The specular measure of outdegree centrality, on the other hand computes the weighted sum of outward-facing arcs. In our analysis, nodes with high outdegree are hosts that provide habitat to a multitude of other factors.

We further follow (Fagiolo, 2007) and use *nwwcc* (Joyez, 2017) in STATA to compute weighted clustering coefficients in which nodes assume different roles (Figure 1). Fagiolo (2007) builds upon Onnela et al. (2005) and Milo et al. (2002) in his work by discriminating between different triangle types that can form within a weighted, directed network. Adapting the formalization proposed in Fagiolo (2007) to our previous treatment, we compute clustering coefficients as the ratio between the number of triangles in the network graph having i as one vertex taking part in the specific subgraph (triangle type) and the number of all possible triangles that i could have formed within the network. $i \in C, I, Z$ where C and I represent our pool of cultural and institutional variables, respectively, and Z represents a third domain in which we insert a group of control variables regarding trust, economic, demographic and geographical factors (see section 5). Our weighted clustering coefficients are computed using the geometric mean, implying that a weak tie reduces the weight of the entire motif (Onnela et al., 2005).

Multiple symbionts are detected through inclustering (two inward facing arcs), multiple habitat-nodes, in a similar fashion, through outclustering (two outward facing arcs). Nodes with high middleman-clustering coefficients are factors that propagate an indirect effect that reinforces the direct effect of other two nodes' connection. We use middleman-clustering to capture transmittor-roles of nodes in our network.

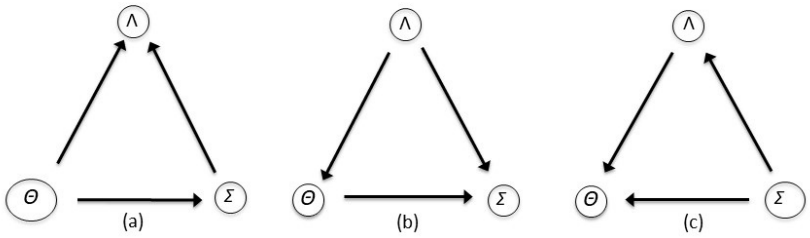

Figure 1: In- and out-clustering patterns, middleman. Adapted from Fagiolo (2007)

In line with our illustrative example, we imagine a triangle pattern to form between attitude towards women's role in society (Σ) and the acceptance of progressive taxation (Λ). We now add a third factor belonging to the domain of controls, Θ, which is a proxy for generalized trust. Figure 1 represents three different positions that formal institutions can take within triplets. In panel a the acceptance of progressive taxation is subject to inclustering: it is a multiple symbiont, feeding on both the attitude towards women's role in society and trust. In panel b the institutional variable is subject to outclustering: it is a habitat-node for both the cultural variable (Σ) and trust (Θ). Finally, in panel c the acceptance of progressive taxation assumes the role of the middleman: it is a habitat node for trust, but a symbiont on the attitude towards women. Therefore, it acts as transmittor or amplifier through the indirect dependence of Θ on Σ.

5 Data

For our empirical analysis, we rely on institutional and control factors measured at the municipality level: in the Brazilian federal system, this is the lowest level of governance - including legislation, at which formal institutions can emerge. We work with the

universe of the 5565 Brazilian municipalities, refraining from using surveys that do not have such statistical representativeness (Hofstede et al., 2010). Instead, we use a Meso-level dataset Jacobi (2018), which combines census data with a municipality-survey (Perfil dos Municipios, IBGE) and their public accounts data (FAZENDADATA, IBGE) of the same year (2010). Official language, colonizing power, and national institutional frameworks are constant, which reduces the relevance of potential confounding factors (Hofstede et al. (2010); (Naritomi et al., 2012)).

Here it is worth to specificy how we distinguish institutions from culture. We consider legally stipulated rules to belong to the domain of institutions (Hodgson, 2001). The locus of their enforcement is the state (Acemoglu and Robinson (2019); Voigt (2018)). Culture, which comprises informal institutions, is proxied by factors that capture socially accepted expectations (Opp, 1982). These reflect in common dispositions that are enforced internally by society (Voigt (2018); Gutmann and Voigt (2020)). We proxy such prevalent shared mental models through aggregate measures instead of individual replies to surveys, in line with social psychology findings that suggest culture cannot be reduced to the individual level (Na et al., 2010).[10]

5.1 Measures of formal institutions

The variables we use to proxy formal institutions are the following:

- number and decisional strength of participatory councils, in which public administration and citizens jointly decide on policies and budget allocation (Avritzer, 2009). The ‰quantity (*participnr*) and mean quality (*participforce*) of Conselhos Partecipativos[11] may proxy state-society interactions (Wampler, 2012) and significantly relate to public spending (Galletta, 2021);

[10] Value surveys are further not available with statistical significance at the municipality level so far.
[11] Computed over potentially 12 thematically different councils.

- the ‰ number of taxes collected (*taxesnr*) and their share within municipal revenues (*taxessh*) may proxy institutional quality (Cummings et al. 2009) and are related to a series of other behaviours and cultural factors (Marè et al. (2020); Gründler and Köllner (2020));

- public income diversification (*pubincdiv*), measured as Herfindahl index over five sources of public reveneues. The variable serves as proxy for sound fiscal management (Carroll (2005); Carroll et al. (2003)) that relates to tax collection and public expenditures and therefore represents an indicator of institutional quality;

- 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), both related to democratic performance (Galletta, 2021) and to social ties, specifically the polarization of society (Burns and Keswell, 2015);

5.2 Cultural factors

The variables we use to proxy cultural factors are:

- women's position in society as studied by Cavapozzi et al. (2021), Inglehart and Baker (2000), Gangadharan et al. (2019), which we proxy through female labour market participation (*femlbmktpart*); and the female wage gap (*femwagegap*):

- attitude towards youth, which partially reflects conservative attitude (Inglehart and Baker, 2000), proxied by the inverse of the mayor's age (*mayoryouth*);

- catholic, proxied as exponential share of Catholics over the municipal population, which may also reflect conservative attitudes (Inglehart and Baker, 2000) and relates to a series of other economic behaviours (Benjamin et al., 2016), trust (Guiso et al., 2009) and to family ties (Marè et al. 2020);

- family ties, proxied by the share of extended families (*extendfam*), which characterize more traditional societies (Inglehart and Baker, 2000) and tend to associate with lower generalized trust (Alesina and Giuliano, 2015) and greater tax evasion (Marè et al., 2020);

- prevalence of the informal economy, proxied as ratio between indirect taxes and factor GDP which captures the formality of aggregate demand (*econformal*) and has been studied e.g. by Godfrey (2011) and Zoogah et al. (2015);

- (unproductive) entrepreneurship (Baumol, 1996), proxied by the ‰ incidence of number of art groups on the municipal population (*artgroups*) through which we seek to capture that collective motivation to challenge contemporary conventions and norms that is embedded in social ties (Lindqvist (2011), (Rindova et al., 2009));

- democratic attitude, proxied as per capita number of candidates that stood for municipal elections (*candidates*), which captures electoral competition (cf. (**?**));

5.3 Thematically Grouped Controls

Social capital/trust: which we proxy as (1) ‰ number of infrastructure facilitating social aggregation (*socagginfra*) such as museums, theatres, stadiums, etc., which are typically provided through public expenditure; (2) the ‰ number of cultural centres, community radios and clubs/associations (*socgather*). We interpret these as non-compulsory municipal venues that emerge by request on behalf of citizens. Similar social gatherings have been considered a potential vehicle for pressure on institutions (Touré, 2021), and for the unfolding of particularized versus generalized trust(Uslaner and Conley, 2003); (3) the likeliness of missing communication (*misscomm*), which we measure as educational fractionalization (Bossert et al., 2011) that looks at illiteracy rates within different age and ethnic groups, e.g. among young white vs. elderly black and computes the compounded "gaps" between all groups, measured as distance between the groups'

illiteracy shares. Missing communication is likely to imply reduced trust and cooperation (Jacobi (2018); Jones and Zhan (2020), Kolo (2012)).

Economic: we include municipal log of 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*).

Remoteness: to control for the degree of connectedness of an area to economic activity, we include a measure of institutional permeability proxied by the municipal collaborations with other governmental levels or municipalities, scaled as ‰ inhabitants (*instpermea*), the density of transportation services per km^2 in the municipal area (*transport*) and the share of population living in rural areas (*rural*).

Demographic: notably population density (*popdensity*), the share of residents aged older than 60 (*pop60plus*) the share of residents with monthly income below 70 reais[12] (*sharepoor*), the adult illiteracy rate (*illiteracy*) and an ethnic fractionalization index (Alesina and Ferrara, 2004) over the five ethnicities officially recorded in the Census (*elf*).

We transform variables to approximate normal distribution and to make count variables comparable across municipalities with different degrees of urbanization (per 1000 inhabitants). Table 1 reports the main descriptive statistics of the variables used in the analysis.

[12] National absolute poverty line below which social transfers are guaranteed no matter the exact family composition

Table 1: Variables included in the analysis

Variable	Type	N.Obs.	Mean	St.Dev.	Min	Max	Trans
publicgood	Institution	5212	0.154	0.069	0.000	0.628	
Participnr	Institution	5563	0.452	0.480	0.000	4.908	‰
Participforce	Institution	5566	1.395	0.738	0.000	4.833	
taxesnr	Institution	5563	0.316	0.394	0.000	3.403	‰
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
femwagegap	Culture	5564	0.722	0.084	0.332	1.120	
femlbmktpart	Culture	5565	0.397	0.039	0.223	0.503	
mayoryouth	Culture	5546	0.584	0.144	0.000	1.000	
artgroups	Culture	5209	-1.008	0.926	-6.620	1.611	log;pcap
extendfam	Culture	5564	0.278	0.086	0.081	0.995	
econformal	Culture	5560	-3.2763	0.719	-6.050	-0.244	log
candidates	Culture	5544	-1.601	1.035	-6.931	1.316	log
catholic	Culture	5563	2.149	0.275	1.081	2.696	exp
misscomm	Social Capital	5565	0.255	0.180	0.000	1.000	norm
socgather	Social Capital	5563	0.145	0.173	0.000	2.484	‰
socagginfra	Social Capital	5563	0.271	0.274	0.000	2.484	‰
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
gdppcap	Economic Structure	5562	1.463	0.696	0.014	4.886	log
intpermea	Remotenness	5563	0.439	0.659	0.000	8.874	‰
transport	Remotenness	5564	0.008	0.017	0.000	0.833	
rural	Remotenness	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	
illiteracy	Demography	5563	16.169	9.840	1.000	44.400	
elf	Demography	5563	0.465	0.119	0.017	0.707	
sharepoor	Demography	5557	1.946	1.085	0.000	4.018	

Source: Authors' elaborations on *Meso-level Data*, 2010.

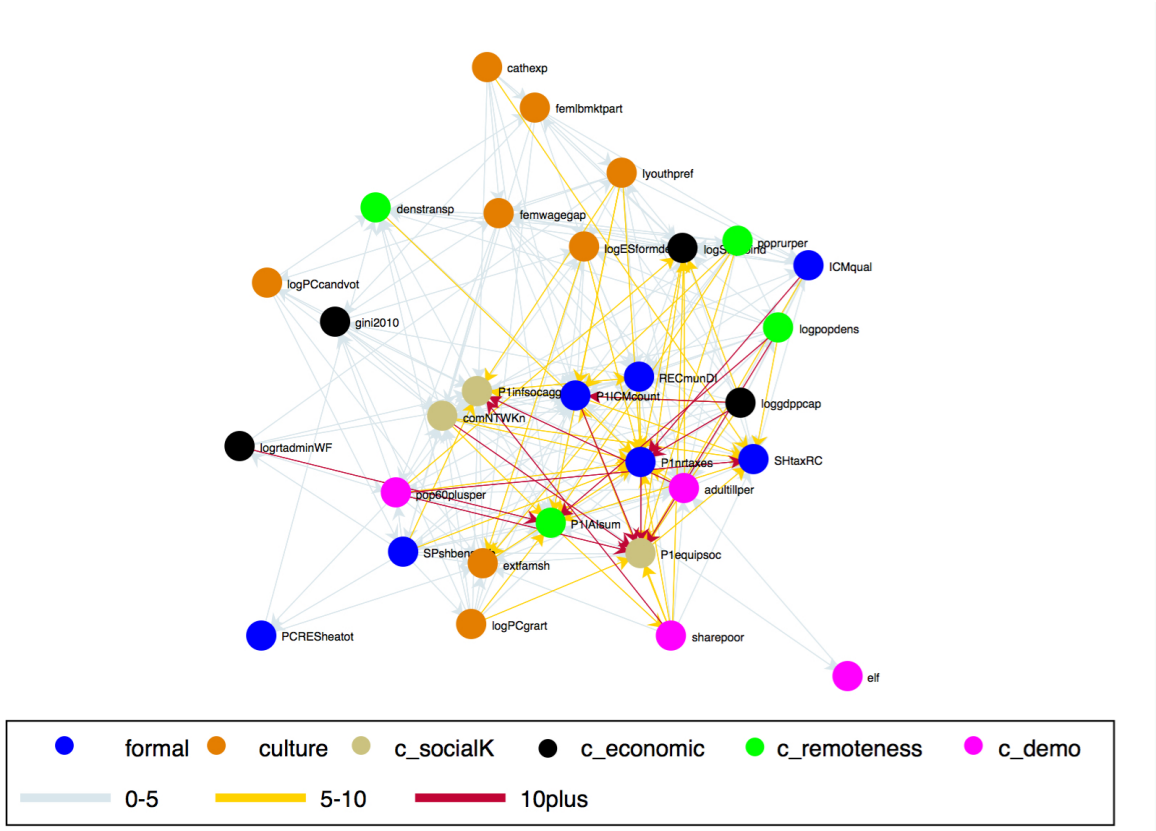

Figure 2: Directed weighted network summarizing computed asymmetric relationships

6 Results

Figure 2 represents the directed weighted network we compute: nodes are labeled according to their thematic belonging. Arcs are coloured in line with weight size categories. Strongest arcs are darker and depict the following inter-dependency flow: the node from which an arc originates is a 'host', providing habitat to the node reached by the arc, which is a 'symbiont'.

6.1 Asymmetric Relations

Within the directed weighted network, we notice that institutions are prevalently engaged in asymmetric relationships in which they depend on other factors (62 relations). Table 2 reports all relations where the asymmetry is larger than 5 percentage points. Symbiont institutions turn out to be number of taxes, share of taxes within municipal revenues, number of participatory councils, and public income diversification. Among such relations, it is cultural factors that most often act as habitat-nodes for institutional variables (19 relations). Among those, the cultural factors engaged as hosts with strongest asymmetry are: the prevalence of the informal sector, the inverse of the mayor's age, the share of Catholics, and the share of extended families. Looking at our control factors, we find that those feeding institutions with largest weight are: share of residents aged older than 60, GDP per capita, share of poor residents, and the incidence of social gatherings proxying social capital.

Within our weighted directed network, institutions however also assume the role of hosts (Table 3), but less frequently (in 36 asymmetric relations). We find greater variety among institutional factors that provide habitat to others in symbiotic relationships: apart from the institutional factors that already play a central role as symbionts (number of taxes, share of taxes within municipal revenues, number of participatory councils, and public income diversification), we also identify the following institutional habitat-nodes: per capita public expenditure on public goods and the quality/strength of participatory councils. In this case, most of symbiotic relationships with asymmetry stronger than 5 percentage points have other institutional variables as their symbionts (number of taxes and share of taxes in municipal revenues). Only one cultural variable is a symbiont on institutions (share of extended families). We find that the strongest asymmetric relationships in which institutions are hosts have social capital variables as their symbiont: number of taxes and the number of participatory councils both feed the incidence of social gatherings.

Table 2: Asymmetric relations with formal institutions as symbiont

Host type	# Relations	Asymmetric relations stronger than 5ppt. Host variable	Symbiont variable	Asymmetry weight
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
Economic Remotenness	11	transport	taxesnr	7.981
		popdensity	taxessh	5.251
		rural	participnr	5.146
Demography	12	pop60plusper	taxessh	32.110
		sharepoor	particpnr	9.262
		illiteracy	taxesnr	7.795
		sharepoor	taxesnr	7.210
		pop60plus	taxesnr	5.149
Total	62			

Source: Author's elaboration based on *Meso-Level Dataset*, 2010

Table 3: Asymmetric relations with formal institutions as hosts

Symbiont type	# Relations	Asymmetric relations stronger than 5ppt. Host variable	Symbiont variable	Asymmetry weight
Institutions	13	participforce	taxesnr	10.887
		publicgood	taxesnr	6.853
		pubincdiv	taxesnr	6.753
		participnr	taxessh	5.551
Culture	5	pubincdiv	extendfam	7.283
Social Capital	7	taxesnr	socgather	48.093
		participnr	socgather	36.261
		participforce	socgather	8.761
		publicgood	socagginfra	5.709
Economic Structure	4	n.a.	n.a.	n.a.
Remotenness	4	taxessh	instpermea	7.958
Demography	3	n.a.	n.a.	n.a.
Total	36			

Source: Authors' elaborations on *Meso-level Data*, 2010. n.a. stands for no relationship with weight above 5ppt found.

6.2 Network Statistics

Turning to the centrality statistics we compute over the weighted directed network (Table 4), we first observe that institutional variables tend to have higher values of indegree than of outdegree, while cultural factors tend to have higher values of outdegree than of indegree. This confirms our finding that cultural factors tend to be hosts more often, as compared to formal institutions that tend to be symbionts. We find our controls on social capital also display high indegree, hinting that social capital is itself a volatile entity, depending on multiple other factors. Demographic and economic control factors tend to have high outdegree, suggesting they mainly serve as hosts (with the exception of industrialization which appears more as a symbiont). In terms of overall centrality in the network, we notice that measures of formal institutions and of social capital tend to be most connected and therefore central in the network (as can also be seen in figure 2).

In terms of Fagiolo's clustering coefficients, which position nodes into specific subgraphs, table 4 shows that institutional variables have on average high values of inclustering, meaning they tend to be part of triplets in which they depend on more than one factor at the same time (two inward facing arcs). We find a particularly striking difference to cultural variables: the average value of inclustering for institutional variables is ten-fold greater than the average value of cultural factors, reinforcing the result emerging from bilateral relationships. Formal institutions are generally symbionts/more dependent on other factors than cultural norms are. The institutional variables with highest values of inclustering are: number of taxes collected, share of taxes in municipal revenues, number of participatory councils, and public income diversification. Among our control factors, we find high inclustering values for two social capital variables (incidence of social gatherings and of infrastructure facilitating social aggregation) and for two of our measures of remoteness (institutional permeability and density of transportation services).

In terms of outclustering, formal institutions again score the highest values. However,

we notice that: (i) this result is driven by two institutional variables, namely the number of taxes collected and the number of participatory councils, which have the largest outclustering of all the variables in our empirical analysis; (ii) other types of factors have outclustering values that are not too different from those of institutions. Interestingly, we find that average outclustering of cultural variables is only half with respect to the average value for institutions. Cultural factors tend to be differently embedded as formal institutions - they are less engaged in triplets as the ones we capture with weighted clustering coefficients. Our clustering results however confirm a tendency we already observed in terms of indegree and outdegree: cultural factors are much more likely to be hosts than to be symbionts. This is consistent with figure 2 wherein cultural factors position themselves mostly on the outskirts, hinting for some greater degree of exogeneity of culture than what can be assumed for institutional factors, which locate at the centre of the network. Among our control factors we find that the following are likely to engage in outclustering patterns: the share of industry in municipal GDP, incidence of social gatherings, share of poor people, and the likeliness of missing communication. These factors are likely to provide relevant habitat for other variables in the network.

Finally, in line with our findings on centrality, we find that institutions also have on average higher values of the middleman statistics than cultural factors. We again highlight the very important role of three formal instiutions as transmittors, namely the number of taxes, the share of taxes in municipal revenues and the number of participatory councils. We also find that factors we included to proxy trust and social capital are key transmittors in the network, suggesting social capital indeed represents an important type of glue between formal and informal institutions. Such findings however suggest that social capital assumes a different role with respect to other cultural factors. Further factors that tend to act as middle-man in triplets are: the share of industry in municipal GDP and the density of population.

Table 4: Network statistics

Variable	Type	Indegree	Avg	Outdegree	Avg	Inclustering	Avg	Outclustering	Avg	Middle Man	Avg
Participforce	Institution	5.011	25.80	23.662	25.80	0.006	0.011	0.025	0.029	0.021	0.045
Participnr	Institution	77.481		46.485		0.010		0.070		0.071	
taxesnr	Institution	117.794		49.116		0.023		0.079		0.116	
healthspend	Institution	1.249		3.227		0.002		0.000		0.011	
pubincdiv	Institution	23.655		20.049		0.010		0.015		0.017	
taxessh	Institution	84.560		7.958		0.026		0.000		0.073	
publigood	Institution	0.615		30.075		0.000		0.016		0.007	
mayoryouth	Culture	0.439	4.33	29.030	17.35	0.001	0.001	0.013	0.014	0.008	0.010
catholic	Culture	0.000		19.262		0.000		0.015		0.000	
extendfam	Culture	25.373		16.465		0.004		0.024		0.030	
femlbmktpart	Culture	1.493		7.377		0.000		0.003		0.007	
femwagegap	Culture	3.690		14.733		0.002		0.012		0.009	
econformal	Culture	3.344		20.860		0.004		0.015		0.011	
candidates	Culture	0.152		5.596		0.000		0.010		0.004	
artgroups	Culture	0.113		25.465		0.000		0.019		0.013	
socgather	Social Capital	178.348	91.42	14.688	22.98	0.039	0.017	0.040	0.028	0.065	0.040
socagginfra	Social Capital	82.824		20.347		0.008		0.013		0.029	
misscomm	Social Capital	13.083		33.897		0.004		0.032		0.026	
gini	Economic Structure	0.604	12.15	7.772	35.56	0.000	0.001	0.004	0.026	0.006	0.018
industry	Economic Structure	47.950		15.589		0.006		0.053		0.053	

Table 4: Network statistics

Variable	Type	Indegree	Avg	Outdegree	Avg	Inclustering	Avg	Outclustering	Avg	Middle Man	Avg
gdppcap	Economic Structure	0.000		90.509		0.000		0.025		0.000	
pubemp	Economic Structure	0.054		28.389		0.000		0.021		0.013	
intpermea	Remotenness	105.607	40.69	10.141	17.22	0.022	0.010	0.015	0.017	0.017	0.017
transport	Remotenness	16.289		15.359		0.007		0.023		0.024	
rural	Remotenness	0.163		26.166		0.000		0.014		0.009	
illiteracy	Demography	11.863	5.29	51.602	46.82	0.004	0.001	0.025	0.022	0.022	0.020
elf	Demography	0.530		1.293		0.000		0.000		0.000	
popdensity	Demography	4.721		60.519		0.000		0.026		0.041	
pop60plus	Demography	4.232		71.958		0.001		0.026		0.029	
sharepoor	Demography	5.094		48.742		0.000		0.034			

Source: Author's elaboration based on (Fagiolo, 2007). *Meso-Level Dataset*, 2010

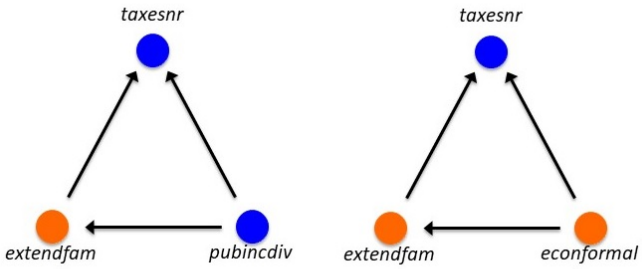

Figure 3: Inclustering patterns involving institutions. Adapted from Fagiolo (2007)

6.3 Zoom I: Institutional Factors Within Triplets

The following figures represent some specific triplets we have extrapolated from the entire directed network as examples in which institutions work either as multiple symbionts (Figure 3), multiple hosts (Figure 4), or as transmittors providing habitat and contemporaneously depending upon other factors (Figures 5 and 6). Figure 3 shows two triplets in which institutions are multiple symbionts. On the left hand, the number of taxes depends upon another institutional variable, public income diversification, and a cultural variables, namely the share of extended families. On the right hand, we see a triplet in which the number of taxes collected depends on the habitat provided by two cultural variables, the share of extended families and our proxy for the size of the informal economy. What can be noted is that in both triplets, the share of extended families - a proxy for traditional family ties - acts as middleman: so the number of taxes feeds on public income diversification (left) and on the degree of formality of the economy (right) directly, and indirectly as both such habitat-nodes also provide an indirect feeding that passes through and is mediated by the share of extended families.

Figure 4 reports an example triplet in which a formal institution, measuring the

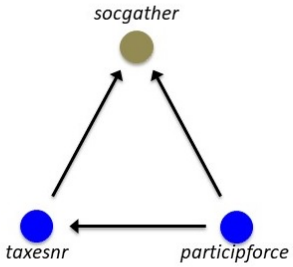

Figure 4: Outclustering patterns involving institutions. Adapted from Fagiolo (2007)

quality of participatory councils is a multiple host (two outward facing arcs). The triplet shows that participatory councils that promote stronger state-society relations may become game-changers within an institutional landscape, as they provide habitat for formal institutions (here: the number of taxes) and for social capital (here: the number of social gatherings).

Finally, figures 5 and 6 show some triplets where institutions act as middleman. In Figure reffig:Middleman-1 the number of taxes is the transmittor variable for an indirect effect that sees GDP per capita (left) and industrialization (right) feeding the number of social gatherings. Both triplets seem to summarize how economic development can affect social capital and that institutions mediate such process.

In figure 6 the factor assuming a middleman position is the number of participatory councils. In both triplets, the participatory institution channels a habitat-effect for social gatherings which comes from GDP per capita (left), or from the share of rural population (right).

Summing up, our in-depth analysis of triplets shows that depending on the specific interactions that are being looked at, institutions tend to occupy positions with different

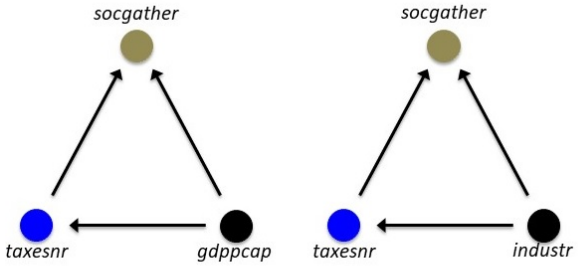

Figure 5: Institutions as transmittor. Number of taxes

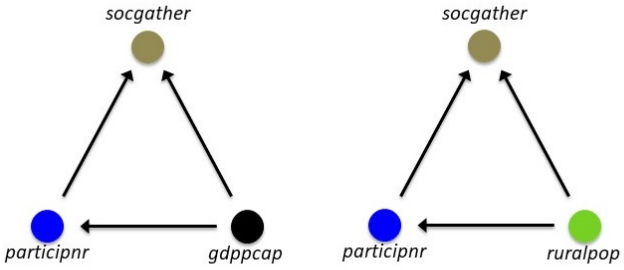

Figure 6: Institutions as transmittor. Number of participatory councils

degrees of dependency.

6.4 Zoom II: One Relation, Multiple Paths

We last zoom into a so-called path analysis in which we focus on two specific nodes of the network: in continuity with our initial illustrative example we select the cultural factor ''female labour market participation'' as proxy for prevalent views of women's role in society and the factor ''number of taxes collected within the municipality'' as proxy for attitude towards taxation. Figure 7 depicts all shortest paths present in the weighted directed network between the two nodes. In line with the inverted argument presented in section 2, we first set our institutional factor to be a symbiont on the cultural host (upper panel). Consequently, we inspect all paths in which taxes depend on cultural views on women (lower panel).

Figure 7 shows that there are six paths of interdependency of taxes on female labour market participation. They are all short (two arcs) and relatively strong (middle to highest asymmetry weight) in the second part of the path. On the other hand, when we invert the directionality of interdependency and set our cultural factor as symbiont on our institutional factor, we only detect one shortest path, which is much longer and mainly combines weakly weighted arrows. Although this is just a very specific example extrapolated from the overall network, it tends to support our other results according to which - despite of general complexity in the relation - cultural factors tend to be hosts, while institutional factors assume the role of symbionts.

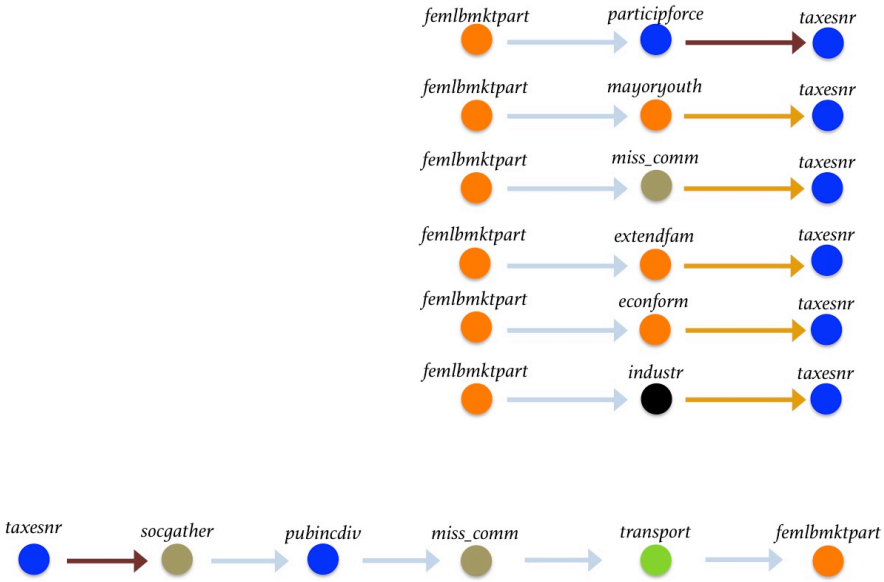

Figure 7: Shortest Paths between Female Labour Market Participation and Number of Taxes Collected within Municipality: Two Directions Compared

7 Summary and Outlook

The approach we introduce in this paper is inspired by ecology and applies correlation network analysis techniques to the study of institutional interdependencies. 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 role for socioeconomic development (Alesina and Giuliano (2015); Bisin and Verdier (2017); Guiso et al. (2009); Gutmann and Voigt (2020); Marè et al. (2020); Maseland (2013); Pitlik and Rode (2017); Tabellini (2010); Touré (2021)).

In overall, our findings confirm an elevated complexity in the interdependencies between institutional and other factors of cultural and structural type. The quest to disentangle unique and unidirectional causalities is likely to result in oversimplifications. Yet, we detect some patterns we find noteworthy of attention: First, institutions tend to assume highly central positions in the network, confirming their relevance and potential leverage for socioeconomic progress. In Brazil, the most central of the institutional measures we consider are the number of taxes collected, the share of taxes on municipal revenues and the number of participatory councils in which citizens join policy-makers in decision-making. Such findings confirm the traditional emphasis given to taxes (Besley and Persson (2011); (Litina and Palivos, 2016); (Marè et al., 2020); (Cummings et al., 2009)), and stress the interesting potential that the innovative Brazilian participatory councils bear in becoming game-changers for the institutional landscape (Avritzer (2009); Galletta (2021); Wampler (2012)). Our analysis for example confirms a certain dependency of taxes on the habitat provided by culture (Gründler and Köllner (2020); Marè et al. (2020)), but it also highlights how taxes and participatory councils act as mediators (or middlemen) for a habitat-effect that goes from economic development towards social capital. Participatory councils, in particular, also deliver habitat for tax collection

itself.

Among the cultural factors we consider, we find that the prevalence of the informal sector, the inverse of the mayor's youth, the share of Catholics and the of extended families are the most relevant hosts for institutional factors. This means that factors such as family ties and religion (cf. Gründler and Köllner (2020); Marè et al. (2020); Inglehart and Baker (2000); Benjamin et al. (2016)), 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.

In terms of the relative position that institutions assume vis-a-vis cultural and structural factors, our analysis suggests the following: because of their centrality, institutional factors tend to be highly interconnected - which also makes them more inter-dependent. While our analysis suggests that cultural factors tend to assume a greater role as hosts providing habitat for other factors, measures of social capital behave more similarly to formal institutions within the overall network: they more often assume roles as symbionts and as transmittors. This is evident in the network architecture in which cultural factors tend to place themselves on the outskirts, where connections are less dense and outdegree values of nodes are greater than their indegree values.

We suggest that our approach and connected results have the following key research implications. Formal institutions are more often symbionts than cultural factors. Our results therefore provide a complexity-based empirical evidence for the argument advanced by Williamson (2000) according to whom cultural factors are more deeply embedded than formal institutions. Our results show that the relative dominance of culture over institutions (Belloc and Bowles (2013); (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 line with such argument, we find that the relative 'dominance' of cultural factors reflects in a greater tendency

to display higher outdegree centrality and outclustering than indegree/inclustering. In the language of our framework this implies that cultural factors tend to be hosts providing habitat for formal institutions, which conversely have a greater tendency to be symbionts.

Still, it is important to stress that our analysis suggests that institutions do not resolve being symbionts only. On the contrary, the more they assume central positions in the network, the more they also become hosts or transmittors for indirect effects themselves. Noteworthy is that within triangular patterns, factors assuming middle-man positions tend to become mediators for multiple interdependencies. For example, in our analysis, the number of taxes collected insert as middleman into a relation in which GDP per capita is the host and the incidence of social gatherings is the symbiont. Similarly, the number of taxes also mediates a dependency of social gatherings on industrialization.

Finally, we observe that while cultural factors tend to assume a more exogeneous role within the overall institutional landscape, our controls proxying social capital do not exhibit such a behaviour in the network. According to our analysis, this suggests that more research into the distinction between culture and social capital/trust is needed (cf. Pitlik and Rode (2017); Voigt (2018)). Indeed, we do find evidence for social capital to be similarly dependent - and perhaps volatile(?) - as formal institutions, and much less solidly grounded as cultural norms appear to be. We suggest further research in this field.

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