Institutional environment of the Brazilian tilapia production: an analysis from multidimensional indexes

O ambiente institucional da produção brasileira de tilápias: uma análise a partir de índices multidimensionais

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Abstract: The Global Value Chains literature recognizes the importance of institutions for both countries and firms, although the subject is under-researched in empirical studies in the field. In this context, this research aims to discuss the institutional environment of tilapia production in Brazil. The institutional environment indexes were estimated using fuzzy modeling from three perspectives (Economic, Social, and Local). The data was collected in a region with a high capacity to lead value chain internationalization. The results indicate that spatial specialization may be a factor leading to a higher offer of credit to production units. However, access to this credit for units located in the production zone may be more difficult due to the requirements of the environmental and operational laws in that area. In this context, we argue that the main bottlenecks of the chain (credit and legal compliance) may create a harmful feedback effect, especially for small farmers. Additionally, we point out the necessity of more efficient communication in terms of the socioeconomic and environmental benefits of the chain. Finally, we highlight the importance of strengthening the institutional framework and social capital for small producers as crucial factors to overcome bottlenecks and ensure sustainability in the Brazilian tilapia value chain.

Keywords: fish farm, fuzzy inference system, indicators, institutions, global value chain analysis.

Resumo: A literatura sobre Cadeias Globais de Valor reconhece a importância das instituições tanto para os países quanto para as empresas, embora o assunto seja pouco estudado em estudos empíricos no campo de pesquisa. Neste contexto, este estudo visa discutir o ambiente institucional da produção de tilápia no Brasil. Os índices do ambiente institucional foram estimados utilizando modelos *fuzzy* a partir de três perspectivas (Econômica, Social e Local). Os dados foram coletados em uma região brasileira com alta capacidade para liderar a internacionalização da cadeia de valor. Os resultados indicam que a especialização espacial pode ser um fator que leva a uma maior oferta de crédito às unidades de produção. Entretanto, o acesso a este crédito para unidades localizadas na zona de produção pode ser mais difícil devido às exigências legais ambientais e operacionais naquela área. Neste contexto, argumentamos que os principais gargalos da cadeia (crédito e conformidade legal) podem criar um efeito de feedback prejudicial, especialmente para os pequenos agricultores. Além disso, apontamos a necessidade de uma comunicação mais eficiente em termos dos benefícios socioeconômicos e ambientais da cadeia. Finalmente, destacamos a importância de fortalecer a estrutura institucional e o capital social dos pequenos produtores como fatores cruciais para superar os gargalos e garantir a sustentabilidade na cadeia nacional de valor da tilápia.

Palavras-chave: pisciculturas, sistema de inferência *fuzzy*, indicadores, instituições, análise de cadeias globais de valor.

1. Introduction

A spatial reorganization of the firms' activities has begun from the second half of the twentieth century, through fragmentation of production, in the face of the improvement of communication and computer technologies, reduction of logistic costs and trade liberalization. In this context, the

concept of the Global Value Chain (GVC) has emerged, aiming to explain this phenomenon: "(...) the full range of activities that firms and workers perform to bring a product from its conception to end-use and beyond includes activities such as research and development (R&D), design, production, marketing, distribution and support to the final consumer" (Gereffi & Fernández-Stark, 2018, p. 306).

Over the past decade, the GVC framework has gained the attention of academics, international organizations and policy planners. It proposes a list of tools to understand how global firms' structure these spatially dispersed activities and how the dynamics of generation and distribution of added values works.

This holistic view of the organization of global firms initially started from two key elements: governance and upgrading. Governance refers to the strategy roll of the leading firms, which exercise power in coordinating network activities beyond their organizational boundaries. The economic upgrading is related to the process of moving to higher positions in the chains, in order to increase the added values, whether at the level of firms, regions or countries (Gereffi, 1999; Gereffi et al., 2005; Bush et al., 2019).

During the last 25 years, research based on the GVC approach has experienced significant interest by academics, generating studies published in a wide range of multidisciplinary journals that initially were primarily concerned with key dimensions of governance and upgrading. However, in the last decade, research has started to discuss in a more systematic way the institutional dimension in the GVC's analyses (Neilson & Pritchard, 2009; Smith, 2015; Dollar et al., 2016; Gereffi, 2019). In this context, this research aims to discuss the institutional environment of tilapia production in Brazil, based on the analysis of a region with high potential to lead the globalization of the domestic chain.

2. Theoretical Foundation

2.1 The scarcity of quantitative and institutional studies on GVC

Dimensions of governance and upgrading are the general focus on the analytical context of literature on GVC, with a relative bias of a qualitative nature (Ribeiro et al., 2024). Regarding this nature, Lall et al. (2009) exposed the deficiency of quantitative measures associated with this framework. However, since Frederick's (2014) pioneering work, measurement efforts in GVC have been intensified, mainly using Input-Output Tables (IOTs) datasets, Supply-Use Tables (SUTs) and foreign trade data.

Based on development initiatives of regional IO tables and increase of data availability, GVC analysis have recently been taken to different research directions improving the measurement process. According to De Backer et al. (2018), this phenomenon creates a basis to go beyond traditional macro and sector level analyses.

Hernández & Pedersen (2017) suggested, from a literature review, that the agenda of future GVC research should consider more quantitative studies analyzing the configuration of GVCs, as well as examinations of chains in a multilevel perspective. It seems clear that the development of quantitative research for GVC analysis is a critical way to systematically evaluate the causal systems that connect chains and firm-level performance, considering for instance elements of governance and institutions (Ponte & Sturgeon, 2014; Eckhardt & Poletti, 2018; Golini & Boffelli, 2018; Giovannetti & Marvasi, 2018).

According Dollar et al. (2016), there are few studies that focus on the institutional perspective of GVC involvement, and examine the impact of regional institutions on firm-level decision. Eckhardt & Poletti (2018) argued that the role of external institutional forces in structuring chain dynamics

remains surprisingly under-researched in the field. For Smith (2015), the concept of institutions remains somehow under-specified in the field of GVC analysis, making it difficult to develop a clearer theoretical causality. According to the author, the researches on the process of understanding the State in different geographic scales, as an institutional and relational actor in the governance of global productive arrangements, are scarce. Tessmann (2020), on the other hand, recommended going beyond an understanding of the State as a facilitator and regulator, proposing that future researches seek to understand how the negotiation of development perspectives along the value chains through institutional arrangements, where political and economic power are linked.

Neilson & Pritchard (2009) emphasized that the consideration of institutions in the GVC analysis was a relevant geographic research tool, highlighting the importance of analyzing the institutional framework and governance together. McWilliam et al. (2020) reinforced this concern by pointing out after a review of the governance literature that there is a need to address how local institutions interact and integrate into governance analysis.

Finally, despite understanding institutions as an under-researched theme, Eckhardt & Poletti (2018) argued that recent literature has slowly begun to move in this direction. For the authors, recent contributions to external institutions highlight the needs of building systematic causal thinking that elucidates the connection between the elements of the institutional environment and the GVCs.

2.2 What are Institutions?

The GVC literature generally acknowledges the importance of institutions (internal and external) both for the insertion of countries into global chains and for the analysis of governance and updating structures. Although this subject remains generally under studied and the connections between the institutions and the other elements that make up GVC's analyses are not yet well understood (Bair, 2005; Neilson & Pritchard, 2009; Ponte et al., 2014; Dollar et al., 2016; Lim, 2016; Mohan, 2016; De Ville, 2018; Eckhardt & Poletti, 2018).

According to De Marchi et al. (2020) between 1994 and 2018, institutions were the focus of only 14% of GVC studies, mostly with macro-level bias neglecting the role of micro-level institutions in literature (Mohan, 2016; De Ville, 2018). Nevertheless, it is possible that this number is significantly lower, because of the five most cited articles for the institutional context pointed out by De Marchi et al. (2020) four of them do not refer in their discussions to GVC or institutions. Curiously, one of these articles "global value chain" is cited only in the abstract, while in the other three "institutions" or "institution" appear only in the abstract or introduction.

We, as well as Smith (2015), understand that the concept of institutions remains somehow under-specified in the field of GVC analysis, and the few researches do not sufficiently delimit what institution means[1]. In any case, elements such as customs efficiency, access to credit, state intervention (policies, taxation, public security, environment, labor and social security), rights, property rights, contract enforcement and rule of law are pointed out as institutions or institutional factors that impact GVCs (Miranda & Wagner, 2015; Dollar et al., 2016; Dollar & Kidder, 2017; McWilliam et al., 2020; Ribeiro et al., 2023).

Institutions are difficult to define; they are a broad concept and used by several research fields even outside the academy. Because of its complexity, even today, the definition of this concept remains conflicting (Hodgson, 2006, 2015). Perhaps, the most famous definition is North's (1990, p. 3) that described institutions as "rules of the game in society or, more formally, are the humanly devised constraints that shape human interaction".

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[1] Mohan (2016), Seabrooke & Wigan (2017), and De Ville (2018) are the main exceptions in recent studies.

After Coase's (1937, 1960) studies, the new institutional economics of history (NIEH) of North (1986) and the transaction cost economics (TCE) of Williamson (1985) are the two main branches that support the new institutional economics (NIE). From different emphases, NIE maintains that institutions are important and affect economic development (Richter, 2005; Ménard, 2014).

We believe that the issues raised and the data collected from the few surveys that incorporate an institutional perspective into the GVC literature are typical of NIE thinking. However, this approach views institutions primarily as exogenous and focused on formal policies. At this point, other approaches to institutions are valuable in developing broader understandings (Richter, 2005; Geels, 2002).

According to Richter (2005), sociological criticism is valuable to NIE for its ability to complement its analytical concepts by bringing sociological concepts such as organizations, implicit agreements, relational contracts, social capital, and trust. Expanding North's definition, in a sociological view of institutions, Hodgson (2006, p. 13) defined institutions as "durable systems of established and embedded social rules that structure social interactions, rather than rules as such. In short, institutions are social rule systems, not simply rules". The "embeddedness" concept of Granovetter (1985) points out that a sophisticated description of economic action should consider its immersion in continuous structures of social relationships. Granovetter (1985, 1992) believed that when dealing with institutional matters, it is important not to lose sight of the fact that economic activities are rooted in networks of social and political ties.

Although the institutional view is commonly focused on natural resource management with theoretical approaches of rational choice and sociological view in the field of fisheries and aquaculture research (Jentoft, 2004; Chuenpagdee & Song, 2012). This present research, as well as Flaaten (2013) and Nadarajah & Flaaten (2017), adopts a closer look at NIE, and consequently the GVC literature, when analyzing aquaculture.

2.3 The tilapia value chain in Brazil and the institutional environment

Fish farming corresponds to approximately 90% of the Brazilian aquaculture production, which in 2020 reached 643,279 t. Tilapia production alone accounts for approximately 50% of this production and 40% of the commercialized value (Instituto Brasileiro de Geografia e Estatística, 2020). Despite being one of the largest aquaculture producers in the world (Food and Agriculture Organization of the United Nations, 2020), export rates of the country's production are still very small. In the case of tilapia, historically (2013 to 2020), Brazil exported less than 1.1% of its total production (Empresa Brasileira de Pesquisa Agropecuária, 2022).

Another characteristic of the tilapia value chain in Brazil is the existence of eleven productive zones distributed in almost all regions of the country[2,3]. According to 2019/20 data a little more 30% of the national production of tilapia was concentrated in five of these eleven zones (Empresa Brasileira de Pesquisa Agropecuária, 2022).

The value chain of tilapia in Brazil presents a great diversity in terms of productivity, socioeconomic, and structural characteristics. The south and southeast regions, which are responsible for more than 70% of the tilapia produced and commercialized in the country, have better road infrastructure, greater credit availability, and higher productivity and technological levels. In these regions, there are also more net cages and feed factories and producers of

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[2] Four zones in the northeast region, three zones in the south, two in the southeast, and one in the Midwest. The researched area of Ilha Solteira is a border between two regions, the southeast and the Midwest.

[3] At the time of the research, the production of tilapia in the northern states (Amazon biome) was prohibited by environmental norms.

fingerlings and juveniles in comparison to the rest of the country (Barroso et al., 2018; Pedroza Filho et al., 2020).

Net cage production system prevails compared to pond system[4], in 2018 the average annual production per production unit was 358 tons. These production units mostly sell tilapia via processing industry and/or middleman. In terms of coordination, verticalized governance models are exclusive to the South and Southeast region, either through cooperatives working on integration system or through large companies operating in several segments of the value chain internally (i.e.: feed and fingerlings production, fish growth, processing). In the rest of the country, a non-verticalized production coordination prevails (Pedroza Filho et al., 2020; Ribeiro & Pedroza Filho, 2022).

As previously discussed, there are extensive institutional elements that can be used to analyze a value chain. Some researches in Brazil points out issues that somehow help to build an institutional environment for fish production in the country. In this context, it is possible to affirm that there are two major institutional problems. First, the difficulty of compliance with environmental and water cession legislation related to the activity is frequent points out as a major bottleneck of the sector, independent of the scale of production, species, location of the farm or production system. Second, low availability or difficulty of access to credit lines are to problems reported by many fish producers, especially small producers. Table 1 summarizes these and other issues pointed out by the literature.

Table 1. Institutional issues of Brazilian aquaculture

Institutional Issues	Description	Researches
Laws compliance	Difficulty of compliance with environmental and water cession legislation	Silva et al. (2007)[b,c]; Barros et al. (2011)[b,d]; Schulter & Vieira Filho (2018)[a,c]; Milanez et al. (2019); Sousa et al. (2019)[b,d]; Ayroza et al. (2020)[b,c]; Barroso et al. (2018)[a,c]; Silva Coêlho et al. (2020a)[b,d]; Pedroza Filho et al. (2020)[a,c]; Valenti et al. (2021)[a,c,d]; Ribeiro & Pedroza Filho (2022)[b,c]
Credit lines	Low availability or high difficulty to access financial resources	Silva et al. (2007)[b,c]; Barros et al. (2011)[b,d]; Barroso et al. (2018)[a,c]; Schulter & Vieira Filho (2018)[a,c]; Sousa et al. (2019)[b,d]; Pedroza Filho et al. (2020); Valenti et al. (2021)[a,c,d]; Ribeiro & Pedroza Filho (2022)[b,c]
Technical assistance	Lack of public technical assistance	Araújo & Sá (2008)[b,d]; Barros et al. (2011)[b,d]; Barroso et al. (2018)[a,c]; Sousa et al. (2019)[b,d]; Silva Coêlho et al. (2020a)[b,d]; Silva Coêlho et al. (2020b)[b,d]; Lopes et al. (2020)[b,c,d] ; Ribeiro & Pedroza Filho (2022)[b,c]
Human capital	Lower Manager's level of education or low availability of skilled labor	Barros et al. (2011)[b,d]; Barroso et al. (2018)[a,c]; Silva Coêlho et al. (2020a)[b,d]; Silva Coêlho et al. (2020b)[b,d]
Public Safety	Occurrence of fish or equipment robberies	Araújo & Sá (2008)[b,d]; Barros et al. (2011)[b,d]; Barroso et al. (2018)[a,c]; Silva Coêlho et al. (2020b)[b,d]; Pedroza Filho et al. (2020)[a,c]
Tax incentives	Insufficient coverage of incentives throughout the chain	Schulter & Vieira Filho (2018)[a,c]; Valenti et al. (2021)[a,c,d]; Ribeiro & Pedroza Filho (2022)[b,c]
Logistic infrastructure	Lower quality of roads used	Schulter & Vieira Filho (2018)[a,c]; Pedroza Filho et al. (2020)[a,c]; Ribeiro & Pedroza Filho (2022)[b,c]
Woman inclusion	Low rates (<25%) of Women's participation in management	Silva Coêlho et al. (2020a)[b,d]; Silva Coêlho et al. (2020b)[b,d]
Compliance with agreements	Non-compliance with commercial agreements	Pedroza Filho et al. (2020)[a,c]; Ribeiro & Pedroza Filho (2022)[b,c]

Notes: Geographic scope: [a]national; [b]local. Fish species: [c]tilapia; [d]others

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[4] This system is more common in the south of the country.

Still in this context, the research applied by Pedroza Filho et al. (2020) in the seven most important tilapia production centers in Brazil, presents an important panorama. First, it is possible to conclude that there is a satisfactory perception regarding the availability of qualified labor and public safety from the point of view of the fish producer. Second, the availability of credit, road quality and risk related to payment default in transactions affect negatively the activity, but at different levels depending on the geographical location. Third, compliance with environmental and water cession legislation is a general institutional problem in the activity.

Finally, it is important to highlight two recent updates that affect this institutional context. The first of these are some changes[5] related to environmental legislation that are evaluated by Schulter & Vieira Filho (2018) and Ayroza et al. (2020) as positive for the development of the sector in general. The second is the inauguration of the drawback customs regime that aims to stimulate the export of tilapia, based on the reduction in taxes of the main inputs used in cultivation. It is estimated that the reduction of production costs resulting from this regime varies from 12% to 37% (Pedroza Filho & Rocha, 2019).

3. Methodology

3.1 Database and fuzzy inference system configuration

Data associated with institutional analysis were used to illustrate a practical case of the fuzzy logic application in the construction of indicators related to the GVC approach. The data were collected in Brazil, in the first quarter of 2019, through a survey directly answered by managers of tilapia production units (TPUs), in the states of São Paulo (SP) and Mato Grosso do Sul (MS).

In total, 36 TPUs answered the questionnaire, 19 of them delimited to the productive zone[6] of Ilha Solteira (SP/MS) and the remaining 17 in 11 other cities of São Paulo (Figure 1); therefore the data were tabulated and processed as two different groups: Ilha Solteira and others of São Paulo. Among the eleven tilapia producing zones catalogued in Brazil, Ilha Solteira is the second largest and corresponds to approximately 5.3% of the total produced in the country (Empresa Brasileira de Pesquisa Agropecuária, 2022). Regarding the production system, all TPUs in Ilha Solteira zone use net cage production in the Ilha Solteira reservoir. On the other hand, in the other group, although the majority use this same system, some TPUs also use pond system.

It is important to highlight that the data, besides its spatial limitation, refer exclusively to farmers' level segment of the tilapia value chain, which in turn, although short, and also restricted to domestic market. As previously pointed out, historically Brazil exports less than 1.1% of its total production. However, according to Empresa Brasileira de Pesquisa Agropecuária (2022), the states of SP and MS represented 68% of Brazilian exports of tilapia in the first half of 2020. In this sense, these areas were chosen because they are currently the most engaged and structurally organized to increase tilapia exports in the future.

Due to a methodological issue related to the size of the system, we have defined three contexts of institutional analysis in this research: (1) Economic, (2) Social and (3) Local. These contexts were based on the synthetic parameters of the '*Local Institutional Context*' analytical dimension proposed by Fernández-Stark & Gereffi (2019) for the analysis of GVCs, and also in the Antràs (2020), Ayroza et al. (2020), Barrientos (2019); Raei et al. (2019); and De Marchi et al. (2020) studies. The institutional issues pointed out in section 2.3 and summarized

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[5] Like: exemption from environmental licensing; updating of laws; decentralization and reduction of steps in processes; and implementation of online systems.

[6] There are 12 production zones catalogued in Brazil, Ilha Solteira's is the second largest in production. In 2020 it was responsible for 5.25% of the tilapia produced in the country (Empresa Brasileira de Pesquisa Agropecuária, 2022).

in Table 1 were also the basis for the construction of the indicators of analysis of the three contexts. Table 2 summarizes the contexts and their respective indicators.
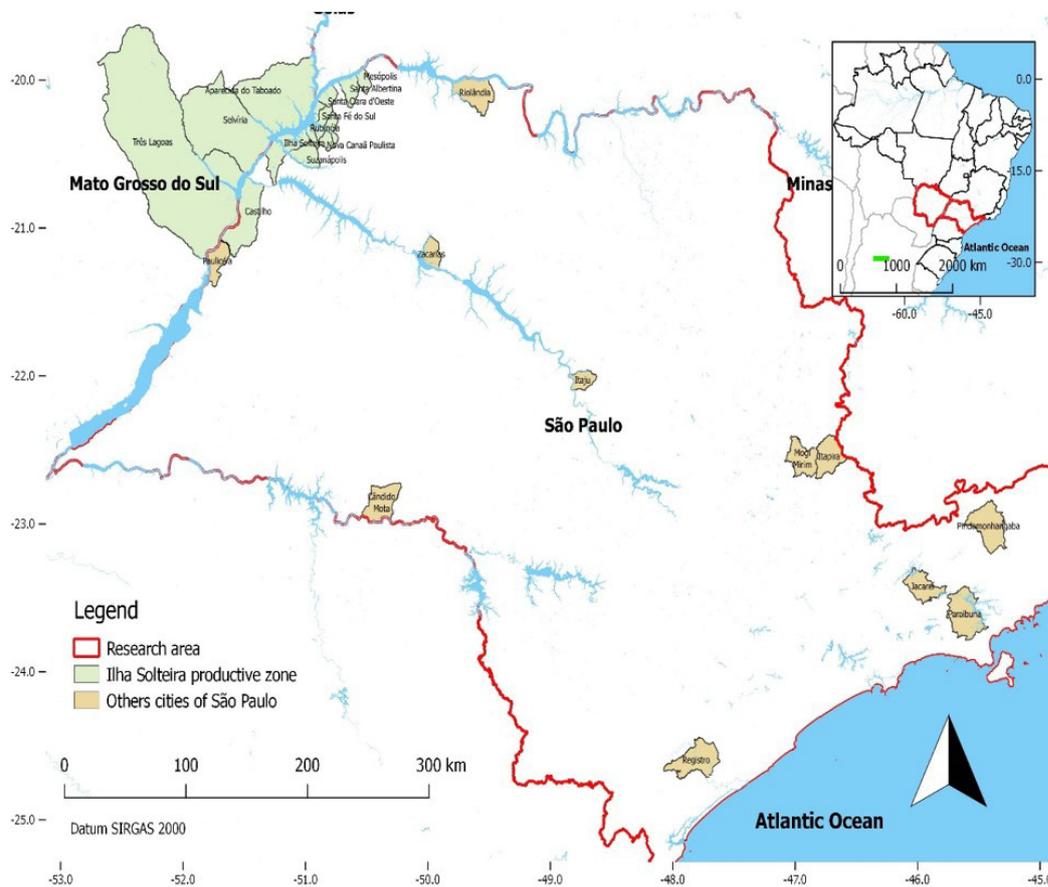

Figure 1. Research spatial distribution. Indicates the cities where the interviewed TPUs are located.
Note: Although the city of Pauliceia is on the margin of the Paraná River it is not part of Ilha Solteira's reservoir.

Table 2. Contexts and indicators for institutional environment fuzzy indexes

Context	Indicators	FIS Inputs	Description
Economic	Quality of infrastructure	Infra.	Evaluation of the quality of roads in the region
	Availability of financial resources	DispRec.	Existence or not of banks or other institutions (development agencies, credit unions, etc.) that offer financing for the activity
	Access to financial resources	AcesRec.	Occurrence or not of factor that restricts access to market credit, when available in the region (i.e. non-compliance with laws)
Social	Manager's level of education	NivEsc.	Education level of the TPU's manager
	Women's participation in management	Mulh.	Occurrence or not of women occupying the position of manager
	Availability of qualified workforce	DispMO.	Evaluation of impact level of the availability of skilled labor as a barrier to activity

Table 2. Continued...

Context	Indicators	FIS Inputs	Description
Local	Environmental Legislation	LegAmb.	Evaluation of impact level of existing environmental legislation as a barrier to activity
	Operational Legislation	LegOP.	Evaluation of impact level of the process to obtain the cession of union water use as a barrier to activity
	Public Safety	SegPub	Evaluation of impact level of public safety as a barrier to activity

Regarding the complexity of the subject institutions, the use of three contexts and nine indicators described in this present research do not seek to delimit everything that surrounds this phenomenon, but rather to point out practical definitions for empirical analysis in aquaculture.

3.2 Fuzzy inference system description

For research purposes, a Fuzzy Inference System (FIS) was implemented with the support of MATLAB® R2018a software. The fuzzy expert system contains nine inputs (indicators) and three outputs (fuzzy institutional environments), that represent indexes of the institutional environment of tilapia farming in their respective contexts.

In this present research, given the characteristics of the indicators and the linguistic variables associated with them, the FIS inputs have taken on triangular and singleton membership function (MF) forms. The outputs took on strictly triangular functions. Equations 1 and 2 represent these two kinds of MFs, with parameters (a,m,b), being a ≤ m ≤ b, with a, m, b and x belonging to the universe set U.

$$\text{Triangular}: \mu_A(X) = \begin{cases} 0, & x < a \\ \dfrac{(x-a)}{(m-a)}, & a \le x \le m \\ \dfrac{(b-x)}{(b-m)}, & m \le x \le b \\ 0, & x > b \end{cases} \tag{1}$$

$$\text{Singleton}: \mu_A(X) = \begin{cases} 1, & if\ x = m \\ 0, & otherwise \end{cases} \tag{2}$$

According to the characteristics of each input and output of FIS, the functions connected to the linguistic terms are: Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH). The transformation of the previous and consequent linguistic terms into fuzzy numbers through the MFs are represented in Tables 3 and 4, respectively.

Table 3. Transformation of antecedent linguistic terms into fuzzy numbers

Terms	Fuzzy Numbers		
	5 Terms	3 Terms	2 Terms
Very Low	(0, 0, 0.25)	---------	---------
Low	(0, 0.25, 0.5)	(0, 0, 0.5)	(0)
Medium	(0.25, 0.5, 0.75)	(0, 0.5, 1)	---------

Table 3. Continued...

Terms	Fuzzy Numbers		
	5 Terms	3 Terms	2 Terms
High	(0.5, 0.75, 1)	(0.5, 1, 1)	(1)
Very High	(0.75, 1, 1)	---------	---------

Table 4. Transformation of consequent linguistic terms into fuzzy numbers

Terms	Fuzzy Numbers
Very Low	(0, 0, 25)
Low	(0, 25, 50)
Medium	(25, 50, 75)
High	(50, 75, 100)
Very High	(75, 100, 100)

Rules bases of MIMO (Multiple-Input/Multiple-Output) type were used, composed by IF-THEN rules, having a previous part (premise) and consequent part (conclusion) connected by the logical connective (operator) "AND".

The definition of the rules base, a central part of FIS, was constituted from deductive logical reasoning based on economic analysis and the literature of GVC and transaction cost economics (Williamson, 1985). Table A.1 (Appendix A) shown the general causal mechanism between indicators and institutional environment. Table A.2 (Appendix A) summarizes the 67 rules of the system.

Finally, the fuzzy indexes of the institutional environment for each context are the outputs of the FIS for each TPU. Bearing in mind that their values are defined in a range from 0 to 100, where 100 is considered the best possible institutional environment; conversely, given the context of analysis, and analogously 0 is regarded as the worst. Comparisons of group means were performed using Student's t-test and the nonparametric Mann-Whitney U test, depending on the previous normality checked by Shapiro Wilk's normality test.

4. Results and Discussion

The study divided the production units into two groups, one belonging to the Ilha Solteira productive zone (Ilha Solteira group) and the others TPUs located in São Paulo cities (Others group). Table 5 present the estimated averages of the contextual indexes for each group.

Table 5. Institutional environment fuzzy indexes

Group	Averages of the contextual indexes		
	FEI	FSI	FLI
Ilha Solteira	66.9	54.5	19.2*
Others	62.8	51.6	37.2*

Notes: FEI is fuzzy economic index; FSI is fuzzy social index; FLI is fuzzy local index. *Indicates statistical significance at 1% between groups

For both groups, the indexes for the institutional environment in the economic context (FEI) were slightly higher than social context (FSI), with both showing levels between Medium and High (Figure 2). On the other hand, in the local context, the FLI for both groups presented poor results, with levels between low and very low (Ilha Solteira) and medium and low (Others) (Figure 2).
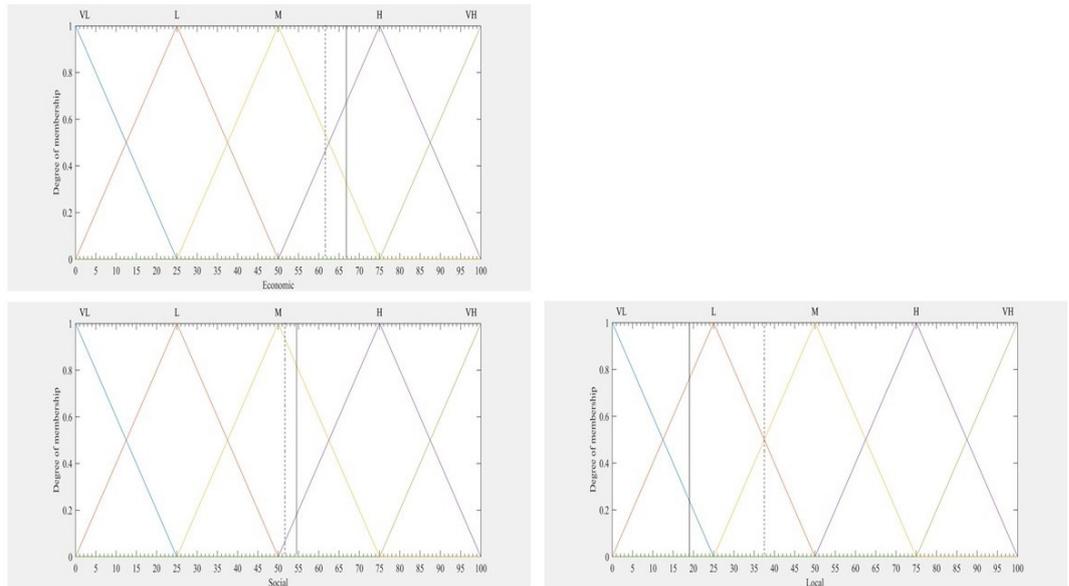
Figure 2. Outputs of inference systems with the membership functions for both groups.
Notes: Ilha Solteira's productive zone (continuous line) and Group of other cities of São Paulo (dashed line). Legend: VL is very low; L is low; M is medium; H is high; VH is very high.

The indexes presented relative homogeneity, with a higher dispersion of values for the FLI, as shown in Figure 3. Considering the TPU's of the two groups, there was only a significant difference ($p<0.05$) between the means for FLI.
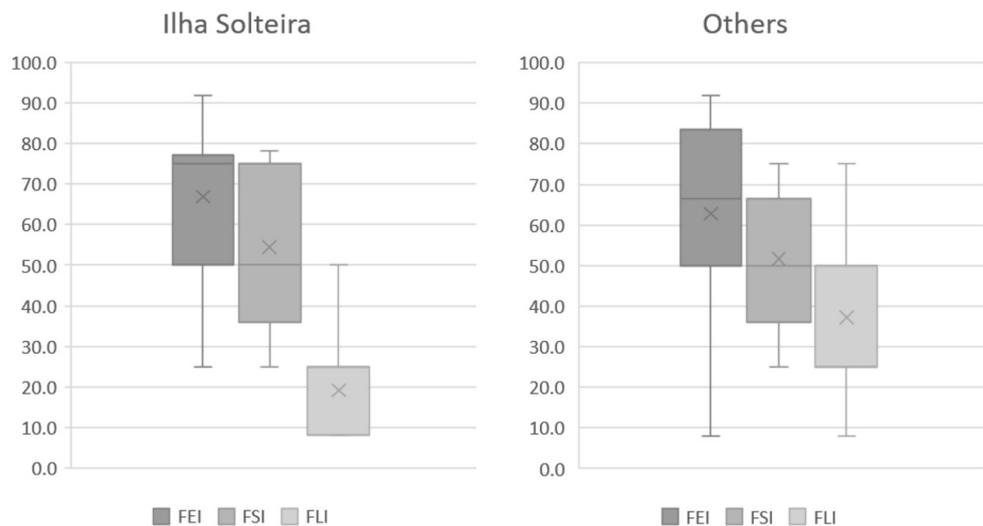

Figure 3. Comparison between indexes.
Notes: The figure represents the means, medians, quartiles and the maximum and minimum values. Legend: FEI is fuzzy economic index; FSI is fuzzy social index; FLI is fuzzy local index.

In the economic institutional context, the results indicated a greater availability to credit for the TPUs in the Ilha Solteira group. In that space, 82% of the TPUs pointed out the existence of banks that finance the activity, on the other hand it is only 68% for non-agglomerated TPUs.

This becomes a relevant issue since the Brazilian literature points to credit as a bottleneck in the tilapia value chain. In this framework, we argue that it is possible that banks may facilitate and stimulate the promotion of loans for tilapia production in the zone, either because they have greater access to the productive and economic space indicators and/or because they have a history of loan transactions carried out for Ilha Solteira TPUs.

In this sense, Zeller & Schiesari (2020) point out that the specialization of small farmers clustered in some Brazilian municipalities is one of the determinants for a greater concession of credit[7] in those spaces in comparison to other non-specialized ones. According to the researchers, farmers' knowledge is a significant determinant for larger loans. In addition, farm size improves the guarantees of the borrowers, which then helps to secure more loans. On average, the production of Ilha Solteira TPUs in 2018 was almost three times higher than the other group. We argue that to some degree the national phenomenon described by Zeller & Schiesari (2020) may be occurring in the Ilha Solteira zone.

In the social context for both groups, the level of education of the managers was relatively high; on average, more than 70% had a graduate degree. On the other hand, also for both groups, the participation of women in management positions was quite low, five (26%) in the Ilha Solteira group and only one (6%) in the other group. These levels are even lower than those observed by Silva Coêlho et al. (2020a, 2020b) for Amazonian fish farming. Still in this context, 33% of these women had the highest level of education (post-graduation), while only 7% for men managers.

Regarding the local context, the more critical one in general terms, both understood the environmental (LegAmb input) and operational (LegOP input) legislation as barriers to the activity. In addition, for both groups, only half of the TPUs pointed out that they were in compliance with the laws. What placed the Ilha Solteira group in a worse condition was its higher evaluations of negative impact on the activity. In this productive zone, 95% of the TPUs pointed out that obtaining environmental licenses and cession of water use were very impacting barriers to productive activity, while the other TPUS in São Paulo this ratio was 65%.

This situation is critical because the lack of environmental compliance can result in negative impacts on the water quality (e.g., levels of oxygen and phosphorus) by the non-respect carrying capacity limits of the reservoirs. The territorial governance of aquaculture activities in public reservoirs in Brazil is the duty of the Ministry of Fisheries and Aquaculture, but due to limitations in terms of human and personnel resources, its effectiveness is very limited. This subject is also relevant because most of the reservoirs are under multiple uses (i.e., electricity generation, tourism, fishing, real estate), which often results in conflicts with these other users. It is important to highlight that these two certifications (environmental and water use license) are necessary for legal compliance in net cage systems, which prevails in Ilha Solteira. On the other hand, the production in the ponds system - used by some TPUs in the others group - requires only the environmental license. Additionally, for the cession of water use there are no exemptions or simplified regimes for small scale fish farmers, as in environmental licensing.

According to Ayroza et al. (2020) the slowness and excessive complexity of the process are common elements between the cession of water use and environmental licensing, with the aggravating issue that the cession of water use can take longer and be even more difficult to obtain. This is a critical issue because as the researchers point out, between 2002 and 2020 in São Paulo, only 24% of these requests were granted, taking 18 to 24 months to be evaluated. Almost 25% of them were requested by TPUs from Ilha Solteira.

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[7] The public resources of the National Program for Strengthening Family Agriculture (PRONAF) are granted by both public and private banks in Brazil.

This scenario endorses the analyses of Barroso et al. (2018) and Pedroza Filho et al. (2020), who identified environmental licensing and the cession of water use as two significant limiting factors for the production growth of the Ilha Solteira area. These studies pointed out the long time spent and the relatively high costs involved in legal compliance. They warned that legal noncompliance was limiting access to the local credit market, as environmental license is mandatory to access credit. This last point exposes a relationship of association and reinforcement between those potentially major bottlenecks in the tilapia value chain in Brazil, non-compliance and low credit.

Improving the quality of national institutional structures in more sophisticated aquaculture countries, such as those in Asia, has facilitated meeting the growing demands of global buyers, as noted by Jespersen et al. (2014). The reinforcement of these structures is a key element for the development of the chain, especially for the countries of the Global South in the face of growing international certification standards. This reinforcement is a task that is not so simple to achieve given the practical complexities and local social standards specific to each aquaculture production zone. Thus, as stated by Bremer et al. (2016), Mialhe et al. (2018) and Bush (2018), it is understood that the development of this institutional arrangement must be developed and thought out in an open, inclusive and urgent manner.

5. Conclusions

The GVC literature generally recognizes the importance of institutions for both countries and firms. Although the subject is under-researched in empirical studies in the field. Thus, this research aims to analyze the institutional environment of the tilapia value chain in a region of Brazil, from three institutional contexts: Economic, Social, and Local.

We argue in the economic institutional context that the spatial specialization promoted by the Ilha Solteira zone may be a factor leading to a comparatively higher offer of credit to its TPUs. By having greater access to individual or collective elements for credit analysis (e.g.: knowledge, productive indicators, economic indicators, loan payment history), banks can increase the offer and concession of credit to the productive zone in detriment of spatially dispersed TPUs. This hypothesis developed by the research is quite relevant, since the low availability or high difficulty to access financial resources are known bottlenecks in the aquaculture value chain in Brazil.

Nevertheless, the most critical element for access to bank credit, the compliance with the rules affected in a significantly more negative way the Ilha Solteira TPUs. In general, the compliance with environmental licensing and water use were key issues for the worst institutional context in the tilapia chain. Although both groups indicated compliance as a factor that negatively affected tilapia production and half of them were not regular, the obligation to require water use for the Ilha Solteira zone potentially affected their TPU more. As discussed, both the cession of water use and the environmental license are slow, costly, and difficult protocols to obtain.

This non-compliance with environmental and operational legislation, not exclusive to the study areas of this research, reinforces another major bottleneck in the Brazilian tilapia value chain: access to credit. This puts the Ilha Solteira area in a curious situation, despite a possible greater abundance of credit for its TPUs, access to this credit may be more difficult due to the environmental and operational laws requirements in that area.

Thinking about the value chain as a whole, this reinforcement of the credit bottleneck by non-compliance with regulation may even create a harmful feedback effect. Where the firm cannot get credit because it is not regularized and has difficulties in regularizing itself because it cannot obtain economic resources for this onerous, complex and slow regularization. This

harmful cycle, which obstructs the development of the sector, can be particularly strangling to small scale farmers (less capitalized TPUs), which despite the potential exemption of the environmental license, must still request a possible cession of water use like any other company.

Overall, the tilapia value chain in Brazil needs to communicate more effectively their characteristics in terms of socioeconomic benefits (e.g., added value, employment, food security) as well as environmental externalities. This information can be instrumental in order to sensitize institutional actors to the sector's demands, especially concerning those from the small-scale fish farmers. It is particularly important since aquaculture is not yet a consolidated and well-known industry in Brazil, compared to other animal protein chains such as poultry and beef. In addition, we highlight the importance of strengthening the quality of institutional structures for the development of aquaculture chains, especially in the South. This is not restricted to creating more simplified and efficient legislation and increasing the availability and access to credit, although it also goes through this. Although these two are probably the biggest barriers, several institutional elements must be observed for a sustainable development of the chain, such as infrastructure quality, labor force quality, public security, inclusion, technical assistance, human capital, etc.

In this context, strengthening the social capital for small-scale tilapia farmers is crucial to overcome these barriers and assure a sustainable position in the value chain. For example, capacity-building initiatives focused on technical aspects and management competencies can contribute to reaching compliance with regulations and improving marketing efficiency. However, considering the current limitations of the public extension service in providing such capacity-building actions, it is necessary to discuss new forms of organizations led by producers to assume this role. In this study, the firms surveyed were not integrated into global chains, despite the significant potential and interest in exports by this productive sector in Brazil. This is an important aspect of this article, considering that in general, the researches in GVC fields emphasize firms already inserted in different levels of participation in international markets. Finally, it is relevant to discuss an agenda that also integrates research that maps the conditions and processes of insertion of firms in GVCs, under different viewpoints and historical perspectives (e.g.: ex-ante and ex-post). Comparisons between these scenarios and their eventual changes after participation in global chains can be significantly relevant for research on GVC analysis, policy makers, and firms.

Authors' contributions:

VSR: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Supervision, Project administration. MXPF: Conceptualization, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Funding acquisition.

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Nothing to declare.

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Appendix A

Table A.1. General causal mechanism between indicators and institutional environment

Context	Indicators	Limits of institutional environment	
		Worst scenario	**Best scenario**
Economic	Quality of infrastructure	worst rating	best rating
	Availability of financial resources	non-occurrence	occurrence
	Access to financial resources	restricted	unrestricted
Social	Manager's level of education	illiterate	post graduate
	Women's participation in management	non-occurrence	occurrence
	Availability of qualified workforce	high impact	non-impact
Local	Environmental legislation	high impact	non-impact
	Operational legislation	high impact	non-impact
	Public safety	high impact	non-impact

Note: The logic of relationship between indicators and the quality of the institutional environment was guided, in addition to the reinforcing of gender equality (female managers), by the economic perspectives of increasing/reducing of transaction costs, labor productivity and barriers to entry and exit.

Table A.2. Summary of rules used for FIS

Economic		Social		Local	
IF	**THEN**	**IF**	**THEN**	**IF**	**THEN**
VH-H-H	VH	VH-H-H	VH	H-H-H	VH
H-H-H	VH	H-H-H	VH	L-H-H	H
VH-L-H	H	VH-L-H	H	M-H-H	H
VH-H-L	H	VH-H-L	H	H-L-H	H
H-L-H	H	H-L-H	H	H-M-H	H
H-H-L	H	H-H-L	H	H-H-L	H
M-H-H	H	M-H-H	H	H-H-M	H
L-H-H	H	L-H-H	H	L-M-M	M
VH-L-L	M	VH-L-L	M	L-M-H	M
M-L-H	M	M-L-H	M	L-H-M	M
M-H-L	M	M-H-L	M	M-L-M	M
VL-H-H	M	VL-H-H	M	M-L-H	M
H-L-L	L	H-L-L	L	M-M-L	M
M-L-L	L	M-L-L	L	M-M-M	M
L-L-H	L	L-L-H	L	M-M-H	M
L-H-L	L	L-H-L	L	M-H-L	M
VL-L-H	L	VL-L-H	L	M-H-M	M
VL-H-L	L	VL-H-L	L	H-L-M	M
L-L-L	VL	L-L-L	VL	H-M-L	M
VL-L-L	VL	VL-L-L	VL	H-M-M	M
				L-L-M	L
				L-L-H	L
				L-M-L	L
				L-H-L	L
				M-L-L	L
				H-L-L	L
				L-L-L	VL
Total of Rules	20		20		27

Note: VL is very low; L is low; M is medium; H is high; VH is very high