



UNIVERSIDADE FEDERAL DO TOCANTINS
CAMPUS UNIVERSITÁRIO DE PALMAS
PROGRAMA DE PÓS-GRADUAÇÃO EM DESENVOLVIMENTO
REGIONAL

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**DEVELOPMENT OF PERFORMANCE INDEXES FOR ANALYSIS OF
GLOBAL VALUE CHAIN: AN APPLICATION ON TILAPIA
PRODUCTION ZONES IN BRAZIL**

PALMAS – TO
2020

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GLOBAL VALUE CHAIN: AN APPLICATION ON TILAPIA
PRODUCTION ZONES IN BRAZIL**

PhD Thesis presented to the Graduate
Program in Regional Development at the
Federal University of Tocantins (UFT) in
partial fulfillment of the requirements for
the degree of Doctor

Supervisor: Dr. Manoel Xavier Pedroza
Filho

PALMAS – TO
2020

Dados Internacionais de Catalogação na Publicação (CIP)
Sistema de Bibliotecas da Universidade Federal do Tocantins

- R484d Ribeiro, Vinicius Souza.
 Development of performance indexes for analysis of global value chain:
 An application on tilapia production zones in Brazil . / Vinicius Souza Ribeiro.
 – Palmas, TO, 2020.
 130 f.
- Tese (Doutorado) - Universidade Federal do Tocantins – Câmpus
 Universitário de Palmas - Curso de Pós-Graduação (Doutorado) em
 Desenvolvimento Regional, 2020.
 Orientador: Manoel Xavier Pedroza Filho
1. Cadeias Globais de Valor. 2. Tilápia. 3. Índice. 4. Inferência fuzzy. I.
 Título

CDD 338.9

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VINÍCIUS SOUZA RIBEIRO

“DEVELOPMENT OF PERFORMANCE INDEXES FOR ANALYSIS OF GLOBAL VALUE CHAIN: AN APPLICATION ON TILAPIA PRODUCTION ZONES IN BRAZIL”

Tese apresentada ao Programa de Pós-Graduação em Desenvolvimento Regional da Universidade Federal do Tocantins para obtenção do título de Doutor.
Orientador: Prof. Dr. Manoel Xavier Pedroza Filho

Aprovada em 01/10/2020.

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In memoriam de Gélío Ribeiro da Silva

AGRADECIMENTOS

A minha amada esposa Jaqueline e ao meus verdadeiros presentes nesses ultimos quatro anos, Manuela e Laura, que me incentivaram nos momentos difíceis e compreenderam a minha ausência enquanto eu me dedicava à realização deste trabalho. Amo vocês!

A minha querida Mãe, Mônica Ribeiro, e meus irmãos Taisa e Vitor Ribeiro, que nunca duvidaram da minha capacidade e torceram para esse momento final chegasse. E minhas amadas sobrinhas Maria Clara, Ana Rita e Helena que orgulham tanto o tio e que sempre me estimularam a ser um exemplo de esforço, determinação e estudo na vida delas. Amo vocês!

Ao querido professor Dr. Manoel Pedroza por ter sido meu orientador e ter desempenhado tal função com dedicação e amizade. Me sinto honrado de compartilhar esses anos com alguém tão humano e profissionalmente exemplar. Aos demais professores do PGDR/UFT, na figura da querida professora Dra. Temis Parente, agradeço por compartilharem vasto conhecimento. E ao professor Dr. Joaquim Bento da ESALQ/USP pelo intenso aprendizado, apesar da minha efêmera estadia na cidade de Piracicaba.

Ao Instituto Federal de Educação Ciência e Tecnologia do Tocantins - IFTO/Campus Palmas, que investiu e acreditou na minha capacitação, sendo parte essencial no meu processo de formação profissional até hoje. Também a todos da Empraga Pesca e Aquicultura pelo fornecimento de dados, materiais e conhecimento que foram fundamentais para o desenvolvimento da pesquisa. Assim como todos aqueles que de alguma forma me ajudaram a construir e desenvolver esta pesquisa, desde os estagiários da Embrapa até os parceiros dos polos que nós ajudaram a coletar dados.

Aos meus amigos de turma, Cleiton, Gislâne, Karla e Sarah por compartilharem comigo tantos momentos de descobertas e aprendizado e por todo o companheirismo ao longo deste percurso. E também aos meus colegas de trabalho do IFTO que demonstraram apoio e torceram pelo meu sucesso nessa empreitada.

RESUMO

A produção aquícola brasileira cresceu sistematicamente ao longo dessa última década, tendo a produção de tilápias como sua atividade principal. Essa cadeia foi o objeto de análise dessa tese que tem como objetivo geral analisar os ambientes de negócios de algumas zonas produtivas de tilápia no Brasil. Utilizando primariamente dados referentes a 463 unidades produtoras de tilápias (TPUs) e quatro zonas produtivas (TPZs) de três regiões do país, a pesquisa fez uso da lógica fuzzy para estimar índices que analisam comparativamente o ambiente de negócios dessas áreas produtivas. Baseado na abordagem de Cadeias Globais de Valor (CGV) a tese desenvolveu 24 indicadores, organizados em quatro dimensões de análise, que foram utilizados como inputs em sistema de inferência fuzzy que por sua vez estimou índices fuzzy multidimensionais de ambiente de negócios (BEFI). A análise dos indicadores e índices comparando as quatro zonas, categorizadas como emergentes e consolidadas, além de classificar os ambientes de negócios apontou questões importantes relacionadas a dinâmica de produção nessas zonas. Adicionalmente, a pesquisa também apontou questões gerais endereçadas ao desenvolvimento da cadeia como um todo. Tais como, os benefícios de uma aproximação com outras cadeias agroalimentares, ambiente institucional de negócios e diferentes arranjos de governança. A tese está estruturada em três artigos, sendo que nos dois primeiros foram desenvolvidas discussões que buscam ampliar a campo de pesquisa em CGV e contribuir para preencher lacunas identificadas na abordagem. No último artigo foram estimados os índices e os resultados discutidos de forma comaprada entre as zonas produtivas. Por fim, a tese apresentou suas limitações gerais e contribuições para uma agenda de pesquisa que busque promover uma expansão de estudos de natureza quantitativa e a nível micro , e que dialogue com cadeias mais curtas e/ou em fase inicial de inserção global, especialmente do Sul Global, tal é o caso das cadeias aquícolas.

Palavras Chaves: Cadeias globais de valor. Sistema de inferência fuzzy. Tilapicultura, Índice de ambiente de negócios.

ABSTRACT

Brazilian aquaculture production has grown systematically over the last decade, with tilapia production as the main activity. This chain was the object of analysis of this thesis, which has as a general objective to analyze the business environments of some tilapia production zones in Brazil. Using primarily data from 463 Tilapia production units (TPUs) and four production zones (TPZs) of three regions of the country, the research made use of fuzzy logic to estimate indexes that comparatively analyze the business environment of these production areas. Based on the Global Value Chains (CGV) approach, the thesis developed 24 indicators, organized into four dimensions of analysis, used as inputs in a fuzzy inference system that estimated multidimensional business environment fuzzy indexes (BEFI). The analysis of indicators and indexes comparing the four zones, categorized as emerging and consolidated, in addition to classifying the business environments pointed out important issues related to production dynamics in these zones. Additionally, the research addressed general issues for the development of the chain as a whole. Such as the benefits of a proximity to other agri-food chains, institutional business environment and different governance arrangements. The thesis is structured in three articles, in the first two discussions were developed that seek to expand the field of research in CGV and contribute to fill gaps identified in the approach. In the last article the indices and results of the zones are discussed in comparative terms. Finally, the thesis presented its general limitations and contributions to a future research agenda that, in addition to other issues, seeks to promote an expansion of studies of a quantitative and firm-level nature in the field. And that also dialogue with shorter chains and/or in the initial phase of global insertion, especially in the Global South. Is the case of aquaculture chains that have a potential impact on such relevant issues as food safety and sustainable development.

Keywords: Global value chains. Fuzzy inference system. Tilapia culture, Business environment index.

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1 INTRODUCTION

1.1 General background

Since the second half of the 20th century, especially in view of the improvement of communication and computer technologies, as well as the reduction of logistical costs and trade liberalisation, there has been a change in the production process of goods by firms.

Jones and Kierzkowski (1990) emphasized that new comparative advantages came into play in that period with the fall mainly of communication and transport costs, denominated as service links. These authors highlighted how production processes were divided into subsequent production blocks, spatially dispersed and connected by services links.

What until then occurred in the form of a single block, based on the Fordist model, and spatially centralized, began to occur gradually in multiblocks spatially distributed around the world. In this new modus operandi, the production process began to work with the possibility of fragmentation into several blocks or steps, performed separately in several countries by different companies (Nonnenberg, 2014).

Since then this phenomenon has been investigated by several academic disciplines, including economic sociology, international economics, regional and development studies, economic geography, international political economy, supply chain management, operations management, and international business (IB) (Kano et al., 2020).

In this context, from the concept of Commodity Chain presented by Hopkins and Wallerstein (1977), Gereffi (1994; 2001) extends it to the Global Commodity Chain (GCC) and later to what is now known as Global Value Chain GVC (Gereffi et al, 2001). According to Kano et al. (2020) "GVC is the nexus of interconnected functions and operations through which goods and services are produced, distributed, and consumed on a global basis".

Particularly in the last decade, GVC has increasingly gained space in academic and political debates, both as a phenomenon that describes various industries around the world, as a framework capable of providing a compression of the world industry organization in a holistic perspective (De Marchi et al., 2020).

Governance and updating dimensions have since been the general focus in the analytical context of the GVC literature, with a relative bias of a qualitative nature and macro analytical

levels (Sturgeon and Gereffi, 2009; Frederick, 2014; Fernández and Trevignani, 2015; Hernandez and Petersen, 2017; Eckhardt and Poletti, 2018).

Despite bringing with it in its essence the phenomenon of globalization and spatial fragmentation of production on a global scale, the elements of the GVC framework are not exclusive to the analysis of globally inserted production chains. From this expanded understanding, this thesis proposes a pioneering study, based on this approach, for the analysis of a chain that is not inserted globally, yet has the potential to do so.

In this case, the production chain of tilapia in Brazil, object of this thesis, despite being one of the largest producers in the world and having the largest slaughterhouse in Latin America, the country exports less than 0.4% of its production. In terms of global trade, historically, approximately 37% of world production from fishing and aquaculture is exported. Although tilapia is not among the main species traded globally, it has successfully increased its share of the global fish market (IBGE, 2018; FAO, 2020).

The value chain of tilapia in Brazil presents a great diversity in terms of productivity, socioeconomic, and structural characteristics. The south and southeast regions have better road infrastructure, greater credit supply, and higher productivity and technological levels. In these regions there are also more net cages and feed factories and producers of 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 system¹, despite the differences because of the system used, in 2018 the average annual production per production unit was 358 tons. These production units mostly sells tilapia via slaughterhouses and/or middleman. In terms of coordination, verticalised governance models are exclusive to the South region, through cooperative systems. In the rest of the country a non-verticalized production coordination prevails. (Pedroza Filho, et al., 2020).

The global aquaculture chain is growing rapidly, the Food and Agriculture Organization of the United Nations (FAO) estimates that the growth in global aquaculture production between 2016 and 2030 is over 35%, in Brazil the estimated growth in that period is 89%. Still according to the organization, although China is dominant in tilapia production, external factors

¹ This system is more common in the south of the country.

have negatively impacted the local industry², and future growth in world exports should be sustained by other Asian producers, such as Indonesia, as well as the expanding Latin American industry (FAO, 2018; FAO, 2020).

To this promising scenario of export leverage must be added two other important recent issues. The authorization of tilapia production, in a net cage system, in the state of Tocantins that presents environmental conditions quite favorable to tilapia production. And the implementation, at the end of 2018, of the drawback customs regime, which aims to make tilapia more competitive internationally, with the potential to reduce production costs by 12% to 37%, by tax reduction (STATE ENVIRONMENTAL COUNCIL OF TOCANTINS, 2018; Pedroza Filho and Rocha, 2019).

1.2 Problem statement and objectives of the research

This thesis is developed over two research problems, the first is summarized in the following question: "Considering that firms in the same value chain may coexist in different business environments, what would be the main factors for this differentiation at the productive zones level?"

As will be presented in the articles, the perspective of the GVC approach is quite broad, which makes it possible to identify these different conditions for firms to operate in the same production chain. In this context, a diagnosis of the tilapia chain in Brazil by Barroso et al. (2018) indicates the existence of different environments or structures in which firms and poles are inserted. This deepening of discussions about tilapia productive zones in Brazil helps to fill a gap in academic research on aquaculture chains in developing countries, from the holistic perspective of the GVC approach. The results of the research in this area will be important to guide the organization public and private of the Brazilian chain for sustainable expansion in domestic and international markets.

From the perspective of the productive sector, a clearer perception of the aspects linked to the dynamics of productive arrangements can be valuable in (re)configuring the strategies of firms and consequently boosting their economic results. Parallel to this, this discussion can guide public actions, in all spheres, in order to improve the institutional, technological,

² Also like "the imposition of tariffs on tilapia imports by the United States of America, as well as by a shift in development priorities by the Government of China" (FAO, 2020, p.86).

infrastructure or management conditions in which the companies are inserted. Above all, if the insertion and/or movement of these firms in the chains is placed as a regional development strategy.

The second research problem seeks by the theoretical perspective to propose elements and discussions that help to fill gaps in research and to answer some open questions in the field of GVC. For this, it is important to advance a research agenda that is capable of combining its broad conceptual tools into an analytical structure that is capable of transiting bidirectionally between the global and the local. The proposal of variables and indicators related to the framework, as well as the use of fuzzy logic can be of great value to format and stimulate genders of research so far little explored in the field.

The general objective of the thesis is to analyze in a comparative way the business environments of tilapia producing zones in Brazil, at the level of producers, from the perspective of the GVC approach and a quantitative method.

The specific objectives are:

- To identify possible gaps in the field of GVC research and discuss the mutual benefits of an approach with the SCP model;
- To propose key elements, especially within the firm, that translate the analysis dimensions of the approach;
- Develop a methodology capable of processing these variables, sometimes qualitative, into quantitative indicators associated with the GVC approach;
- To estimate and analyze quantitative indexes for the business environment in different tilapia production zones in Brazil.

1.3 Structure of the Thesis

The thesis is organized in three articles. In the first article, the approach of GVC is presented, discussing its main analytical pillars and the main characteristics of its empirical research. Research gaps in the field are pointed out and a list of analytical elements is proposed to help fill these gaps in future research. Parallel to this, the article also discusses different mutual benefits of approaching GVC with that of Structure, Conduct and Performance (SCP) in designing future research.

From the gaps in field research and the framework of elements previously proposed, the second article aims to present a new methodological design capable of operating quantitative and micro analytical level research. To this end, it proposes a model based on fuzzy logic, applied to a case study of institutional environments of tilapia producing units in São Paulo and Mato Grosso do Sul. It estimates indexes under four institutional contexts (Relational, Economic, Social and Local), presenting reflections on the institutional environment studied and on issues related to the subject looking at aquaculture chains in the Global South. Finally, it points out limitations, challenges and multiple contributions of the use of fuzzy logic for the CGV field.

Based on the model developed and tested in the second article, the third article incorporates other dimensions of GVC analysis, in addition to the institutional one, in search of analyzing the business environments of the tilapia chain in Brazil. For this, it estimates multidimensional business environment fuzzy indexes (BEFI) from data of 463 TPUs distributed in four productive zones (TPZs), in three different regions of the country. In a detailed discussion of indicators and indices, the article presents some important reflections related to key issues for strengthening the business environments of the researched zones. Additionally, in light of the literature related to aquaculture chains in Brazil and worldwide, it discusses relevant issues for the development of the national chain, as well as for its eventual insertion in global chains.

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ARTICLE 1

Global value chain approach and firm-level analysis: A proposal of analytical elements

Abstract

In literature related to the global value chain (GVC) approach, researchers recognize a gap in the number of quantitative studies with firms and clusters as microanalysis units. Based on a literature review, this article proposes a framework of analytical elements that contribute to filling this gap. The study also seeks to suggest, from an approximation between GVC and a model of structure, conduct and performance (SCP), some mutual benefits for both approaches. From the dialogue within the field of SCP research and the framework of analytical elements presented, the research highlights a promising path for a future research agenda in GVC. Additionally, the article discusses the limitations and capabilities in the use of these elements and the potential impacts of future research that seeks to fill GVC's gap. Finally, it highlights both the academic and political importance of the nature of studies it seeks to stimulate.

Keywords: micro level; quantitative; research agenda; structure, conduct and performance; value chain

1-Introduction

Due to globalization of production, trade liberalization and reduction of logistical costs intensified at the end of the 20th century, an analysis approach called global value chains (GVC) was introduced in production chain studies. From this perspective, the functions of a value chain become fragmented and scattered around the globe. The merit of the GVC approach lies in the fact that the analyses do not focus solely on the stages of transforming input into goods and services, i.e., the concept of input–output, but rather on a broader context. It considers the generation of value of the final product or service, considering aspects related to chain governance, technological development, institutional aspects, geographical scope and stakeholders' role. (Gereffi, 2019; Gereffi and Fernández-Stark, 2018).

Since the 2000s, there has been growing interest in research related to the GVC framework involving various fields such as sociology, economics, regional studies, geography, and technological innovation. However, firm-level studies with a quantitative approach are scarce and generally involve limited dimensions of analysis without advancing toward an integration of the plentiful possible views. Parallel to this, regardless of the unit of analysis (macro or micro), the nature of the discussions is strongly marked by a qualitative perspective (De Backer, Lombaerde and Iapadre, 2018; Frederick, 2014; Sturgeon and Gereffi, 2009;).

In this context, this article aims to propose elements of analysis that can be used in micro and quantitative research in the field of GVC. The research also presents an embryonic scenario of approximation between the GVC approach and the structure, conduct and performance model (SCP) some points that can benefit both fields of research.

The article is divided into six sections, the first being a general introduction to the topic. In the second section, the bases of the GVC and structure, conduct and performance (SCP) paradigms are briefly presented. The third section describes the research methodology, followed by the fourth section, which presents the gap in empirical research on the GVC approach and a literature review aimed at studies of a quantitative nature and/or with a microanalysis scope (firms and clusters). The fifth section discusses the possible root causes of this empirical gap and proposes a framework of elements that contribute to its minimization. Additionally, in this section, reflections concerning the integration of the two approaches are presented. Finally, the sixth section details the final considerations of the research as well as the future limitations and expectations regarding the expansion of research that will fill this gap from academic and political perspectives.

2-The GVC and SCP approaches

2.1 The bases of GVCs and their dimensions of analysis

The origin of the GVC approach has as a background the world-system theory school with the research of Hopkins and Wallerstein. The concept of commodity chain³ presented by these two authors was subsequently expanded to global commodity chain (GCC) by the developmentalists Gereffi (1994), taking into account a growing context of academic interest for what was understood as a new and/or intense phase of globalization in the 1990s (Araki, 2007; Bair, 2014; Hopkins and Wallerstein, 1977, 1986).

In the context of fragmentation of world production, the GVC framework arises from the confluence of three theories: world-systems theory, dependency theory and development theory. In 1999, the GVC initiative was introduced in a workshop held in the United Kingdom (UK), driven by two distinct research traditions, namely, GCC and economic clusters. The aim was to create an integrated research framework that could link macro (global), meso (industry and countries) and micro (enterprise and communities) variables in the face of economic globalization (Gereffi, 2019).

³ ‘A network of labour and production processes whose end result is a finished commodity’ Hopkins and Wallerstein (1986, p. 159).

The effort to build a global chain analysis framework suppressed the expression commodity, leading to a neutral industry, and incorporated Porter's (1989) idea of value, which gave rise to the concept of GVC. Theories from other disciplines, such as transaction cost economics (TCE), industrial cluster research and convention theory, were introduced in global chain analysis. (Lee, 2010; Sturgeon, 2008).

This trajectory allowed the research field to have a multidisciplinary nature, thereby expanding its dimensions of analysis. The perspectives for analyzing research traditions in the late 1990s, i.e., top-down (GCC) and bottom-up (economic clusters), led to the formation of two main pillars of the GVC framework, governance structures and upgrading trajectories, respectively (Gereffi, 2019). More recently, Gereffi and Fernández-Stark (2018) identified the following basic dimensions of analysis for GVC.

1. **Input–output:** focuses on identifying the main activities and segments linked to a GVC. Mapping the core activities of a chain is a key element for analysis in this dimension. Additionally, understanding the structure and dynamics of the chain by observing each firm and its roles in its own evolution and trends is another key factor of this analysis.

2. **Geographic scope:** is first based on global supply and demand, evolving toward an observation of international trade flows. In this sense, this approach enables an analysis of the configuration and position of countries and firms in the GVC.

3. **Governance:** allows us to understand how the chain is controlled and governed on the basis of players' power asymmetries. Further, based on the variables of transaction complexity, the ability to codify these transactions and supplier competence (capacities), the authors observe the characteristics of the five types of governance: market, modular, relational, captive and hierarchical.

4. **Upgrading:** is directly related to productive upgrading, which aims to achieve higher value-added in a chain. A widespread definition⁴ of upgrading in GVC is making better products, making them more efficiently, or moving into more competent activities. Upgrading standards differ depending on the industry and country, with six typologies for the phenomenon: process, product, intersectoral, functional, entry, backward linkages and end-market.

5. **Local institutional context:** identifies how local, national and international conditions and policies shape a country's participation at each stage of the value chain. There are three sub-contexts in this dimension: economic, social and local institutional. The first covers labor and infrastructure costs as well as the feasibility of access to other financial

⁴ See De Backer, Lombaerde and Iapadre (2018) and Tian, Dietzenbacher and Jong-A-Ping (2019).

resources. The second includes aspects related to the availability of skilled labor, access and quality of formal and informal education, women's participation in the workforce, etc. The last one deals with elements related to labor and tax laws and regulations as well as tax, international trade and science and technology innovation policies.

6. **Stakeholders:** comprise the last dimension of analysis. This dimension proposes mapping each of the agents involved in the chain, explaining their roles and going beyond the identification of the input–output dimension. Because it considers all players⁵ involved, it goes beyond firms directly linked to production processes. It also analyzes how the relationships between these players are governed at the local level and which institutions are in a position to drive change.

Although the first three (last) dimensions are closer to a macro context (micro), the richness of elements of analysis in GVCs allows research to approach such dimensions in an isolated or integrated way, whether top-down or bottom-up. This enables a better understanding of the role, dynamics and organization of productive and commercial processes from the viewpoint of firms and countries in a scenario of value generation and production fragmentation.

2.2 The SCP paradigm

The SCP paradigm comes from the tradition of research on industrial organization, notably neoclassical, and is often used in research on industrial competitiveness. The origin of the paradigm refers to the research of Bain (1959) and Mason (1953), who postulated the existence of causal relations between the structure of a market wherein a firm operates, its conduct and its performance (Lelissa and Kuhil, 2018a; Lopes, 2016).

In this sense, the industry structure determines the firm's strategies, which, in turn, determine the firm's performance, resulting in a line that infers causality from structure to performance. Under the paradigm, in general terms, structural variables (such as companies' market power) affect conduct variables (such as collusion or competition), which, in turn, affect performance variables (such as profits) (Laribi and Guy, 2018).

In the early 1980s, Michael Porter presented two important criticisms of the model. The first was that the model would be stochastic, not considering the dynamics that a structure

⁵ This includes companies, industrial associations, workers, educational institutions and government agencies, including export promotion and investment attraction departments, departments of foreign trade, economy, and education, among others.

undergoes over time, such as changes in concentration, barriers to entry and differentiation of products. The second point raised was that this structure would be an exogenous element that firms are unable to change and thus become its hostage. Since then, new approaches have adjusted the model, making the structure an endogenous element that is affected by the feedback of conduct and performance as well as by public policies that determine market rules (Laribi and Guy, 2018).

Notably, Ferguson's (1988) observations also remain relevant regarding the use of the research tool in the field of industrial organization. The author noted that the relationships between structure, conduct and performance were more complex than originally anticipated and that a limited vision on market operations can be dangerous when seeking to formulate public policies under the view of the model.

Over the years, the SCP model has become a widely used tool to analyze industrial structures, firms' competitiveness and market power, despite the competition⁶ in the wave of research linked to the new empirical industrial organization (NEIO) in the field of industrial organization. An example of the use of the paradigm in empirical research is the analysis of the relationship between market concentration and bank performance by comparing methodologies or simply testing the basic hypothesis that collusion structures result in higher profits.

In this field, the results⁷ with regard to the hypothesis are ambiguous. As Ajlouni (2010) observed when analyzing 49 studies for the banking sector between 1960 and 1980, 20 studies reported an impact of the relationship between market structure and banking performance, 14 studies presented completely insignificant relationships, and 15 studies inferred varied results, i.e., sometimes positive and sometimes not according to the data used or different measures of structure and performance.

3-Research methodology

A literature review was conducted using the Scopus and Google Scholar databases to identify studies associated with the GVC and SCP approaches. Scopus is the largest abstract and citation database in the world provided by Elsevier that cover peer-reviewed literature. Google Scholar, on the other hand, although less selective, covers a large number of technical reports, working papers, thesis/dissertations, books or book chapters, unpublished materials

⁶ See Lelissa and Kuhil (2018a) for other frameworks that challenge the SCP paradigm, such as the efficient hypothesis, contestable market theory and quiet life hypothesis.

⁷ See Athanasoglou, Brissimis, and Delis (2008); Aguirre, Lee, and Pantos (2008); Ajlouni (2010); Lee (2012); Khan, Ahmad, and Chan (2018); Lelissa and Kuhil (2018b); Gonzalez et al. (2019).

(such as preprints), and other document types across different fields (Martín-Martín et al., 2018).

We used three steps to build our study base. In the first stage, we used Scopus to select articles or reviews in English with the term “global value chain” in the title, abstract, or keywords, and published until 2019. After applying this query string, we obtained 1,461 articles and reviews. From this, we identified the top five most cited authors and selected the 63 articles or reviews that were authored by them (Table 1).

Table 1. Summary of Top 5 most cited authors in GVC literature.

Author	Main filiation	Numbers until 2019				Mains Subject area
		Total citations (all docs)	Documents		GVC reviews or articles	
			All	GVC		
Gereffi, Gary	Duke University, USA	7,743	70	29	20	SOS; BMA; EFF
Humphrey, John	University of Sussex Business School, UK	6,051	44	11	10	SOS; EFF; BMA
Schmitz, Hubert	University of Sussex Business School, UK	4,769	59	8	7	SOS; EFF; BMA and ENV
Sturgeon, Timothy	Massachusetts Institute of Technology, USA	4,458	21	11	9	SOS; BMA; EFF
Ponte, Stefano	Copenhagen Business School, DEN	3,962	72	20	17	SOS; BMA; ENV
Total		26,983	266	79	63	

Source: authors' elaboration based on Scopus. Notes: The number of authors' citations refers to all types of documents, i.e. in addition to articles and reviews include books or chapters, conference papers, editorials, etc. The criteria for classifying documents and articles or reviews as GVC studies was the same described by the query string of step 1 ("global value chain" in the title, abstract, or keywords). The number of documents published sorts the three main areas of publication. SOS- Social Sciences; EEF - Economics, Econometrics and Finance; BMA-Business, Management and Accounting; ENV - Environmental Science.

In the second step, in order to address the objective of building a group of elements for firm-level and quantitative analysis, we have added the following terms to the query string of the first step:

- “firm-level” or “cluster”; AND “analysis” or “analyze”
- “quantitative” or “measuring” or “measurement”; AND “analysis” or “analyze”

With this, we created two study groups and added 133 new sources, totaling a database of 196 manuscripts. Table 2 presents some characteristics of these studies from the two new query strings.

Table 2. Characteristics of the articles and reviews selected in step 2.

Approach of GVC studies	Total	Publication period					Top subject areas (total)	Top Journals (total)
		2019	2018	2017	2016	<2015		
Micro level	89	21%	10%	12%	12%	44%	Social Sciences (48)	Eur. Plan. Stud. (6)
							Business, Management and Accounting (28)	Entrep. Region. Dev. (5)
							Economics, Econometrics and Finance (27)	Sustainability (4)
							Environmental Science (21)	Reg. Stud. (3)
Quantitative	44	25%	27%	18%	5%	25%	Economics, Econometrics and Finance (19)	Physica A Stat. Mech. Appl. (3)
							Social Sciences (16)	Econ. Syst. Res. (2)
							Business, Management and Accounting (11)	Plos One (2)
							Environmental Science (7)	Rev. Dev. Econ. (2)
							Agricultural and Biological Sciences (4)	Rev. Int. Polit. Econ. (2)
Total	133	23%	16%	14%	5%	42%		

Source: authors' elaboration based on Scopus. Note: An article or review may belong to more than one subject area.

At the end of the second step, we used the query string described in step 1 to search manuscripts associated with SCP, replacing the initial search term "global value chain" for "structure conduct and performance". The 10 most cited articles and reviews were selected from the 78 found. Thus, we constituted an initial collection of 206 researches, 196 of them related to GVC and 10 to SCP.

In step 3, Google Scholar was used to consult other documents associated with the same Scopus search terms for title, abstract and keywords, without this time delimiting the language or year of publication. On this database, special attention was given to documents with high citations and/or authors frequently cited in the studies of both approaches. The choice to use Google Scholar was because this base has a wider coverage compared to the Web of Science and Scopus for subject categories such as Social Sciences, and Business, Economics and Management, which concentrate most of the publications in GVC. Furthermore, this database is more practical and efficient to identify manuscripts with high citation rates in practically all subject areas (Harzing and Alakangas, 2016; Martín-Martín et al., 2018; Martín-Martín, Orduna-Malea and López-Cózar, 2018).

With this final addition of resources, the literature review of this research included more than 300 articles⁸, reviews and documents of other nature. These studies were classified according to their characteristics of basic or applied research. The basic ones were evaluated for their relevance and theoretical basis of the GVC and SCP approaches, and the most relevant ones served for a brief characterization and conceptualization of the main elements of these paradigms. The applied research studies associated with the terms formed the basis for diagnosing the main topics, key elements and analytical biases of the two approaches. Finally, the proposed framework of elements of analysis was derived from the deductive reasoning developed throughout the literature review, while reflections on the synergistic contributions of the two approaches took an inductive methodological path.

4-The research gap and a glance at the literature review

4.1 The tradition of GVC research and its gap

The topics of multinational companies, trade, national development strategies, industrial upgrading and small and medium-sized enterprises have always been associated with the GVC framework. Because it is rich in dimensions of analysis, researchers from substantially diverse areas have been attracted by the theoretical structure developed over the last 20 years. International organizations are also attracted by printing their political and ideological bases on publications. In this sense, the researched topics based on the GVC approach have significant depth (Gereffi, 2019).

In the field of GVC, research often refers to the dimensions of governance analysis and upgrading. This concentration is sensible because these were considered the fundamental pillars of the GVC initiative, as discussed in the previous section. This historical background also explains, at least partially, the tradition of macro and meso (sectorial) level analyses of research.

Given this mindset, the first gap observed in the field is the scarcity of studies that consider the institutional dimension in its analysis. Research often refers to institutions as relevant to the insertion and evolution of a country, region, cluster or firm in GVCs (two of these will be discussed further). However, the role of the dynamics of institutional aspects in

⁸ The metric limitations of Google Scholar did not allow a detailed description as it was carried out at Scopus database.

global chains remains under-researched (Dollar, Ge and Yu, 2016; Eckhardt and Poletti, 2018; Miranda and Wagner, 2015; Neilson and Pritchard, 2009).

In parallel to what has been exposed, a perspective of qualitative approach is also noted in the literature review. Sturgeon and Gereffi (2009, p.5) state the following: ‘The GVC framework provides a conceptual toolbox, but quantitative measures are lacking’. The authors refer, above all, to studies with a macro approach proposing recommendations for public policies. Frederick (2014) observes that research of this nature often uses qualitative data.

The gap in studies that consider quantitative approaches and have microanalysis units (firms and clusters) is recognized by the academic community and international organizations. The broad conceptual tooling provided by the approach requires that several conceptual and methodological aspects be combined into an analytical structure that can transition bi-directionally between global and local. In this regard, improving the understanding of the reality of individual companies in chains through specific research capable of processing a broad nature of data and information comprises a leading path in the field of GVC analysis (De Backer, Lombaerde and Iapadre, 2018; Giovannetti and Marvasi, 2018; Golini et al., 2018; Nielsen, 2018; Hernández and Pedersen, 2017; Keane, 2014).

Having recognized the empirical gaps in the field and considering that this article contributes to the dissemination of bottom-up investigations (at the firm or cluster level). And prioritizes a quantitative bias in its design, we present below a brief review of literature of the most recent research in this direction.

4.2 Some empirical quantitative evidences at the firm and cluster level

The pioneering works led by Robert Koopman and Zhi Wang, followed by the important observations of Robert Johnson, on production fragmentation, helped researchers, policymakers and international organizations move toward measuring international trade in terms of value addition rather than gross exports (Johnson, 2014; Koopman, Wang and Wei, 2014; Wang, Wei and Zhu, 2013;).

Frederick (2014) was one of the researchers who first sought to approximate the GVC and I–O (input–output) approaches. Concerned with quantification in GVC from industrial data, particularly on the aspects of upgrading and governance, the researcher specified ways to achieve improvement in this field using I–O datasets, supply–use tables and trade data.

In this context, efforts have been made to use quantitative databases to analyze GVC, mostly using global I–O (input–output) arrays: World Input–Output Database (WIOD) and

Trade in Value Added (TiVA). These efforts include a wide range of topics, such as the distribution of value addition across countries, consequences of productive fragmentation for employment and revenue, spatial configuration of fragmentation, productivity gains and per capita income, upgrading in chains and methodological alternatives to measure value added in I–O models (Banga, 2014; Constantinescu, Mattoo and Ruta, 2017; Criscuolo and Timmis, 2017; Del Prete, Giovanetti and Marvasi, 2018; Gurgul and Lach, 2018; Jonhson, 2018; Miroudot and Nordström, 2015; Raei, Ignatenko and Mircheva, 2019; Timmer et al., 2015).

Moreover, regarding the use of quantitative data, several studies used other databases, such as trade censuses, the Orbis and Zephyr databases and the estimates of demand elasticity, to understand the determining factors of vertical integration of firms from suppliers' position in the chain and elasticity of demand faced by suppliers and end producers. With certain exceptions, the works converged to the evidence that producers of final goods (e.g. parent companies) tend to integrate stages that are more downstream (upstream) when the elasticity of product demand is relatively higher (lower) (Alfaro et al., 2019; Antràs and Chor, 2013; Rungi and Del Petre, 2018).

Regarding the relationship between governance and upgrading, Golini et al. (2018) analyzed the effects that different forms of governance with suppliers and customers have on economic (product, process and functional), environmental and social modernization. The authors extracted data from the International Manufacturing Strategy Survey, with quantitative information at firm level concerning a large number of companies located in different contexts (size, countries, products, and positions in the value chain). The results showed that participation in GVCs supported only some forms of upgrading and only under specific relational or captive governance structures.

In relation to the topic of insertion in GVCs and its consequences, Del Petre, Giovannette, and Marvasi (2017) conducted an investigation using data from World Bank Economic Surveys. Based on firms in North Africa, the researchers found that those included in GVCs have better performance (*ex ante*) and show incremental gains in *ex post* productivity. In addition, they suggested that policies designed to support certifications and compliance with international standards and increasing trust among firms in different locations are important elements for inserting developing countries into GVCs.

From a different database, Eora multi-region input-output table (MRIO) covering 189 countries, Raei, Ignatenko, and Mircheva (2019) came to rather approximate conclusions on this topic. For the authors, participation in the GVC positively impacts per capita income and productivity; however, they warned that upgrading in chains is not automatic and frequent. In

this sense, they highlighted the importance of institutional characteristics (the execution of contracts and infrastructure quality) and unit cost of labor as determining factors for participation in these value chains.

As with the latest research, others with the background of I–O matrices that traditionally have a scope of macro (countries) and meso (industrial sectors)⁹ analysis can contribute to a better understanding of the dynamics of firms and/or clusters in GVC, either in terms of their results or methodological proposals. An example of this last case is the research conducted by Tian, Dietzenbacher, and Jong-A-Ping (2019), who discussed the upgrading dimension, with direct contributions to the micro level discussion (firms and clusters) in the GVC approach.

Based on their literature review, these authors proposed eight indicators¹⁰ to measure industrial upgrading. Later, from the perspective of up-down analysis, they compared and analyzed the upgrading of different countries and sectors using World Input–Output Tables (WIOT). Regarding the measurement task, the article had an important contribution in proposing upgrading indicators consolidated to the different aspects of the phenomenon, something that until then had only been addressed in a fragmented manner by researchers who discussed the topic. (Tian, Dietzenbacher and Jong-A-Ping, 2019).

Based on our analysis, these proposed upgrading indicators can be suitable for use in surveys at firm level. The significant challenge of collecting and using microdata¹¹ in research plays an important role for firm-level topics in GVC, given that the data on I–O tables and global trade have their limitations and do not clarify, for example, many questions concerning the dimensions of governance and upgrading. Nor do those related to stakeholders and institutions, which, as indicated earlier by the two research studies, play an important role in the insertion and continuity of firms and countries in GVC.

In relation to studies that have a firm-level analysis perspective, it is important to establish a caveat. Because the phenomenon of production fragmentation has been identified in literature, case studies within the firm have been developed to either track intermediate goods or identify the distribution of added values of a given product along its value chain (Ali-Yrkkö et al., 2011; Dedrick, Kraemer, and Linden, 2009; Feenstra, 1998; Ye, Meng, and Wei, 2015).

⁹ See Timmer et al. (2015) and Lu (2017).

¹⁰ These eight indicators: the labour productivity growth, capital compensation growth, capital intensity growth, growth of value added exports, growth of the share in value added exports, growth of the unit value added exports, growth of the skill intensity of employment and growth of high-skilled labour exports.

¹¹ Nilsen (2018) identifies initiatives for the use of microdata within the scope of the European statistical system by applying research at the firm level and its subsequent connection to the TiVA dataset.

These studies play an important role in the dissemination and consolidation of the phenomenon of fragmentation. However, their large sampling and analytical, geographic and temporal limitations do not allow for a broader understanding of the effects and transformations of firms and/or clusters when included in GVCs. Accordingly, at the end of this section, we present two recent studies with the GVC approach that had a microanalysis unit and used data from a census and surveys that applied to Italian firms.

Giovannetti and Marvasi (2018) started from a census conducted in Tuscany (Italy) to investigate how positioning and governance relate to productivity. In an econometric analysis¹² with data at firm level, the authors raised a hypothesis of self-selection of Italian companies regarding participation in GVCs, citing the conclusions of Del Petre, Giovannette, and Marvasi (2017).

The authors also noted that productivity is higher in GVCs than in domestic value chain companies, which they believe corroborates the existing literature. Conversely, they identified something that they believed was not emphasized in the literature: medium-sized companies in hierarchical chains are more productive than those in market chains. Finally, they proposed that future research should investigate the causal link between participation in the value chain and productivity and noted that such a link should be bi-directional. They added that this challenge requires a panel of companies and good instruments of participation in the chain, positioning, and governance.

Golini and Boffelli (2018) analyzed the textile and clothing Industrial District (ID) in Bergamo (Italy) and sought to understand the role of the processing industry in supporting the participation of companies in GVCs. Thus, they employed the GVC approach framework and investigated the nature and content of the links between the stages of production.

The initially developed methodology mapped the productive activities in ID, which enabled the analysis of the position of each firm, as well as the scope of its participation in the role of 111 activities. Subsequently, surveys were applied in four structures¹³ in a population of 443 firms with a response rate of 32.7% (145). Finally, interviews were conducted with representatives of two local leader firms (Golini and Boffelli, 2018).

In their study, the connection of Italian firms to the GVC proved to be relatively light, while within the district it was substantially strong. On average, 31% of the firms' purchases and 30% of the sales were made with other firms in the district, and Italy considers that these

¹² They used a regression model, with variables dummies, based on Ordinary Least Squares (OLS) estimations.

¹³ The four structures were as follows: general company information; production activities carried out; upgrading (product, process, function, chain, environmental and social) and GVC participation indicators.

percentages increased to 69% and 71%, respectively. However, if you consider the rest of the world (outside Europe), the companies in the district only exported 11% and imported 18% (Golini and Boffelli, 2018).

Other elements for the district's integration into the value chain that are particularly interesting and little analyzed in the field of empirical research were presented. For example, although a significant number of firms performed one or few of the 111 activities, which corroborates with the literature, almost half of them were vertically integrated, often discontinuously, into a production stage, when it is generally associated with integration in pre- and post-manufacturing stages (Golini and Boffelli, 2018).

Finally, the authors highlighted the importance of new studies to investigate the causal links between different variables and proposed that research be carried out by comparing IDs of the same industry and country and IDs of different products in the same region such that it could be replicated over time (after five years). The objective and quantitative methodology with the potential to generalize different productive clusters drew attention to an emergency topic in the field of GVC, which is the issue of the connection between the global and local in value chains and their reflections on regional development.

Similar to this present research, other studies observed that GVCs are not essentially global in nature but rather focused on regional clusters of production and that multinational enterprises (MNEs) play a key role in these networks. A research agenda of this kind, namely, one that is concerned with specific policies¹⁴ that can help firms, clusters, regions and countries benefit from GVCs and addresses the difficulties of participating in them, appears to be a development in this field (Criscuolo and Timmis, 2017).

5-The proposal of analytical elements and reflections of an approximation of approaches

5.1 Research obstacles and an investigative framework for research in GVC

The reasons for the scarcity of research in the field of GVC with a quantitative nature and/or unit of microanalysis may be associated with certain factors. The first factor is the very genesis of its developmental precursors, despite the current bottom-up (economic clusters) that founded the upgrading pillar (Gereffi, 2019). Since then, the research carried out, which mainly

¹⁴ See Gereffi (2019).

focused on governance and upgrading, was concerned with the countries' role in global chains with a qualitative analysis bias.

This line of research was intensified by international organizations that gradually adhered to the GVC framework such as International Labor Organization and United Nations Industrial Development Organization in the early 2000s. Followed by World Bank, WTO, OECD, and national development agencies, accelerating with the financial crisis of 2008–2009. The research conducted by these organizations contributed to a greater scope and visibility of the approach and increased the quality and relevance of the published results. However, multiple uses of GVC definitions exists according to organizations' particular political and ideological backgrounds (Gereffi, 2019).

Although international trade data disclosure initiatives in terms of value addition encourage a wave of quantitative research in the literature, as presented in the subsection 4.2, initiatives to work with micro data are still in an embryonic stage. The intensification of quantitative research focusing on firms and/or clusters is aligned with the collection, processing, and dissemination of data of this nature. However, the availability of micro data alone does not guarantee a proliferation of studies focused on firms and clusters.

This hypothesis is based on the evidence that such a shortage prevails since the beginning of the GVC approach, before and after the initiatives of Robert Koopman and Zhi Wang (Koopman, Wang and Wei, 2014; Wang, Wei and Zhu, 2013;). Given that bottom-up research with primary data, even with reduced scope, could have been produced, such research remains considerably recent. This point is related to the second factor that we believe hindered the consolidation of this type of agenda, namely, the difficult task of establishing firm variables at the micro level considering the abundance of elements of analysis presented by the framework.

This difficulty becomes more arduous when considering the institutional aspects pointed out in literature, which are minimally investigated from the bottom-up perspective. Despite considerable advancement in the dimensions of governance and upgrading when establishing analytical elements generally correlated with the issue of productivity, this shortage poses a risk of underestimation of the last two contexts to the detriment of the others present in literature.

The third factor is intrinsically associated with the second, but it is more difficult to establish an agenda of quantitative studies in the field. In transposing the obstacle of theoretical abstraction to the creation of analytical elements at the micro level, data collection, processing, and analysis are other critical points. This is because most aspects associated with the dimensions of the framework analysis such as governance, institutional, upgrading and

stakeholders are qualitative; their measurement or translation in quantitative terms is a methodological obstacle difficult to equate.

Understanding that the first reason or problem speculated herein was based on the genesis of the initiative and the research profile of the first individuals interested in the topic and that the third derivative of the second is of a particularly methodological nature, we focus on the second problem. Table 3 is the result of an exercise in the construction of the elements of analysis that can be applied to firms and/or clusters and that, however generic they may be, move toward proposing stricter variables of analysis in the field of research of the GVC approach.

Table 3. Elements of the global value chain (GVC) approach: A proposal for micro and quantitative investigations.

Dimensions of GVC	General objectives	Key elements (Chain, clusters and firms)
Input–output	Analyze the dynamic and structure of companies under each segment of the GVC. Additionally, understand how the main activities and segments are organized.	Mapping of activities and number of firms involved in research and design; inputs; production; distribution and marketing, sales and recycling. In terms of the chain: global production; sales, jobs and taxes paid. In terms of the company-specific characteristics: size; state-owned or private; value share in the chain; number of jobs; profits; costs; productivity; utilization rate, quality of logistics infrastructure; access and availability of inputs, equipment and natural resources.
Geographic scope	Analyze the configuration and position of countries and firms in the GVC. It is important to understand the domestic, regional and global level of firms' activities and products.	Geographical distribution of firms and clusters; spatial configuration and geographical range of activities, inputs and sales; share of exported production; share of imported inputs and potential to export or expand exports.
Governance	Understand which governance structure predominates in the chain, cluster and firms and its consequences. It is also important to understand relationships and their barriers between actors.	Identification of existing governance typologies; information coding level; barriers to entry and exit; partner change frequency; power relations; scale of confidence; switching costs.
Upgrading	Analyze movements and their conditions to reach higher value activities on GVCs.	Considering the types of upgrading and their presence in firms or clusters analyze technological improvement (process and/or product); acquisition of a new role in the chain; acquisition of machinery or equipment; future upgrading expectations; relationship between clusters and upgrading.
Institutional context	Identify and understand how institutional aspects affect GVCs.	Availability of labor; formality of labor (labor rights); skills level and costs; quality of women's participation in the labor force; availability and access to education; financial resources and tax incentives; efficiency and quality of laws and regulations; bonds of trust; mutual fidelity and social cooperation.
Stakeholders	Map each of the other agents involved in the chain. Additionally, analyze how relationships between these actors are governed at the local level and which institutions are in a position to drive change.	Number of actors involved; existence and role of export and investment promotion agent; participation of governments and non-governmental organizations; level of strategic articulation between stakeholders and conditions to drive change.

Note: Exclusively for a better presentation of the elements proposed by this present research, we organized them in the six contexts proposed by Gereffi and Fernández-Stark (2018). This proposal does not seek to limit each element exclusively to a single context, because some of them are clearly transversal. For example, trust can be a key element to analyze the relationships of the actors in governance, but it is also a valuable topic for social capital and institutional thinking. For the construction of this table it is important to highlight that the literature consulted, described in section 3, ranged from the seminal research on GCC and GVC (Gereffi, 1994, 1995; Humphrey and

Schmitz, 2000; Raikes, Jensen and Ponte, 2000) to the most recent literature present in section 4 of this present article.

Regarding the above table, the division of objectives and key elements based on the dimensions of the GVCs was a practice adopted merely to organize the presentation. Given that the dimensions of analysis are intertwined, the same extends the proposed elements. In this sense, there is no compartmentalization of objectives and elements but merely a standard suggestion that can and should be reorganized based on the nature of each research study.

Notably, for all the key elements noted herein, we recommend analyzing historical perspective and trends. For example, understanding governance elements, such as the structure in which firms or entire chain segments operate or the level of trust between partners, from an evolutionary perspective, is vital to understanding the dynamics of the possible configurations of GVCs.

In this sense, although it is still early to analyze and project the changes that the Covid-19 pandemic may have on the configurations of GVC. Verbeke (2020), point out as a hypothesis of change in governance models, that leading companies may engage more relational (and less formal) micro-level contracts with key partners identified as more reliable in the chain¹⁵. For the author, the reliance of multinational enterprises on global and national institutions for the protection of business interests exposed by the pandemic may be the engine of this change. For example, it may be more efficient for key partners to access and process local economic information and expectations than the leading insular company. This may reflect more robust and resilient strategies for the chain.

From the perspective of this article, value chains, be they more or less globalized, become increasingly mutated and open to experiencing shocks¹⁶; thus, we reiterate the importance of studies that can be replicated over time, allowing the dynamics of these changes to be captured, particularly in the case of chains in the global insertion stage.

The analysis of firms and clusters cannot be static, and the actions of domestic or foreign governments should be treated as endogenous in the analyses. Although we include elements that seek this connection, we understand that considerable advancement is still needed in this direction.

¹⁵ For more details on the main characteristics and differences of the five governance structures (market, modular, relational, captive, and hierarchy) in the GVC literature, see Gereffi and Fernández-Stark (2018).

¹⁶ Regarding this point, In the past there was Bovine Spongiform Encephalopathy (BSE), commonly known as mad cow disease, that significantly impacted the meat value chain in the world. Nowadays we call special attention to COVID-19 pandemic, the tension in world trade policy, particularly between China and the USA, as well as a still premature slowdown in international trade (Aslam et al., 2018). In addition, the expansion of the use of 3D printers can have considerable repercussions for productive organization in several chains across the world.

We understand the difficulty of operationalizing the collection, processing, and analysis of many of the proposed key elements. After all, good ideas are usually accompanied by substantial difficulties in putting them into practice. Nonetheless, some of these elements of difficult operationalization and/or analysis alone bring proposals for future research into the field, such as the ‘relationship between clusters and upgrading’, which we believe is important to understand the movements of upgrading in a GVC.

5.2 GVC and SCP: An embryonic proposal for approximation

Although the objective of this research is not to propose a debate on the integration of the two approaches, we invariably take some steps in this direction. Concerning SCP, the elements of analysis presented herein contribute more toward bringing the analytical dimensions of the GVC to the discussion on industrial organizations that use the model and toward launching the variables of analysis from Table 3 into the field.

Note that Figueiredo Junior, Meuwissen, and Oude Lansink (2014) have already proposed an extension of the SCP model, in a categorized manner, connecting it to value chain strategies. At the time, they presented arguments that justified such an expansion, considering the limitation of the traditional model in dealing with value chains¹⁷. One of the examples given was that the choice of organizational arrangements between competitors is part of the behavioral and non-structure dimension, and organizational decisions do not always follow a desirable ordered sequence.

Although they refer to some authors linked to the tradition of GVC, this connection is relatively mild and associated with studies that addressed, above all, the two main pillars of approach, governance and upgrading, in a macro development view. In addition to this viewpoint, the authors made it clear that the unit of analysis of the extended model was not a company but rather part of a value chain in one territory that competes with another in a different location (Figueiredo Junior, Meuwissen and Oude Lansink, 2014).

In a pragmatic manner, the variables of analysis framework in the specific case of the SCP framework can potentially contribute to alleviating the limiting issues presented by Ferguson (1988), regardless of how problematic the interpretation, collection and processing of this information may be. This can also be extended to the alternative approaches of the

¹⁷ The authors reviewed researches that analyzed a range of chains, in South America, Asia and Africa, such as: shrimp, tourism, textiles, cashew, catfish, floriculture, etc.

industrial organization because as Lee (2007) noted, improving the quality and availability of data at market level can boost NEIO-based studies.

Within the scope of this article, GVC increases a wealth of analytical elements for SCP due to its dimensions of analysis and/or more specifically the variables presented previously in Table 3. Conversely, the latter sheds light on important structuring elements for the empirical research of the former in view of the main objective of this work, which is to present elements of analysis that can be used in micro and quantitative research level in the field of GVC framework. Further, considering the tradition of the SCP paradigm in developing studies of this nature, Bain's (1959) central hypothesis derives an important issue for GVC studies.

In other words, given the logical chain of this paradigm, different structures lead to different behaviors and results between firms. Accordingly, the measurement of multiple forms of performance of firms or clusters included or in the process of being included in GVC, considering the rich set of tools that the approach presents, proves an interesting avenue of research. Notably, research in the field of value chains, as presented in the section 4.2, seeks to understand causal links typical of the SCP literature, such as establishing relationships between governance and upgrading, governance and productivity and entry in GVC and productivity. However, in addition to the performance being summarized to productivity proxies (which may be much richer than that), the recognition of the feedback effects of the industrial organization model attained little attention in studies associated with GVC literature.

Another contribution is that the SCP model can be useful to GVC studies in aspects related to the design of investigations. Reframing analysis elements from the GVC approach to the logic of the three axes of SCP can clarify aspects such as causal link testing, as in general, the GVC framework does not facilitate this task. This could be a way to meet specific demands of a research agenda, as proposed by Giovannetti and Marvasi (2018) and Golini and Boffelli (2018). In this sense, establishing causal hypotheses from the perspective of SCP is clearer, such as for the following variables: firm governance typologies (Structure); R&D investment strategies (Conduct); and acquisition or not of a new role in the chain (Performance). These elements would be, respectively, in the dimensions of governance and upgrading.

In summary, the tradition of research at the micro and quantitative level is broader in the literature of the industrial organization compared to the recent approach of GVCs, which in turn presents a range of analytical elements. Thus, the integration of this tradition with the global chain framework is a two-way road that benefits both lines of thought and contributes to greater visibility and robustness of published results.

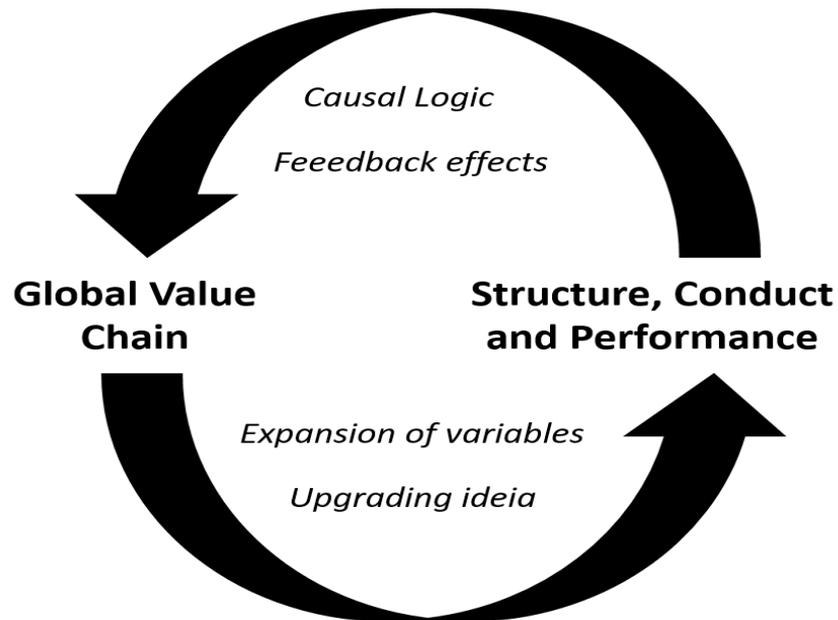


Figure 1. Summary of some benefits of the approximation of paradigms.

6- Conclusion, limitations and expectations

Our research indicated an existing gap in quantitative research with microanalysis units (companies and clusters) in the recent field of GVC and discussed factors that over the years have made this phenomenon possible. As a result, it presented elements of analysis based on literature that could be used in empirical research to mitigate the gap reported in Table 3. The limitations associated with the use of these elements, particularly methodological ones, were noted alongside the possibility of exploring specific topics for future investigations based on said limitations.

Parallel to this, the research brought the approaches of GVC and SCP closer together, pointing out mutual benefits for both. On the one hand, GVC expands the discussion to global value chains and presents an extensive range of analytical elements. On the other hand, the tradition of investigating the causal relationships between microeconomic elements of the SCP model establishes important structural foundations for quantitative and firm-level research in the field of GVC.

Additionally, we believe that analyses that integrate the two approaches and consider the reference of the range of elements presented in this research have the potential to support future research agenda that gives greater visibility and robustness to the published results. This scenario is particularly important for greater consolidation and acceptance of the GVC approach in academic and political settings.

On this last point, it is of paramount importance to advance in studies with the characteristics that we intend to promote, as an integrated discussion of studies of different natures and units of analysis, under the same lens, are crucial to subsidize more appropriate interventions by governments. Improving industrial policies and socioeconomic development in the different stages of GVC will only be possible with a broad and multifaceted view of the phenomenon.

The inability of current policies and global chains (especially medical supplies) to respond to the economic and health crises exposed by the Covid-19 pandemic reinforces this argument. We need to incorporate a broader systemic and strategic perspective to analyze and plan for more robust and resilient GVCs.

Acknowledgements

This work was supported by Federal Institute of Education, Science and Technology of Tocantins, Campus Palmas.

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ARTICLE 2

A Novel Quantitative Approach to Global Value Chain Analysis: Proposal of an Index for the Institutional Environment Applied to Brazilian Aquaculture

Abstract

Based on identified gaps in the literature of Global Value Chains (GVC), this research explores the possibility of using fuzzy logic to incorporate quantitative analytical elements to this approach. Thus, this study aims to present a methodological alternative capable of measuring some analytical elements of the GVC approach and also to discuss the institutional environment of tilapia production in Brazil. Institutional environment indexes were estimated by using fuzzy modelling in four perspectives (Relational, Economic, Social and Local), which applied in an illustrative case of Brazilian aquaculture. Were demonstrated by research the viability of using fuzzy inference systems (FIS) to address various aspects of the framework that involve a certain degree of human judgment and have so far been underexploited by the literature. In this sense, this research contributes to reducing the gap of quantitative studies in the research field. Also, presents some critical issues related to the institutional environment under review and indicate the importance of reinforcement in the institutional framework for less developed aquaculture chains, as in the case of the Global South. Finally, were identified limitations, challenges and contributions of the use of fuzzy logic in the field of GVC.

Keywords: fuzzy inference system; indices; institutions; tilapia culture

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 and 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.

Didactically, the GVC approach works as a bridge between the international business and development literature and reflects the confluence of three distinct theoretical traditions:

world-systems theory; dependency theory and development theory. This framework is also concerned with understanding the dynamics of these new productive configurations in the development of countries and regions (Lee and Gereffi, 2015; Gereffi, 2019).

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 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, Humprey and Sturgeon, 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 and Pritchard, 2009; Smith, 2015; Dollar, Ge and Yu, 2016; Gereffi, 2019).

The research question that guides this article is how to quantify elements related to the GVC framework. In that direction, this present research seeks to (1) to present a methodological alternative capable of measuring quantitatively the analytical elements of the GVC approach, and additionally (2) discuss issues related to the institutional environment. For this purpose, this study employed an illustrative case of estimation of institutional environment indexes in Brazilian tilapia chain.

2. Literature gaps in GVC, institutions and contribution of fuzzy approach as methodological proposal

2.1 The scarcity of quantitative and institutional studies

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. Regarding this nature, Sturgeon and Gereffi (2009) exposed the deficiency of quantitative measures associated with this framework. However, since Frederick's pioneering work (2014), 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, De Lombaerde and Iapadre (2018), this phenomenon creates a basis to go beyond traditional macro and sector level analyses.

Hernandez and Petersen (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 and Sturgeon, 2014; Eckhardt and Poletti, 2018; Golini and Boffelli, 2018; Giovannetti and Marvasi, 2018).

According Dollar, Ge and Yu (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 and 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 and Pritchard (2009) emphasised 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 and 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 and Pritchard, 2009; Ponte et al., 2014; Dollar, Ge and Yu, 2016; Lim, 2016; Mohan, 2016; De Ville 2018; Eckhardt and 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 means¹⁸. 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 and Wagner, 2015; Dollar, Ge and Yu, 2016; Dollar and Kidder, 2017; McWilliam et al., 2020).

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”.

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,

¹⁸ Mohan (2016), Seabrooke and Wigan (2017), and De Ville (2018) are the main exceptions in recent studies.

NIE maintains that institutions are important and impact 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, 2019).

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 (2016, 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 and Song, 2012). This present research, as well as Flaaten (2013) and Nadarajah and Flaaten (2017), adopts a closer look at NIE, and consequently the GVC literature, when analyzing aquaculture. However, we take significant steps, even if little by little, into understanding the sociological view and the important task of broadening the understanding of institutions, incorporating in our analysis a “trust” element that is central to the relational dimension of social capital proposed by Nahapiet and Ghoshal (1997; 1998) and is a valuable variable to fuzzy thinking that will be presented below.

2.3 Fuzzy logic: applications and potential use in GVC analysis

The Iranian mathematician Lofti Asker Zadeh with the publication of the article “Fuzzy Sets” first introduced the fuzzy sets theory in 1965. In this, the mathematician sought to solve the problem of the imprecision of the human mind. By Zadeh's theoretical proposition, a fuzzy

"A" set defined in the universe of "X" discourse is characterized by a membership function, which maps the elements of X to the interval [0,1] (Zadeh, 1965).

$$\mu_A: X \rightarrow [0,1]$$

Thus, the membership function associated with each "x" element belonging to "X" is a real-number in the interval [0,1] that represents the degree of membership (adherence) of the "x" element to the set "A" for each (Fig. 1).

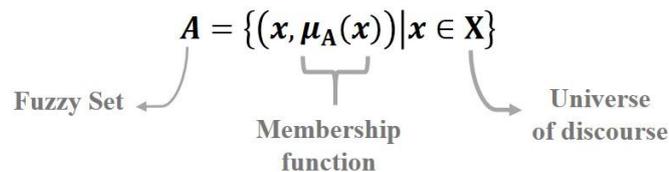


Figure 1. Determination of fuzzy sets.

Fuzzy set theory is used by fuzzy logic¹⁹ to extend traditional bi-value logic (true or false, yes or no, and so forth) assuming that the true values are nebulous sets defined in the range 0 to 1. What makes fuzzy logic powerful is its ability to model human thought, since it uses approximate reasoning instead of precise reasoning. This logic provides a significant contribution to research using unclear data, often expressed in linguistic terms, and quite close to human perception (Kozarević and Puška, 2018).

In recent decades, fuzzy logic and fuzzy systems²⁰ have been widely adopted in the scientific community, since they are input-output models where input variables do not have exact values, but present influential probabilities of each variable on the final outcome (Silver et al, 2020).

According to Kala (2016), a fuzzy inference system (FIS) is a system that maps inputs and processes them based on pre-established rules producing outputs. The architecture of this system can divide into four key elements: fuzzification, rules base, fuzzy inference and defuzzification.

¹⁹ Historically, the theory of fuzzy sets preceded fuzzy logic in its wide sense (Zadeh, 2008).

²⁰ For a comprehensive presentation of the various methods based on fuzzy theory see Islam et al. (2017).

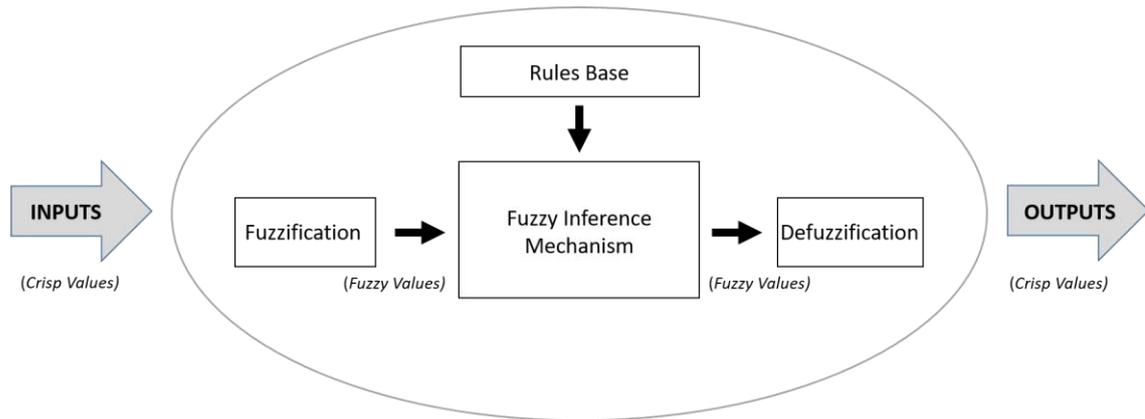


Figure 2. Main elements of Fuzzy Inference System.

Synthetically a FIS can also be understood as an inference process based on fuzzy rules (or approximate reasoning) of the "IF-THEN" type, which connects antecedents and consequents, making use of membership functions and fuzzy operators (Belhadj, 2011).

Fig. 2 represents the main elements of a FIS. In the fuzzing stage, crisp values translated into fuzzy values, which are determined by the degrees of adherence to the membership functions that are in turn connected to the linguistic variables. The rule base is a structure of linguistic statements of the type "IF-THEN" that stocks all the knowledge of the system. In the inference module, the fuzzy values obtained and processed by inference methods, where operations of implication, composition and aggregation of rules occur. Finally, defuzzification transforms, through different techniques, the aggregation results of the previous step into crisp values (Idrus, Nuruddin and Rohman, 2011; Geramian et al, 2017).

Historically, academic research used fuzzy logic and FIS in various areas such as engineering (civil, electrical, space, industrial, environmental, agricultural, mechatronics, computing, among others), medicine, psychology, management and business, economics, biology, chemistry, physics, political science, and so forth. Although little known by researchers not familiar with intelligent systems (Singh et al, 2013).

In the literature, there is a large number of researches applied to value chains or supply chains that seek to model decision processes based on several contexts such as *performance* (Chen, Li and Huang, 2006; Sufiyan, 2019; Liu et al., 2019), *sustainability* (Govindan, et al., 2013; Orji and Wei, 2015; Tapia and Samsatli, 2020) or *risk management* (Zeng, An and Smith, 2007; Fares and Zayed, 2010; Islam et al., 2017). Other research applied in different contexts attempted to measure a variety of other topics, such as *productivity and job satisfaction* (Fayek and Obuda, 2005; Eyupoglu, Jabbarova and Saner, 2017), *quality and engagement in education* (Smetanina, Maximenko and Klimova, 2013; Yes,

Conduit, and Plewa, 2018), and *credit rating for Small and Micro Enterprises (SMEs)* (Shi, Chen and Wang, 2016; Gong, 2017).

In a closer cut with the methodological design of this present research, several works tried, based on fuzzy logic, to build indexes for *poverty* (Belhadj, 2011; Finco, Ribeiro and Baillis, 2014; Ribeiro and Finco, 2015); *energy sustainability* (Di Addario et al., 2016); *social sustainability* (Hendiani and Bagherpour, 2019); *academic performance* (Lopes and Lanzer, 2002); *resilience and performance in supply chains* (Rajesh, 2019); *economic performance in cooperatives* (Khatchatourian and Treter, 2010); *water quality* (Kaushal and Basak, 2018; Oliveira et al., 2019) and *urban development* (Eraqi, 2016).

Finally, Bi, Huang and Ye (2015) through Analytical Hierarchy Process (AHP) and triangular fuzzy numbers, researched the technological innovation of the Chinese manufacturing industry integrating the GVC framework and the linear technological innovation process for analysis of innovation risk. The research sought to describe how global risk factors influence the upgrading and low carbon technological innovation process. In it, the authors used the GVC approach to initially position the Chinese manufacturing industry as one that adds low value in global chains, reinforcing the importance of upgrading to achieve higher added value activities. Moreover, the authors utilized the three processes of value creation in chains (R&D, manufacturing and assembly and marketing), identified by Pananond (2013), to analyse the risks associated with innovation from the globalization perspective.

Presented this range of applications of the use of fuzzy logic for different areas of knowledge, which carry multiple theoretical approaches, this article suggests the same for the GVC framework. Given its broad dimensions²¹, which are intertwined and complement each other, the literature reveals a list of analytical elements that are difficult to measure or compare given their intrinsic qualitative nature and therefore involve a certain degree of human judgment. For example, competence or capacity of suppliers, the ability to codify transactions, the complexity of transactions, power, leadership, trust, reciprocity, quality of laws, access and availability of resources among others.

In this sense, the use of fuzzy logic presents itself as appropriate and promising for GVC studies. Since it is capable of processing information of this nature, either alone or in conjunction with quantitative measurement variables already used in literature, such as census data, trade or I-O tables.

²¹ Input-Output Structure, Geographic Scope, Governance, Upgrading, Local Institutional Context and Stakeholders Analysis (Gereffi and Fernández-Stark, 2018).

3. Methodological approach

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 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 zone²² of Ilha Solteira (SP/MS) and the remaining 17 in 11 other cities of São Paulo; therefore the data were tabulated and processed as two different groups: Ilha Solteira and others of São Paulo²³. 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, is capable of providing sufficient information to illustrate a case of application of fuzzy tooling to the GVC approach.

Despite being one of the largest aquaculture producers in the world, the country's production export rates are still modest. In the case of tilapia²⁴, historically (2013 to 2018), Brazil exports less than 0.4% of its total production (FAO, 2018; IBGE, 2018; CIAQUI, 2020). However, according to CIAQUI(2020) 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.

²² There are 12 production zones catalogued in Brazil, Ilha Solteira's is the second largest in production. In 2018 it was responsible for 9.6% of the tilapia produced in the country (Barroso et al., 2018; CIAQUI, 2020).

²³ The choice of comparison between two groups is only to illustrate a methodological alternative of the use of FIS. In this sense, despite presenting some interesting research questions, the objective of this article is not to discuss answers to eventual differences between the groups' results, but to validate the method presented.

²⁴ Tilapia production ranks first in the country, with a volume of 311,540 tonnes, corresponding to 54% of national aquaculture in 2018 (IBGE, 2018).

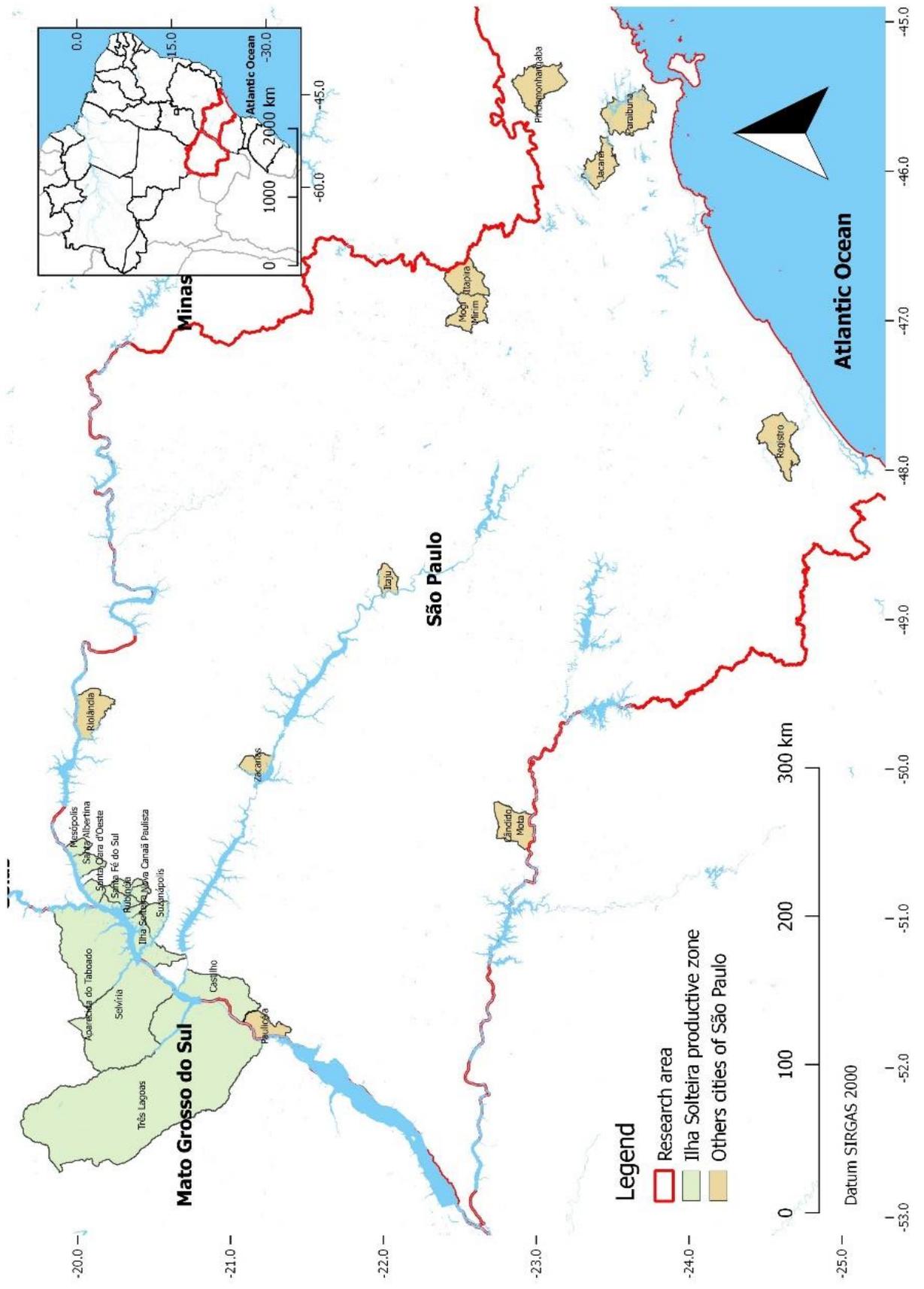


Figure 3. Research spatial distribution. Indicates the cities where the interviewed TPU are located.
 Note: Although the city of Pauliceia is on the margin of the Paraná River it is not part of Ilha Solteira's reservoir.

Due to a methodological issue related to the size of the system (which will be presented below), we have defined four contexts of institutional analysis in this research: (1) Relational, (2) Economic, (3) Social and (4) Local. The first was based on one of the three dimensions of social capital, which applied to the scope of firms proposed by Tsai and Ghoshal (1998)²⁵. Thus, we seek to insert in the model, more directly, relational aspects inherently immersed in the institutional field. The other three contexts were based on the synthetic parameters of the '*Local Institutional Context*' analytical dimension proposed by Gereffi and Fernández-Stark (2018) for the analysis of GVCs, and also in the Miranda and Wagner (2015), Dollar, Ge and Yu (2016) Dollar and Kidder (2017) studies. Table 1 presents these four contexts, with their respective indicators described.

²⁵ For the authors, social capital covers several aspects of a social context. In the relational dimension, the properties that sustain relationships, such as trust and reciprocity, are highlighted. The other two interrelated dimensions proposed by the authors were Structural and Cognitive.

Table 1. Contexts and indicators for institutional environment fuzzy indexes

Context	Indicators	FIS Inputs	Description
Relational	Trust Scale	Conf.	Level of confidence of the producer in its trading partners
	Frequency of change of business partners	FMudPar.	Frequency scale of change business partners by the producer
	Compliance with trade deals	CumpAcord.	Occurrence of non-compliance with trade agreements, characterized by the evaluation of default as a difficulty in commercialization of the product
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
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 four contexts and twelve 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.

For research purposes, two Fuzzy Inference Systems (FIS) were implemented with the support of MATLAB® R2018a software. According to Islam et al (2017), fuzzy methods can

be classified into three major groups: Basic; Extended and Hybrid. The method applied in this present research was of the extended type, the fuzzy expert system.

The fuzzy expert system is the most popular of the knowledge-based systems, where knowledge is described by a set of instructions, for example, IF-THEN rules. IF-THEN rule systems are most widely used in the processing and representing fuzzy knowledge (Jin, 2003). This type of FIS is well suited for the construction of predictions and applications in the decision-making process, based on linguistic assessments, expert judgement and close cause-effect relationships (Fayek and Oduba, 2005).

Each one of the two FIS contains six inputs and two outputs, FIS 1 is composed of the inputs relating to the relational and economic context, and the FIS 2 of the inputs relating to the social and local context. The two systems generate four outputs that represent indexes of the institutional environment of tilapia farming in their respective contexts.

As previously mentioned, the choice of using four analytical contexts for the institutional environment was due to operational issues of model size. If we chose to use in a single FIS all twelve inputs (without division into contexts) with a single output (representing a single institutional environment index) the total of rules at the base of the system would be enormous, with more than 194,000 rules.

This methodological alternative of fuzzy sub-indexes construction to reduce the size of the rule base was the same adopted by Oliveira et al. (2019). In the construction of the Raw Water Quality Index (RWQI), the authors performed a first step of the inference systems for three sub-indexes, where their outputs were used in a second stage as inputs of the last system, which finally generated the RWQI. If we wanted to present here a fuzzy index of the aggregate institutional environment, which would consolidate the four contexts, this would be a viable alternative.

3.2 Mamdani's specialist fuzzy system modules

3.2.1 Fuzzing and Basis of Rules

According to Jang, Sun and Mizutani (1997), the membership function (MF) can take different formats, and the choice of the appropriate function depends on the context and the type of indicators described. More precisely, this choice depends on the characteristic of the linguistic variable and its linguistic terms. Or, in other words, it depends on the range of answers that can be given in a predefined way or on a possible categorization into more open questions.

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 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 $a \leq m \leq b$, with a, m, b and x belonging to the universe set U.

$$\text{Triangular: } \mu_A(X) = \begin{cases} 0, & x < a \\ \frac{(x-a)}{(m-a)}, & a \leq x \leq m \\ \frac{(b-x)}{(b-m)}, & m \leq x \leq b \\ 0, & x > b \end{cases} \quad (2)$$

$$\text{Singleton: } \mu_A(X) = \begin{cases} 1, & \text{if } x = m \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

According to the characteristics of each input and output of the systems, 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 2 and 3, respectively.

Table 2. 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)	-----
High	(0.5, 0.75, 1)	(0.5, 1, 1)	(1)
Very High	(0.75, 1, 1)	-----	-----

Table 3. 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”, as shown in Table A.1 (in Appendix A).

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 the social capital (Nahapiet and Ghoshal, 1997; 1998) and transaction cost economics (Williamson, 1985). Table A.2 (Appendix A) shown the general causal mechanism between indicators and institutional environment. In all, 85 rules constituted 38 for FIS 1 and 47 for FIS 2. In more detail, for the Fuzzy Index of Institutional Environment in the Relational Context (FRI) rules were constructed referring to the respective linguistic terms (L, M, H) of each of the three indicators, totalling 18 (3x3x2) rules. For the Economic Context Index (FEI), 20 (5x2x2); Social (FSI), 20 (5x2x2) and Local (FLI), 27 (3x3x3). Table A.1 (in Appendix A) presents the rules used for FRI in FIS 1, while Table A.3 (in Appendix A) summarizes the 85 rules used for both FIS.

3.2.2 Inference and Defuzzification

When using rule bases such as those described above, conclusions should be based on all rules, thus making it necessary to aggregate all individual relationships into one set of rules. For this aggregation, several methods are used. However, most methods applied are Mamdani and Sugeno (Di Addario, 2016; Geramian et al., 2017).

Although it is possible to apply either method through the MATLAB® software, the Mamdani method was chosen for this illustrative case, for two reasons. Firstly, the fuzzy output of the system is accompanied by the membership function, which for this article leaves the presentation of results more intuitive, in the method of Sugeno this does not happen. The second factor is that the chosen method supports MIMO watering systems, while the other only MISO (Multiple-Input/Single-Output)²⁶.

When there are multiple precedents applied to a rule, the fuzzy operator (i.e., AND, OR, NOT) is used to obtain a single number that represents the result of the previous evaluation. To evaluate the disjunction (intersection) of the rule of precedent, the fuzzy operation "AND" is used, in an analogous way for conjunction (union), the operator "OR" is used, while for complement (complement) the operator is "NOT" (Fullér and Werners, 1991). These are expressed by the operations, where s is a S-norm and t is a T-norm:

$$\mu_{A \cap B}(x) = s\{\mu_A(x), \mu_B(x)\} = \min\{\mu_A(x), \mu_B(x)\} \quad (\text{intersection}) \quad (4)$$

$$\mu_{A \cup B}(x) = t\{\mu_A(x), \mu_B(x)\} = \max\{\mu_A(x), \mu_B(x)\} \quad (\text{union}) \quad (5)$$

²⁶ For an illustrative case of comparison between the use of the two methods and a synthesis of the differences between them see Hamam and Georganas (2008) and Shleeg and Ellabib (2013).

$$\mu_{co(A)}(x) = 1 - \mu_A(x) \text{ (complement)} \quad (6)$$

The logical operations are formed such that the function *min* and function *max* are among the most applied. Although other functions such as product and probabilistic OR are also applicable in the expression of these fuzzy operators, function *min* and function *max* are always simple, effective and widely used (Wang, 2015).

Taking as a rule, of the type:

$$\text{IF } x \text{ is } A_i \text{ THEN } y \text{ is } B_i, \quad i = 1, \dots, n \quad (7)$$

In Mamdani's model, the outputs²⁷ are built by the superposition of the consequent individual rules, of the type (Bandemer and Gootwald, 1995):

$$R_1 : \text{IF } x_1 \text{ is } A_1 \text{ THEN } y_1 \text{ is } B_1;$$

$$R_2 : \text{IF } x_2 \text{ is } A_2 \text{ THEN } y_2 \text{ is } B_2;$$

...;

$$R_i : \text{IF } x_i \text{ is } A_i \text{ THEN } y_i \text{ is } B_i \quad (8)$$

Being, $A_i \in B_i$ fuzzy subsets of universes $U \in V$, each rule can be interpreted from as:

$$R_i = A_i \otimes B_i \quad (9)$$

Where, \otimes is product operation. Being their membership function given by:

$$\mu_{R_i}(x, y) = \min(\mu_{A_i}(x), \mu_{B_i}(y)) \quad (10)$$

In summary, according to each rule (8) control of a system (6), the method of Mamdani used all individual rules to compose them into fuzzy R relationship, to the whole system. Being the aggregation operator represented by "U", we have (Bandemer and Gootwald, 1995):

$$R = \cup_{i=1}^n R_i = \cup_{i=1}^n (A_i \otimes B_i) \quad (11)$$

With membership function $\mu_R(x, y)$:

$$\cup_{i=1}^n R_i(x, y) = \max\{\min(\mu_{A_i}(x), \mu_{B_i}(y))\} \quad (12)$$

Based on the compositional inference rule suggested by Zadeh (Zadeh, 1973), we have the output set $B'(y)$:

$$B'(y) = A'(x) \circ R(x, y) \quad (13)$$

Being, " \circ " a compositional operator, whose membership function is given by:

$$\mu_{B'}(y) = \cup_x \{\mu_{A'}(x) \wedge \mu_R(x, y)\} = \cup_x \{\cup_{i=1}^n (\mu_{A'}(x) \wedge \mu_{R_i}(x, y))\} \quad (14)$$

Where, \wedge is a t-norm operator.

After the inference module, defuzzification occurs, which consists in determining the crisp value, that is, obtaining the best representation for the fuzzy output set, applying a

²⁷ The inference of an output fuzzy value given an input value is only possible due to the *generalized modus ponens* rule, see Hellendoorn (1992).

defuzzification method to the set $B' = \bigcup_{i=1}^k B'_i$ resulting from the aggregation of all fuzzy output sets $B'_i, i = 1, 2, \dots, k$. This way, defuzzification consists in converting the outputs of fuzzy rules into a crisp value, through different schemes, being the main ones: center of area (CoA), center of gravity (CoG) and the mean of maxima (MoM) (Jin, 2003; Talon e Curt 2017).

In this illustrative case, the CoA method was used, also known as centroid. This method determines the center of the fuzzy set area and returns the corresponding crisp value. The center of the area is calculated by:

$$CoA = \frac{\sum_{k=1}^n \mu_A(X_k) X_k}{\sum_{k=1}^n \mu_A(X_k)} \quad (15)$$

Finally, the fuzzy indexes of the institutional environment for each context are the outputs of the FISs 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 illustrative case

In addition to developing a methodological proposal for the quantitative analysis of GVC, this article also carried out an illustrative application using data associated with institutional analytical contexts related to tilapia production in Brazil. The study divided the production units into two groups, one belonging to the Ilha Solteira productive zone (Ilha Solteira group) and the other groups located in São Paulo cities (Others group). Tables 4 and 5 present the estimated indexes for each TPU in each context, as well as the averages of each group.

Table 4. Fuzzy indexes for TPUs of Ilha Solteira's productive zone.

TPUs ID	Fuzzy Indexes			
	FRI	FEI	FSI	FLI
1	25.0	75.0	50.0	25.0
2	92.0	50.0	50.0	8.0
3	50.0	50.0	36.1	8.0
4	75.0	50.0	50.0	25.0
5	25.0	25.0	50.0	25.0
6	75.0	63.5	75.0	25.0
7	75.0	75.0	75.0	8.0
8	50.0	25.0	29.5	25.0
9	92.0	92.0	78.2	25.0
10	75.0	75.0	25.0	8.0
11	92.0	92.0	63.8	25.0
12	92.0	75.0	75.0	25.0
13	92.0	92.0	50.0	8.0
14	92.0	50.0	29.5	50.0
15	92.0	77.2	75.0	8.0
16	92.0	92.0	75.0	8.0
17	75.0	75.0	36.1	25.0
18	92.0	75.0	50.0	25.0
19	50.0	62.4	62.5	8.0
Mean	73.8	66.9	54.5	19.2

Note: TPUs ID is tilapia production unit's identification; FRI is fuzzy relational index; FEI is fuzzy economic index; FSI is fuzzy social index; FLI is fuzzy local index.

Table 5. Fuzzy indexes for TPUs from other cities of São Paulo.

TPUs ID	Fuzzy Indexes			
	FRI	FEI	FSI	FLI
20	50.0	50.0	50.0	50.0
21	75.0	25.0	25.0	50.0
22	77.3	50.0	75.0	25.0
23	75.0	66.4	75.0	75.0
24	75.0	75.0	58.1	92.0
25	25.0	92.0	36.1	25.0
26	75.0	50.0	36.1	8.0
27	25.0	92.0	75.0	25.0
28	77.3	75.0	50.0	75.0
29	75.0	8.0	58.1	25.0
30	77.3	75.0	36.1	50.0
31	60.8	50.0	50.0	8.0
32	75.0	50.0	75.0	25.0
33	60.8	92.0	50.0	25.0
34	50.0	75.0	36.1	25.0
35	25.0	92.0	46.1	25.0
36	25.0	50.0	46.1	25.0
Mean	59.0	62.8	51.6	37.2

Note: TPUs ID is tilapia production unit's identification; FRI is fuzzy relational index; FEI is fuzzy economic index; FSI is fuzzy social index; FLI is fuzzy local index.

The indexes presented relative homogeneity, with a higher dispersion of values for the FLI, as shown in Fig 4. Considering the TPU's of the two groups, there was only a significant difference ($p < 0.05$) between the means for FRI and FLI.

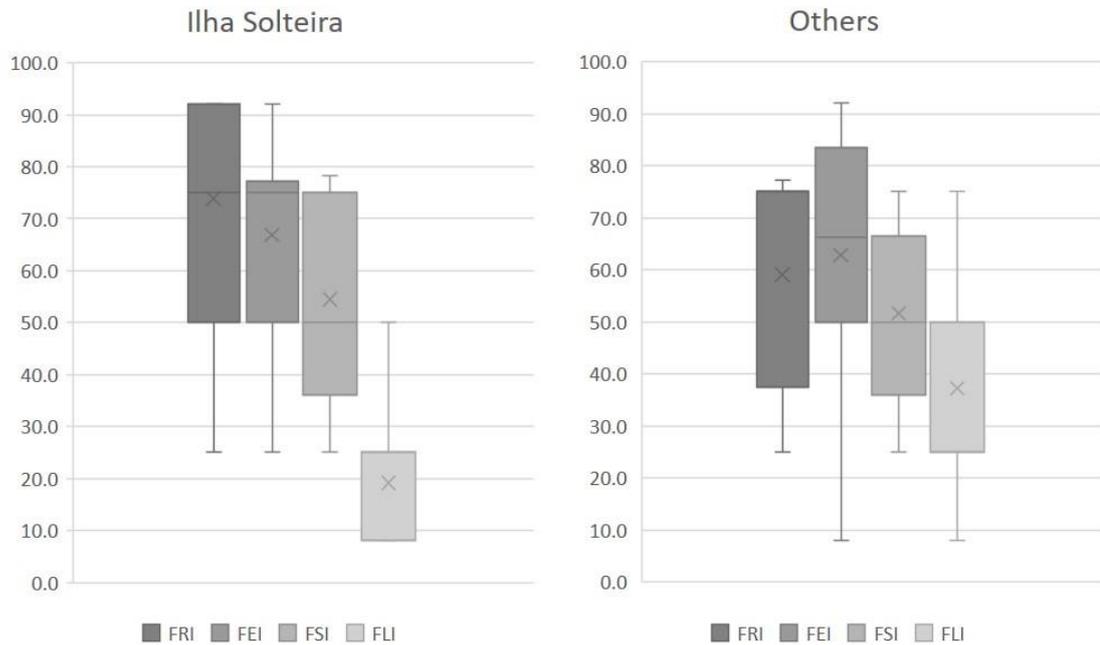


Figure 4. Comparison between indexes. The figure represents the means, medians, quartiles and the maximum and minimum values. Legend: FRI is fuzzy relational index; FEI is fuzzy economic index; FSI is fuzzy social index; FLI is fuzzy local index.

In the relational context, there is a better institutional condition of the companies of the Ilha Solteira group (73.8) compared to the other group (59.0). The condition of a High (Fig. 5) relational institutional environment for the Ilha Solteira TPU's was due to better performance of the indicators of frequency of change of trading partners (FMudPar.) and compliance with trade agreements (CumpAcord.).

More moderately, Ilha Solteira's production units showed better stability of maintenance of commercial partners over time, compared to the other groups' units in São Paulo. It is important to note that the trust scale (Conf.) was significantly high for both groups. In our analysis, this may indicate that the degree of change may be more associated with structural market factors, such as the number of potential partners (for purchasing inputs and selling tilapia) and their prices, and less with the relationship of trust established between players over time. This should be taken into account in calibrating systems for future research that seeks to use this model.

Finally, as reported by the other companies in Sao Paulo, the greater occurrence of noncompliance with trade agreements in the default form, in the relational context, weighed most heavily on the difference in status between the two groups.

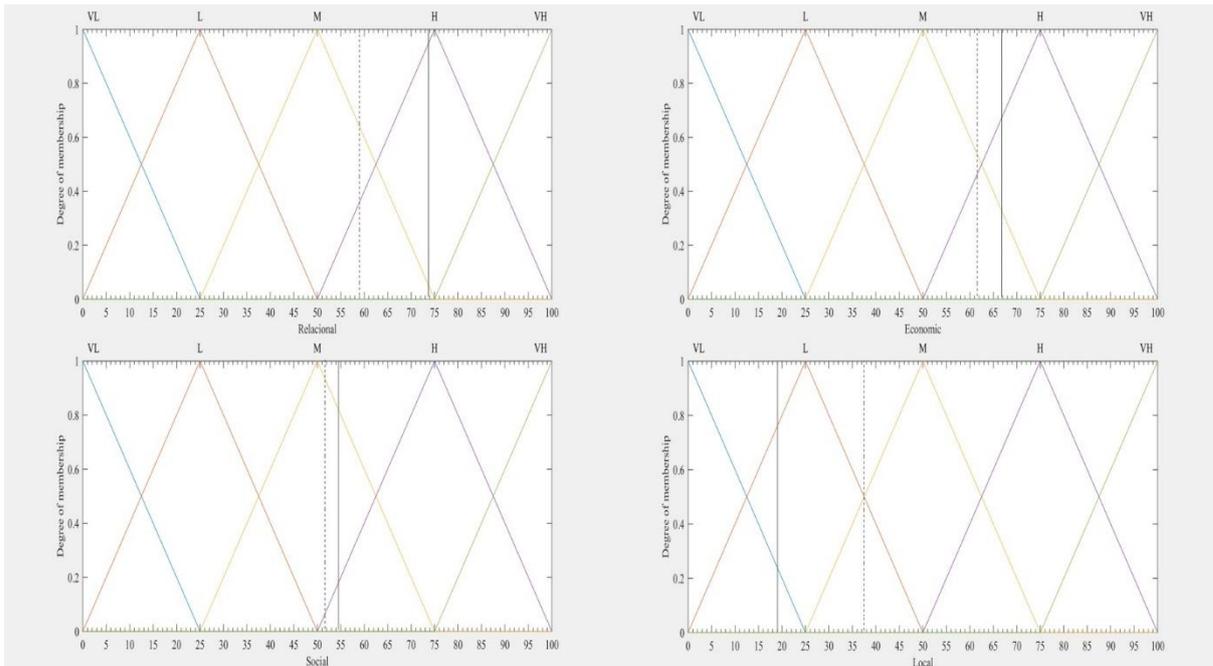


Figure 5. Outputs of inference systems with the membership functions for both groups. Ilha Solteira's productive zone (continuous line) and Group of other cities of São Paulo (dashed line). Legend: VL is very low; L is low; M is medium; H is high; VH is very high

The FEI and FSI indexes were not statistically different between the groups, with levels between Medium and High for both. On the other hand, in the local context, the FLI of the other TPU's in the state of São Paulo (37.2) indicated a better institutional environment (between Medium and Low) compared to that of Ilha Solteira (19.2) with an environment evaluated between Low and Very Low, as shown in Fig. 5. It is important to note that this context was the most critical among the four estimated for evaluating the institutional environment of fish farms, mainly because of the level of environmental (LegAmb) and operational (LegOP) legislation indicators.

In General, environmental and water cession²⁸ legislation were the key issues for this critical environment. Despite the difference between the two groups, in broad terms both understood these legislations as barriers to entry which would lead to a significant impact on the activity. What put the Ilha Solteira group in a worse condition was the fact that their negative impact evaluations were considered relatively higher to activity than other TPUs. For illustration, only one Ilha solteira TPU evaluated both legislations as having little impact, the additional 18 found both legislations as very impacting.

²⁸ The cession of aquaculture areas in union waters is a complex process that involves several institutions such as Union Patrimony Secretary, Ministry of Agriculture, Livestock, and Supply (MAPA), Fishing and Aquaculture Secretary, Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and Navy. It may require significant costs and a long time for its conclusion.

This scenario ratifies the analyses of Barroso et al. (2018) who identified, in 2016, the environmental licensing and the cession of aquaculture area in waters of the union as two significant limiters to the productive growth of the Ilha Solteira area. Thus, considering that almost all the companies in this region produce tilapia in cage systems using the reservoir of the Ilha Solteira hydroelectric power plant. At the time, they pointed to the high time spent and relatively high costs involved in achieving such legal clearances, as well as the critical role of legal non-compliance limiting access to the local credit market.

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.

However, in the understanding of this leading role, we do not aim to reduce everything to this single agent, plus we believe as it is observed in the literature that non-governmental organizations (NGOs), international organizations and private technical assistance can also play a relevant role in this reinforcement (Miller and Atanda, 2011; Jespersen et al., 2014).

This present research demonstrated the capacity of FIS to process information of different natures (quantitative and qualitative), which opens the way for the development of new studies at various levels (macro, meso, and micro), discussing the broad dimensions of GVC analysis. The difference between this methodology and that of what prevails in GVC studies is the possibility of building models with quantitative outputs from inputs of different natures.

However, the central point of this methodological innovation is that the fuzzy logic extends the traditional logic of bi-values (true or false, yes or no, etc.), which opens the possibility of processing information that is difficult to measure or compare because these often involve some degree of human judgment. We believe that numerous elements of analysis within the GVC fall into this spectrum; in this context, the fuzzy logic differs from other methodologies used in the literature so far.

Quantitative research in GVC generally used census data, trade, or I-O tables with macro- or meso-level views of chains (Antràs and Chor, 2013; Timmer et al., 2015; Criscuolo

and Timmis, 2017; Golini et al., 2018; Gurgul and Lach, 2018; Rungi and Del Petre, 2018; Alfaro et al., 2019). Other researches in this category have looked at the firm level (Brancati, Brancati and Maresca, 2017; Del Prete and Rungi, 2017; Giovannetti and Marvasi, 2018; Golini and Boffelli, 2018). However, in none of them were used information that is considered the main object of fuzzy thinking.

The case applied to the institutional context, which is still under-researched and under-specified by the GVC literature, demonstrated the possibility of using this novel approach to process information that generally involves a value judgment, for example. This present research had no intention to establish or test any hypothesis in the realm of GVC. Nevertheless, we highlight that fuzzy logic can be useful in testing hypotheses or searching for causal correlations beyond what the researches have sought so far. Fuzzy thinking can help better elucidate if and how institutional aspects of most different theoretical schools influence the configurations and trajectories of GVC. This can be valuable to GVC researchers and policy makers.

These analytical possibilities clearly extend to other contexts, such as governance and upgrading, that are valuable to this literature. Nevertheless, using fuzzy logic presents challenges and limitations. If working with the data usually used to measure GVCs, such as I-O datasets, Supply-Use Table and trade data, already presents huge difficulties comparing between different countries and regions, this challenge takes on even greater proportions if the analytical level is micro (firms and clusters). This constraint should be considered in further research using the same methodology, given the need to work almost exclusively with primary data from globally dispersed firms; and even if macro studies are carried out, the availability and intrinsic characteristics of data and information related to the institutional, governance, or upgrading context also limit the measurement and comparison process.

Considering the holistic framework of GVC, another challenge in utilizing the fuzzy logic is to synthesize in the form of variables and indicators the most relevant design of each research. In addition, these analyses must consider the possibility of replication, extrapolation, and comparison among companies, regions, or countries.

5. Conclusion

The use of fuzzy logic for empirical GVC analysis can help to fill some research gaps. It can be a means to test causal relationships proposed by the approach more systematically,

involving different levels of analysis (macro, meso and micro) and contexts, with the potential to go beyond the frequent emphasis on modes of governance. In this article, an illustrative case of the use of fuzzy logic was applied to tilapia fattening units in Brazil with the institutional environment as an analysis dimension.

The analysis of institutional indices for the Ilha Solteira group and for the group of others TPUs indicated a better institutional relational environment for first group, by reason of a lower occurrence of non-compliance with trade agreements. It suggests a lower risk in marketing to those fish farms spatially agglomerated to the detriment of those dispersed in the state of São Paulo.

The results also pointed out a difference between the indexes for the local context, which is significantly worse for Ilha Solteira producers. However, we argue that the critical elements for this context, the compliance with environmental and union water transfer standards, are common bottlenecks for the entire tilapia chain in Brazil. Besides, we highlight the importance of strengthening the quality of institutional structures for the development of aquaculture chains, especially in the global south.

In this case, 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 this field emphasize firms already inserted in different levels of participation in international markets. 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 conjuncture and historical perspectives (for example, ex-ante and ex-post). Comparisons between these scenarios and their eventual changes after participation in chains can be significantly relevant for policy makers and the research on GVC.

Despite the barriers of utilizing fuzzy logic in this field, the collection, availability or formatting of data is a promising alternative to process and measure elements of analysis of the approach. These elements are often nonlinear, and with a certain degree of subjectivity and, therefore, this new framework will contribute to enriching the analytical approach further.

Finally, in terms of contribution to the academic field, there is no similar approach that operates indicators and indexes applicable to firms and clusters, even in the emerging studies of a quantitative nature. These measures associated with the GVC analysis framework can enable comparison and monitoring bases to different value chains in different geographic locations, opening opportunities for new policy making and theoretical contributions.

Acknowledgements

This work was supported by Federal Institute of Education, Science and Technology of Tocantins, Campus Palmas. Also by BRSAqua Project, coordinated by Embrapa Fisheries and Aquaculture, and financed by BNDES (Brazilian Economic Development Bank) and MAPA (Ministry of Agriculture, Livestock and Food Supply), in partnership with CNPq (National Council for Scientific and Technological Development).

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ARTICLE 3

Performance of the main tilapia culture zones in Brazil from the perspective of the global value chain approach: Current scenario and challenges of global insertion

ABSTRACT

This study provides a broad discussion on the tilapia productive chain in Brazil. It aims to analyse the business environments of tilapia sector in the main production zones in Brazil, supported by the Global Value Chain (GVC) approach. For this purpose, this study used a wide range of multidimensional indicators collected from tilapia production units (TPUs) and distributed in four selected and categorised tilapia production zones (TPZs). Based on fuzzy modelling, this analysis was carried out by comparing multidimensional indexes of business environments estimated by a fuzzy inference system. The research concluded that more verticalised governance models are more promising for the development and internationalisation of the chain in Brazil. It also concluded that in productive zones where these forms are not fully dominant, the role of competent suppliers, associated with active technical assistance, can play a key role for technological development at the TPU level. Additionally, it was highlighted that the synergy of this chain with other more internationalised agri-food segments, such as poultry and pigs, can be a key element in overcoming future obstacles arising from a global integration process. Moreover, the main configurations and barriers faced by each productive zone in the current scenario and the challenges related to an eventual institutional upgrading necessary to meet international marketing standards are also highlighted. Finally, the study proposes a research agenda that expands the range of quantitative and micro studies in the field of GVC, seeking to better understand, from multiple perspectives and scopes, the possible effects and results associated with the internationalisation of the aquaculture chains of the Global South.

Keywords: aquaculture, business environment index, fuzzy logic, global south, global value

1. Introduction

Brazilian aquaculture production reached 579,262 tonnes in 2018, for which fish farming was responsible for approximately 90% of this production. Tilapia production ranks first in the country, with a volume of 311,540 tonnes, corresponding to 54% of national aquaculture in 2018. This production evolved systematically; between 2013 and 2018, the average growth rate was 13% a year, while in aquaculture in general, this increase was 4.3% a year. This growth is driven by the intensification of the use of net cages in public waters and the formation of productive agglomerations around the country's large reservoirs of hydroelectric power plants (Barroso et al, 2018; IBGE, 2018).

Despite being one of the largest aquaculture producers in the world, the country's production export rates are still modest. In the case of tilapia, historically (2013 to 2018), Brazil exports less than 0.4% of its total production. Unlike its Latin and Caribbean neighbours, almost all of the tilapia produced is consumed domestically, like in some African countries such as Zambia and Ghana, which also take the first steps in the globalisation of their aquaculture chains (Asiedu, Failler and Beyens, 2016; IBGE, 2018; Kaminski et al, 2018; FAO, 2018; CIAQUI, 2020).

Although in modest volumes, the export of Brazilian tilapia grows annually more than the average of fisheries and aquaculture, mainly driven by a change in level that occurred in 2016 when the country went from an average—in the previous three years—from 105 tonnes/year of exports to an average of 778 tonnes/year, between 2016 and 2018, an increase of more than 600%. In 2018, export categories were tilapia fillet (79.8%), followed by fresh or chilled tilapia (17%) and frozen tilapia (3.2%) (IBGE, 2018).

In Q4 2018, an important institutional arrangement was established throughout the country to stimulate the export of tilapia. The drawback customs regime, which has been used by companies in the sector since the beginning of 2019²⁹, seeks to make tilapia more competitive internationally by reducing production costs. Based on the reduction in taxes of the main inputs used in cultivation, it is estimated that the cost reduction resulting from this regime varies from 12% to 37% (Pedroza Filho and Rocha, 2019).

In view of the stagnation of the fishing chain since the 1980s, the world's aquaculture chain is growing rapidly and is currently responsible for supporting the supply of fish for human consumption. Food and Agriculture Organization of the United Nations (FAO) estimates that between 2016 and 2030, the world's aquaculture production will grow more than 35%, while in Brazil the estimate and growth is 89%. Academic interest in this chain became more intense as of the late 2000s, since then a vast majority of studies have used the analytical framework of value chains to address issues related to Global Value Chain (GVC) literature, especially governance and upgrading (Bush et al, 2019; FAO, 2018;).

However, so far, studies using the GVC approach have given greater attention to the most developed aquaculture chains in the world, especially in Asia. This results in a gap in studies in regions where aquaculture chains are less developed or, as in the case of Brazil, are in the pre-insertion phase in global chains (Lim, 2016; Kaminsk et al, 2018). In this context, this study is pioneering in addressing an aquaculture chain in Brazil from the different

²⁹ It should be noted that this same regime has been used since 2005 by pork and poultry chains, which are major exporters of meat worldwide.

perspectives provided by GVC analysis. To our knowledge, this is the first study in the world to adopt elements of the approach to diagnose and analyse a value chain not yet embedded in global markets.

Going beyond the aquaculture chain, and expanding to the most diverse objects of approach studies, this research also adopts an innovative methodological design with regard to quantitative studies that use GVC analysis. Being able to construct indicators and indexes applicable to firms and clusters of the most diverse productive sectors, these measures associated with the framework of GVC analysis synthetically operationalise the bases for comparison and monitoring of value chains in different regions and timelines.

In this context, this research aims to analyse the business environment of tilapia production zones in Brazil through multidimensional indicators and indexes, specific to the GVC approach, constructed from expert fuzzy inference models. In addition to this introduction, the article is divided into five other sections, and in the following section we present the GVC approach and its research agenda. In the third and fourth sections, we present the methodological procedures of the research and their results. Then, the results presented earlier are discussed based on the literature. Finally, in the sixth and final section, we present the final considerations of the research.

2. Global Value Chain Analysis

The period of rapid economic globalisation during the 1990s and reorganisation of productive relations coordinated by large transnational companies, which in turn have spread globally to productive tasks and in an intra-product system, are two important components to understand the emphasis on global production networks within the framework of the GVC approach.

This framework arises from the confluence of three theories, namely, world-systems theory; dependency theory and development theory. Its analytical framework can be understood as an evolution of the Global Commodity Chain concept based on five fundamental contexts, namely, input–output structure, geographic scope, governance environment, institutional structure and upgrading (Gereffi, 1994; Gereffi and Fernández-Stark, 2018).

The first two dimensions map the structures of activities, companies and links, as well as their spatial configuration in value generation. Governance identifies and analyzes the power relationships that coordinate allocation of resources along the value chain, both within and outside each actor's organisational boundaries. The institutional context (domestic and

external) is concerned with understanding how institutional aspects (i.e. laws, standards, policies, etc.) affect the coordination and performance of both firms and countries in the GVC. Finally, the upgrading dimension analyzes the dynamics of the advancement of firms or countries towards higher value positions triggered in global chains and their impacts from the economic, social and environmental point of views.

The researchers' increased interest in the approach in recent decades has been accompanied by greater attention given to the governance dimension and to a lesser extent to the upgrading dimension. In recent years, a more multidimensional view has emerged on the topic of global chains, for example, seeking to understand how institutional elements—local and external—interact with other contexts of GVC analysis (Eckhardt and Poletti, 2018; Tessmann, 2020).

This vision based on a global economy network and the unique ability to show how economic activities are connected at the global, national, regional and local levels were also important for a wide acceptance of the framework by international organisations. The World Bank, World Economic Forum, World Trade Organization, Organisation for Economic Co-operation and Development and United Nations Conference on Trade and Development were some organisations that, based on the GVC approach, have stimulated global trade and development programmes, mainly focusing on emerging countries (Fernandez, 2015; Gereffi, 2020).

However, from the developmental perspective, it is important to highlight that these supranational political measures contribute to reinforcing a pattern of subordinate and restricted integration of global networks controlled by a limited number of nations. This scenario goes against the use of GVC analytical tools for the purpose of reversing the process of subordination and exclusion of developing countries, which was a matter of great relevance for pioneering scholars of the approach (Fernandez, 2015).

From the point of view of formulating development strategies of peripheral countries, it is important to consider the phenomenon of global chains from a historical perspective, examining the trajectories of dependence shaped by states and their relations of subordination and inequality. This is relevant to develop specific strategies that condition inputs or provide alternatives to the global chains constituted based on a clearer understanding of the structure and dynamics of the potentialities and limitations faced by the networks of actors in the Global South (Fernandez, 2014; Fernandez and Trevignani, 2015).

This issue is an important research agenda for the field as it expands the theoretical boundaries of the approach regarding the development policies of nations beyond the idea of

upgrading, which is structurally limited and strongly controlled by leading companies. This resumption of the reflections of global value chains and development policies that were present in the early stages of the construction of the approach emerges as a current concern in the field of research (Fernandez, 2015, Gereffi, 2019).

Another concern of the GVC research agenda is filling the gap in quantitative and multilevel studies (Giovannetti and Marvasi, 2018; Golini and Boffelli, 2017; Hernandez and Petersen 2017; Ponte and Sturgeon, 2014). This could help elucidate some open issues in the field, such as better understanding the causal relationships that connect the GVC and the performances or positions of firms, clusters and countries in different analytical contexts.

Parallel and immersed in these broader questions of the GVC literature, we endorse that the research paths for the study of aquaculture value chains proposed by Bush et al (2019) may also be important for the analysis of other objects that take into account global chains. Such as (1) analysis of welfare, especially farmers and the dynamics of agrarian change; (2) a clearer understanding of the relations between modernised chains and international standardisation norms with local and traditional socio-economic practices; (3) a better understanding of the consumer market beyond trade flows; (4) analysis of the impacts of digital platforms (i.e. Amazon and Alibaba) and technologies (i.e. blockchain) in the (re)configuration of value chains and (5) attention to the destination of waste and by-products of productive processes.

3. Methodological Procedures

3.1 Research area and data

The data used in this research were collected in the first quarter of 2019 through a survey (Appendix B) answered by tilapia production units (TPUs) in Brazil. The database comprised information from 569 TPUs distributed within the national territory, with the exception of the north region, and covered the 12 tilapia production zones catalogued in the country by EMBRAPA Fisheries and Aquaculture and other production units.

In the study, the analysis was based on four spatial delimitations called tilapia production zones (TPZs), namely, Submédio Baixo São Francisco (SMBSF), Oeste of Paraná (Oeste-PR), Boa Esperança and Serra da Mesa and Cana Brava (SMCB) (Figure 1). Its limits were defined by the municipalities indicated by Barroso et al (2018) as belonging to the zones of SMBSF and Oeste-PR. For the productive zones of Boa Esperança and SMCB, the limits were established by a list of municipalities indicated by stakeholders (extensionists, researchers

and organisations representing the productive sector) consulted by EMBRAPA Fisheries and Aquaculture with direct operation in these regions³⁰.

It is important to highlight that these zones are located in regions of Brazil with significant differences in terms of human development. Boa Esperança and SMBSF zones are located in the northeast region with the worst Human Development Index (HDI) indicators in the country. On the other hand, SMCB (midwest) and Oeste-PR (south) zones are located in states and regions with high HDI (PNUD, 2020).

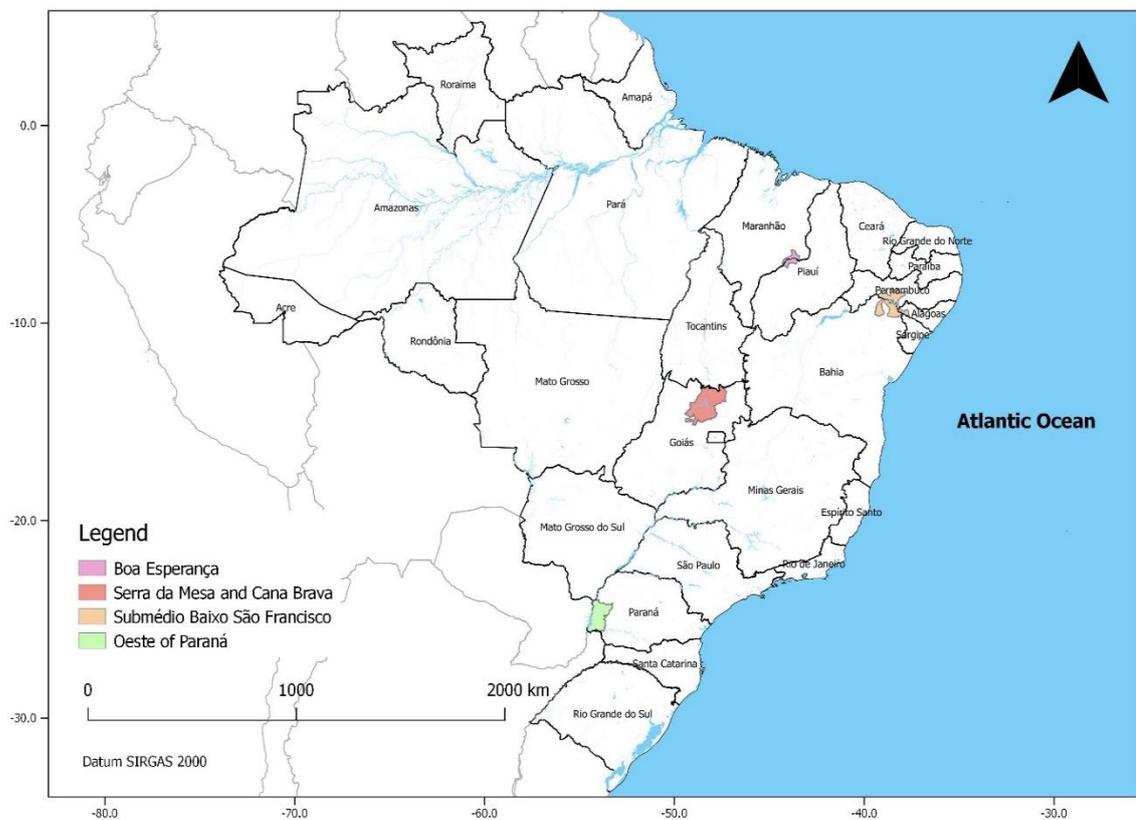


Figure 1. Productive zones researched.

For the purpose of defining the sample size, the estimation of the number of TPUs in these zones was also based on the same sources. The total number of fish farms by zones was as follows: Boa Esperança (48), SMCB (53), SMBSF (143) and Oeste-PR (219). Note that in the first three zones, all the TPUs use the system of production in net cages, while in the latter, the pond system prevails. Of the four TPZs, there are cooperatives that organise fish farms in

³⁰ To see the list of cities visit: <https://www.embrapa.br/en/cim-centro-de-inteligencia-e-mercado-em-aquicultura>

the form of integrated production systems only in the latter³¹. In this research, of the 219 TPUs investigated for Oeste-PR, 214 were in this type of vertical system, integrated with two of the largest tilapia-producing cooperatives in Brazil.

As an additional methodological procedure, we divided the TPZs into two analysis groups. The TPZs of Oeste-PR and SMBSF were classified as ‘consolidated’, while Boa Esperança and SMCB were classified as ‘emerging’. Both emerging zones are the newest in the activity, being in operation an average of 2.5 years (SMCB) and 5.4 years (Boa Esperança). To classify Oeste-PR and SMBSF as consolidated, the zone’s production volume³² was considered in addition to the operation time—of 11 years and 15.3 years, respectively—based on the data from CIAQUI (2020), where these two zones present two of the three highest results for each criterion.

3.2 Data processing

The research data were processed in two stages (Figure 2). First, fuzzy indexes of business environments were calculated for four dimensions of the GVC analysis based on the data of all TPUs of each of the four TPZs. Second, these indexes were processed together in a Mamdani expert fuzzy inference system using the MATLAB® software, which ultimately generated multidimensional business environment fuzzy indexes (BEFI) for each production unit. The aggregation of these indexes by production zones, in this last stage, presented quality scores of aquaculture business environments at the level of farmers for each of the TPZs surveyed.

In parallel to the two stages, statistical tests were performed to compare the averages of the indexes by groups of productive zones through the parametric Student’s t-test and the nonparametric Mann–Whitney U test, depending on the normality previously verified by the Shapiro–Wilk test. Correlations between variables were also tested using Spearman’s coefficient.

3.2.1 Step 1

³¹ Martins, Trienekens and Omta (2019) recognize three organisation types that apply vertical coordination to produce pigs in Brazil, namely, investor owned firms (IOF), cooperatives and mini-integrations. In this present research, all TPUs were organised in the format of cooperatives.

³² According to CIAQUI (2020), in 2018 the production and participation of the zones in national production were respectively: Boa Esperança (2,253tons; 0.7%), SMCB (2,754tons; 0.9%), SMBSF (28,591tons; 9.2%) and Oeste-PR (91,793tons; 29.5%).

By Zadeh's (1965) theoretical proposition, a fuzzy³³ set 'A' defined in the universe of discourse 'X' is characterised by a membership function μ_A , which maps the elements of X to the interval [0,1]. Thus, the pertinence function associated with each element 'x' belonging to 'X' is a real number $\mu_A(x)$ in the interval [0,1], which represents the degree of membership of element 'x' to set 'A' for each $x \in X$.

The use of fuzzy logic and its hybrid techniques have applications in several areas. More specifically for management and business, there is a wide range of applications aimed at decision-making, modelling, measurement of indicators, risk management and evaluation and performance. (Chan, Chan and Yeung, 2009; Finco, Ribeiro and Bailis, 2014; Mardani, Jusoh and Zavadskas, 2015; Islam et al, 2017; Liu et al, 2019; Oliveira et al, 2019; Zanon et al, 2019).

According to Jang, Sun and Mizutani (1997), membership functions can take different formats, and the choice of the appropriate membership function depends on the context and type of indicators to be described. More precisely, this choice depends on the characteristic of the linguistic variable and its linguistic terms. That is, the range of answers that can be given in a pre-defined manner or the eventual categorisation of the answers given by the respondents when asked a more open question.

In the first stage of this research, for each of the indicators (Tables 1 and 2), we estimated degrees of adherence to the fuzzy subset of business excellence environment using linear and singleton relevance functions. The choice of these functions in this stage facilitates the establishment of the links between the elements and a benchmark of the literature in GVC for business environments of excellence. Lelli (2001) argues that linear membership functions are very popular in the analysis of deprivation of freedoms by using subsets of poverty as they are easy to specify, interpret and visualise.

³³ Also recognised in the literature as a foggy or diffused set.

Table 1. Indicators for input–output.

Dimension	Indicators	Descriptions
Input–output (IO)	Work productivity (IO ₁)	Ratio between annual production (tonne) and number of workers involved in production.
	Processing capacity (IO ₂)	Quantity of processing units in the production zone.
	Inputs and equipment network (IO ₃)	Quantity of suppliers in the production zone (i.e. feed, fry, vaccines, etc.).
	Availability of inputs and equipment (IO ₄)	Occurrence or not of difficulty for producers to find inputs or equipment in the production zone.
	Natural resources (IO ₅)	The existence or not of factors that limit the use of natural resources and significantly impact production. When existing, the quantity of problem (s) (droughts, low water quality, natural predators, etc.) was also analysed.
	Logistic infrastructure (IO ₆)	Evaluation of the quality of roads in the region from the farmer’s perspective.
	Form of transport of the product (IO ₇)	Evaluation of the forms of transport used by producers for the marketing of tilapia.
	Absorption of production (IO ₈) (IO ₈)	Occurrence or not of the complete absorption of production by the market, reported by farmers.
	Gross margin (IO ₉)	Calculation of gross margin of production, as a proxy for profit. Through the average sales price (R\$/kg) less the average operating cost (R\$/kg).
	Commercial barriers (IO ₁₀)	Frequency of reporting five potential factors that hinder the sales of production in the production area.

Table 2. Indicators for governance, upgrading and institutional dimensions.

Dimension	Indicators	Descriptions
Governance (G)	Trust scale (G ₁)	Confidence of the producer in its trading partners.
	Barriers to entry (G ₂)	Evaluation of the degree of impact (on three levels) for eight barriers to enter into the activity.
	Frequency of change of business partners (G ₃)	Frequency scale of change in business partners by the farmer.
	Compliance with trade deals (G ₄)	Occurrence of non-compliance with trade agreements, characterised by the evaluation of default as a difficulty in commercialisation of the product.
Upgrading (U)	Technological improvement (U ₁)	Quantity of technologies used from a list of ten technologies associated with tilapia production.
	Acquisition of papers in chain (U ₂)	Number of activities developed beyond fattening from a list of six activities associated with fish farming.
	Purchase of machinery and/or equipment (U ₃)	Occurrence or not of purchase of machine and/or equipment for production in the last five years.
	Future upgrading expectations (U ₄)	Expectation of purchase of machines and/or equipment, increasing the number of technologies used and acquisition of new roles in the chain, for the next years.
	Technological level (U ₅)	Quantity of technologies used, classified as having a high productive impact, in a list of five.
Institutional (I)	Economic incentives (I ₁)	Existence or not of government incentives for farmers. In this case, ICMS exemption or not was used
	Availability of financial resources (I ₂)	Existence or not of banks or other institutions (development agencies, credit unions, etc.) that offer financing for the activity.
	Access to financial resources (I ₃)	Occurrence or not of factor that restricts access to formal market credit, when available in the region (i.e. non-compliance with laws).
	Public technical assistance (I ₄)	Existence or not of technical assistance offered by public institutions.
	Availability of qualified workforce (I ₅)	Evaluation of impact level of the availability of skilled labour as a barrier to activity, from the farmer's perspective.

Note: ICMS is Brazilian states tax on the circulation of goods and transportation and communication services.

This exercise of defining of the nature and direction of relationships between elements associated with indicators with literature in GVC, central part of all fuzzy inference process, occurred through a deductive methodological process supported in consultation with field experts and researchers of EMBRAPA Fisheries and Aquaculture. For instance, the definition

of technologies and/or roles in the Brazilian tilapia culture chain, as well as their respective degrees of impact on the upgrading phenomenon, was only possible through the participation of researchers from the institution who analysed and validated this crucial part of the study. The causal mechanism of each indicator is generally presented in Appendix C.

Moreover, in this exercise, note that because of the difficulty of finding comparative parameters in the literature, given the productive particularities of the zones, for the indicators IO₁, IO₂, IO₃ and IO₄, the parameters used to define the highest (1) and lowest (0) degree of membership of the productive units to the fuzzy subset of business excellence environment—for each group (emerging and consolidated)—were defined by the very characteristics of the interviewees or zones, excluding any outliers. Thus, the production unit with higher and lower labour productivity (IO₁) and gross margin (IO₄)—for each group—received one degree of membership $\mu_A(x)$ to the fuzzy subset, 1 and 0, and the other degrees were calculated as a linear function of these limits. Similarly, for the indicators of processing capacity (IO₂) and network of equipment inputs (IO₃), these limits, for each group, were defined by the quantity of firms established in the zones themselves.

These parameters limit the comparison of these indicators between groups, restricting, in this case, the analysis to intra-groups. However, as this occurred for indicators of only one of the four dimensions, possible comparisons between groups for the other contexts were not compromised given that they present the same parameters that define the degrees of membership to the fuzzy subset of business excellence.

As the final product of this first methodological step, we have the dimensional fuzzy indices representative of each of the four analysis dimensions, estimated by the average of the degrees of membership of the indicators associated with each dimension, which in turn assumed real values $\in [0,1]$. Thus, the fuzzy index of the input–output (I_{io}) dimension was defined by the average of the degrees of membership of its 10 indicators. Similarly, the same procedure was adopted for the other three dimensions. Thus, the closer the dimensional fuzzy indices of a production unit are to 1, the better evaluated is that firm's business environment in that context.

3.2.2 Step 2

In the second step, the four dimensional fuzzy indexes for each TPU were used in a Fuzzy Inference System (FIS) that estimated multidimensional fuzzy business environment indexes for each TPU. Thereafter, an aggregate index for each TPZ was defined by the means of the indexes of each of its TPUs.

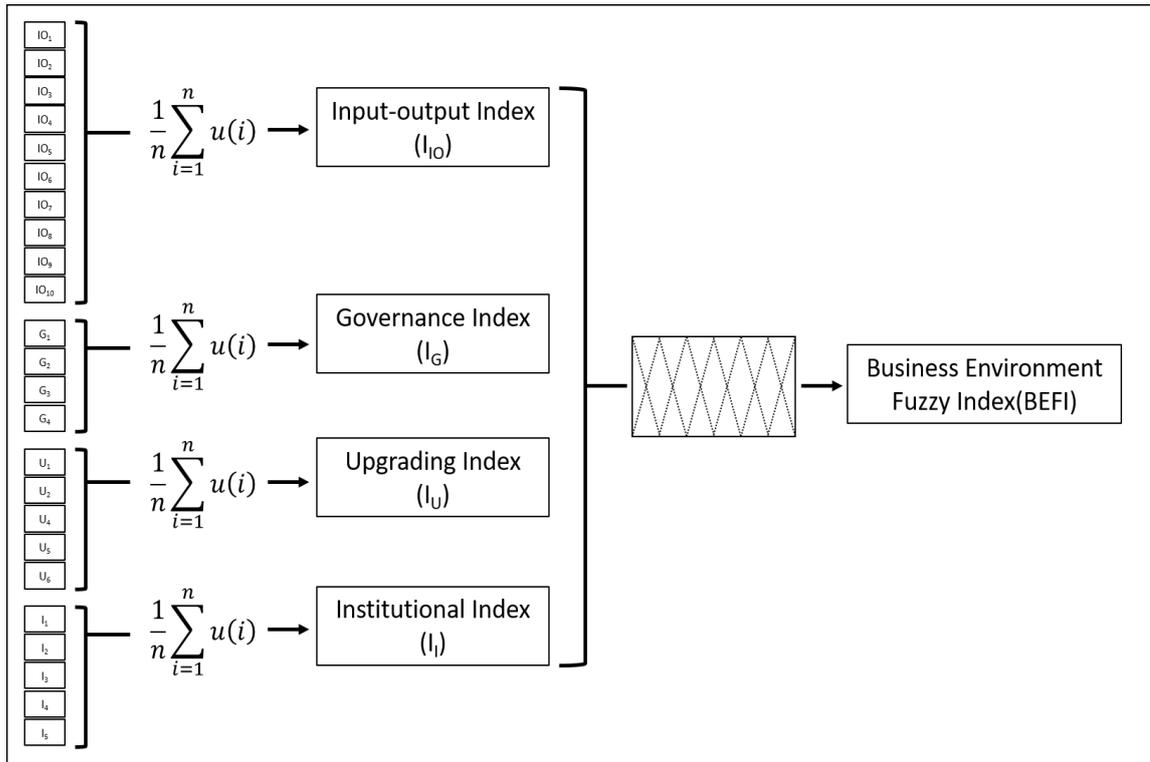


Figure 2. Illustrative view of the research method.

FIS is a system that maps inputs and processes them based on pre-established rules producing outputs. This system’s architecture can be divided into four key elements, namely, fuzzification, rule base, fuzzy inference and defuzzification (Kala, 2016).

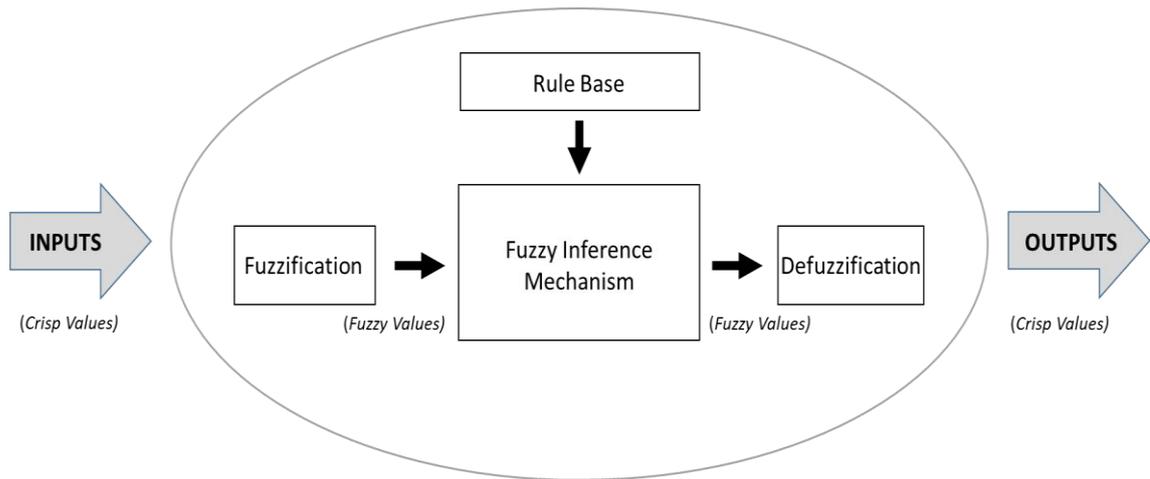


Figure 3. Main elements of the fuzzy inference system.

In the fuzzification stage, crisp values are translated into fuzzy values, which are determined by the degrees of membership to the membership functions that are in turn connected to linguistic variables. The rule base follows the ‘IF-THEN’ language statement

structure that stores all the system knowledge. In the inference module, the obtained fuzzy values are processed by inference methods, where operations of implication, composition and aggregation of the rules take place. Finally, using different techniques, defuzzification transforms the aggregation results of the previous stage into crisp values (Geramian, et al, 2017; Idrus, Nuruddin and Rohman, 2011).

The first stage of this research partially processed the FIS fuzzification module as it transformed crisp values into fuzzy values. However, based on the result of this first stage, which are the fuzzy indexes (FI) for each dimension of analysis, triangular membership functions were used—with parameters (a, m, b) —defined by:

$$f(x; a, m, c) = \begin{cases} 0, & x < a \\ \frac{(x-a)}{(m-a)}, & a \leq x \leq m \\ \frac{(b-x)}{(b-m)}, & m \leq x \leq b \\ 0, & x > b \end{cases} \quad (1)$$

That partitioned these FI, or FIS inputs, into three fuzzy subsets called Low (L), Medium (M) and High (H), which in practice are associated with a classification of the analytical dimensions of business environments.

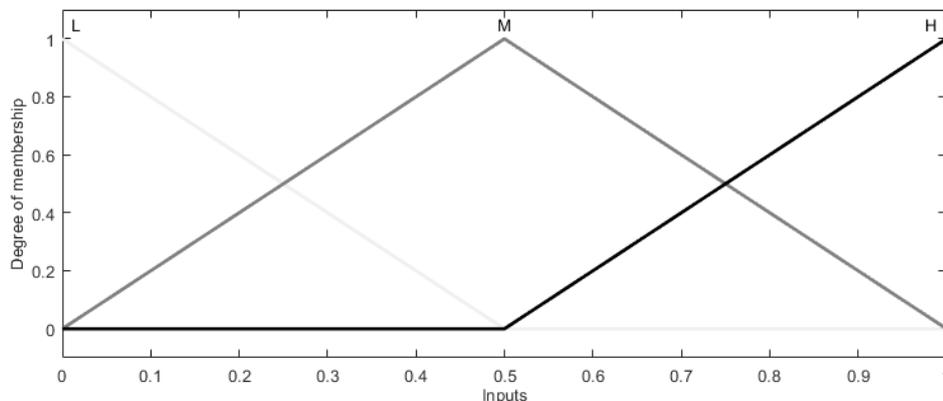


Figure 4. Membership functions of inputs.

In this first module of the system, triangular functions were also defined in the outputs. These outputs, which are the BEFIs, were partitioned into subsets with a granulation from Very Low (VL) to Very High (VH). In the system configuration, in addition to a great number of subsets at output, compared with inputs, the BEFI scores assumed a scale from 0 to 100, where 100 refers to a production unit or tilapia production zone with full membership to the fuzzy VH subset.

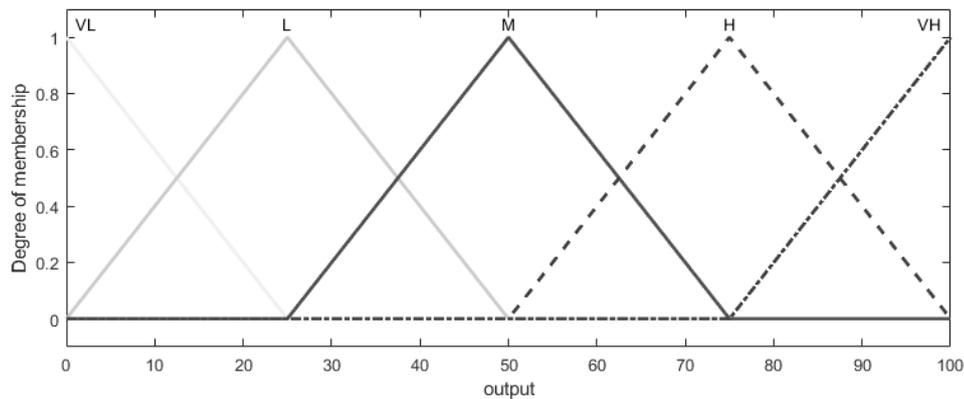


Figure 5. Membership functions of outputs.

The rule base of this Mamdani expert FIS was made up of IF-THEN rules, which in turn comprised an antecedent (premise) and consequent (conclusion) part, with operators of logical implication of type ‘AND’. According to Zanon et al (2019), because of the lower computational effort required, the t-norm operator (minimum), as in equation (2), is generally adopted.

$$\mu_{A \cap B}(x) = s\{\mu_A(x), \mu_B(x)\} = \min\{\mu_A(x), \mu_B(x)\} \quad (2)$$

A total of 81 rules were used in the system, summarised in Appendix C. Note that the size of an FIS rule base is closely related to the number of inputs/outputs, as well as the number of previous and consequential propositions used. This justifies the strategy of the methodological procedure in two stages using only four inputs in the second for the FIS, instead of the 24 indicators. A system of this nature with 24 inputs would make research operationally unfeasible as it would require a combination of billions of rules.

When using rule bases such as those aforementioned, conclusions should be based on all rules; therefore, it is necessary to aggregate (compose) all individual relationships into a set of rules. Several methods can be used for this aggregation, but the most frequently applied methods are those of Mamdani and Sugeno (Di Addario et al, 2016; Geramian et al, 2017).

In the system inference module, we opted for the Mamdani method, which is most frequently used for the construction of indexes and indicators. The benefit of this method for this present research is that unlike the Sugeno method, the system’s fuzzy output is accompanied by the membership function that—for the purpose of this article—makes the presentation of the results more intuitive.

The implication relationship between the fuzzy numbers resulting from the logical operations and the consequent numbers for each activated rule can be expressed by the minimum implication operator (Mamdani), according to equation 3. The composition of the set of rules, represented by ‘U’ and related to the entire system, based on the *Max–Min* rule of

inference is expressed equation 4. Finally, in the inference module, the output set $B'(y)$, given a set of inputs $(A_{1,i}, A_{2,i}, \dots, A_{n,i})$, can be obtained by equation 5, where ‘ \circ ’ is a composition operator and ‘ \wedge ’ is the t-norm operator (Bandemer and Gootwald, 1995; Benini and Meneguette Junior, 2008).

$$\mu_{R_i}(x, y) = \min(\mu_{A_i}(x), \mu_{B_i}(y)) \quad (3)$$

$$\bigcup_{i=1}^n R_i(x, y) = \max\{\min(\mu_{A_i}(x), \mu_{B_i}(y))\} \quad (4)$$

$$B'(y) = \bigcup_{i=1}^n \left(\mu_{A_{1,i}}(x_1) \wedge \mu_{A_{2,i}}(x_2) \wedge \dots \wedge \mu_{A_{n,i}}(x_n) \right) \circ R(x_1, x_2, \dots, x_n, y) \quad (5)$$

As in the previous module, the defuzzification process can take place through different methods, the main ones being centre of area (CoA), centre of gravity and the mean of maxima (Jin, 2003). This illustrative case used the CoA method, also known as centroid, which is the most frequently used method. This method determines the centre of the fuzzy set area and returns the corresponding crisp value. The centre of the area is calculated according to equation 6.

$$CoA = \frac{\sum_{k=1}^n \mu_A(x_k) x_k}{\sum_{k=1}^n \mu_A(x_k)} \quad (6)$$

Furthermore, with regard to the methods used in the last two modules of the FIS, we identified in the literature that several studies that sought to build fuzzy indexes through expert systems used both or at least one of the two methods chosen for this study (Di Addario, et al, 2016; Kaushal and Basak, 2018; Oliveira et al, 2019; Zanon et al, 2019).

Finally, the FIS outputs generated after defuzzification are the respective BEFIs for each TPU. Its values are defined in the range of 0 to 100, 100 being the best possible business environment and, analogously, 0 being the worst.

4. Index Results

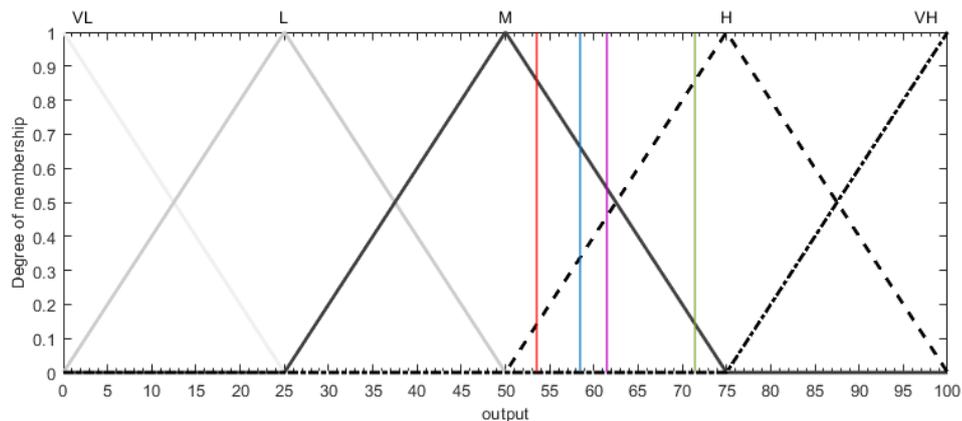
Table 3 presents the FIS results in the form of the mean BEFI scores for each of the TPZs.

Table 3. Outputs of the system.

Group	Tilapia Production Zone	BEFIS Means
Emerging	Boa Esperança	58.56*
	Serra da Mesa and Cana Brava	61.68*
Consolidated	Submédio Baixo São Francisco	53.39*
	Oeste of Paraná	71.25*

* Indicates statistical significance at 1%, that the BEFIS means of the zones are different inside the same group

Figure 6 illustrates the degree of membership of BEFIS to fuzzy subgroups of business environments. In this sense, we can observe that emerging TPZs approach business environments between regular and good with relatively higher degrees of belonging in the regular typology. Conversely, the production zones of SMBSF and Oeste-PR indicated a significantly high degree of belonging, close to 0.90, for environments considered as regular and good.

**Figure 6.** Outputs of FIS for all TPZs.

Note: SMBSF in red, Boa Esperança in blue, SMCB in purple and Oeste-PR in green

In turn, Table 4 also presents the scores of dimensional indexes and FIS inputs in the form of the mean for each TPZ. The analysis of these results is significantly important to better understand the nuances surrounding different realities of the researched areas. In this sense, the following subsection will discuss these results based on the indicators that composed these indexes.

Table 4. Inputs of the system.

Group	Tilapia Production Zone	Dimensional Indexes Means			
		I-O	Gov.	Upgr.	Inst.
Emerging	Boa Esperança	0.494*	0.780*	0.426*	0.391
	Serra da Mesa and Cana Brava	0.582*	0.860*	0.743*	0.328
Consolidated	Submédio Baixo São Francisco	0.619*	0.859	0.092*	0.637*
	Oeste of Paraná	0.836*	0.885	0.813*	0.801*

*Indicates statistical significance at 1% between zones of the same group

However, initially, based on Table 4, we can point out that for emerging productive zones, the governance dimension received the best scores and institutional dimension received the worst score, and the upgrading dimension presented the greatest difference between the zones. In the group of consolidated TPZs, as well as in the previous group, the governance dimension presented the best result, and the upgrading dimension showed the greatest difference between the zones, which was significantly more pronounced compared with the gap in the TPZs of the emerging group.

4.1 Emerging productive zones

In summarised form, Figure 7 illustrates a comparison of the results obtained for the dimensional indexes of the emerging productive zones. In these terms, it is important to highlight that there was a statistically significant difference between the means of the indexes for all categories of analysis except for the institutional dimension.

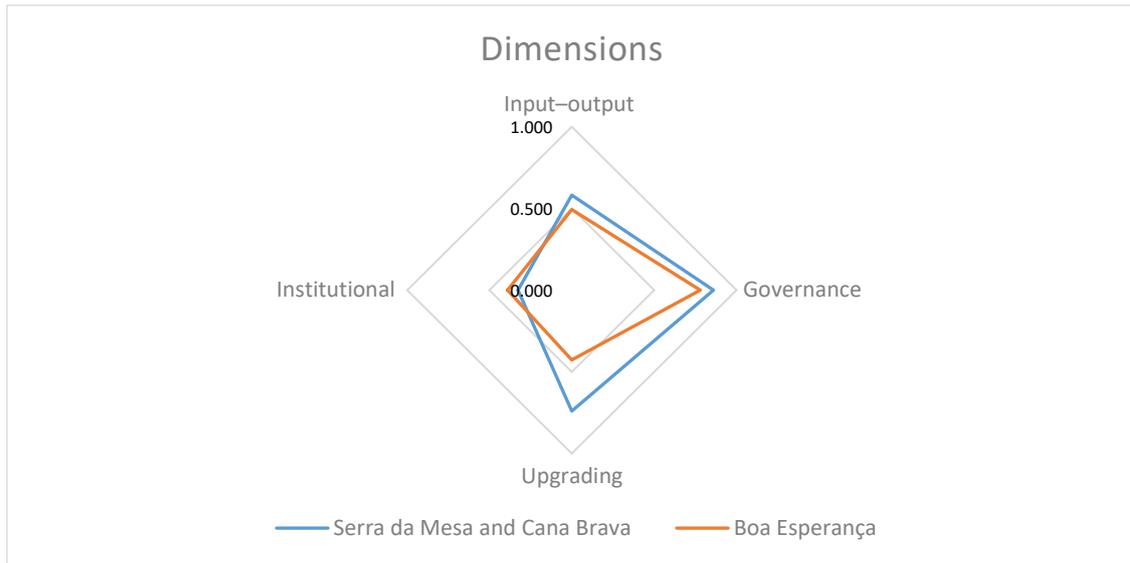


Figure 7. Means of dimensional indexes for emerging zones.

In the I-O dimension, it was common for zones to have low scores for availability of inputs and equipment and transport infrastructure. Generally speaking, producers rated the roads of the zones as bad or very bad and revealed difficulties in finding suppliers of some input or equipment in the region. Both TPZs also presented low scores of labour productivity.

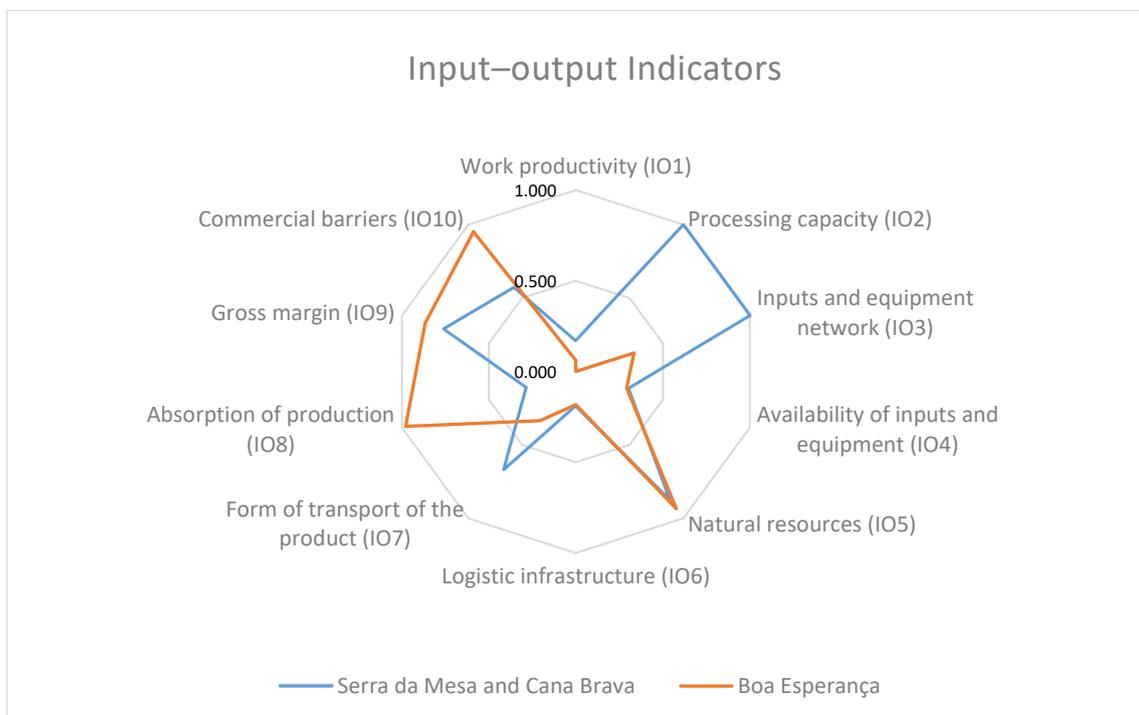


Figure 8. Indicators of input-output dimension.

Although the difficulty to find suppliers is common in both zones, SMCB presented higher scores for the indicator of network of inputs and equipment and processing capacity

compared with the production zone of Boa Esperança in Northeastern Brazil. The mid-west TPZ presented comparatively a more comprehensive structure of slaughterhouses, producers of fingerlings and juveniles, feed factories and net cages factories.

Conversely, the northeastern region (Boa Esperança) presented better indicators related to the marketing of tilapia. In 2018, 98% of producers in that area reported that they had all their production absorbed by the market, compared with only 28% of the mid-west area (SMCB). Overall, the difficulties and problems pointed out to market production were significantly greater in the SMCB zone, including producers who presented negative gross margins during the period.

In the governance dimension, the scores of the entry barrier indicator should be highlighted. The SMCB zone had a slightly higher score for this element than the TPZ of Boa Esperança at 0.860 and 0.780, respectively. When asked about the main difficulties for someone whose objective is to install fish farming in the region, ‘high investment’ was unanimous for both groups, which is considered a high impact barrier.

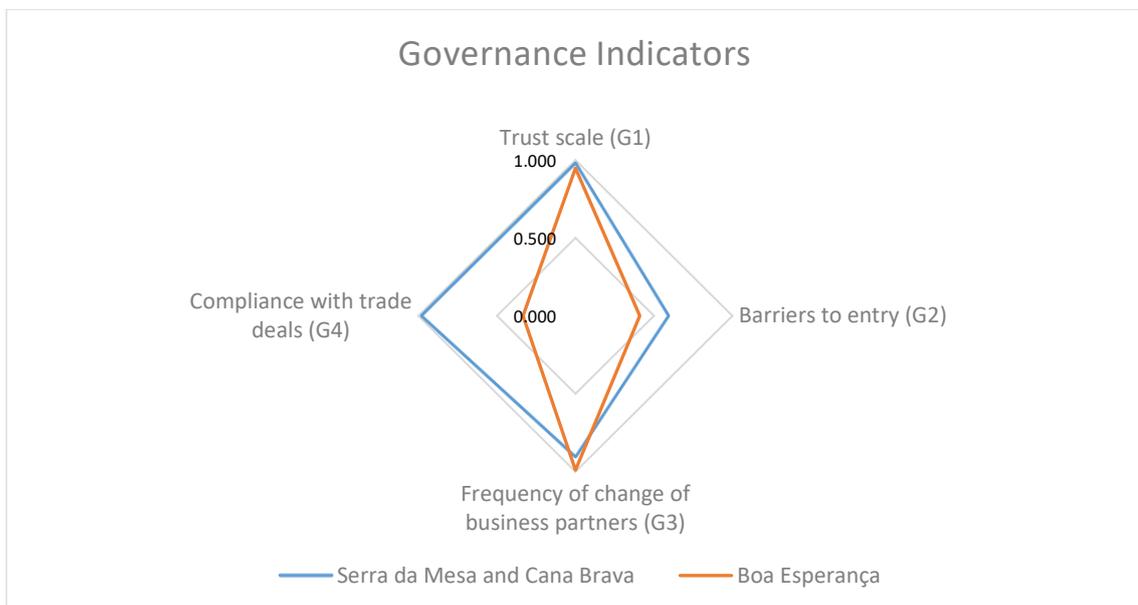


Figure 9. Indicators of governance dimension.

Such a barrier is directly associated with the difficulty of accessing funding for the activity, which leads to its implementation occurring almost exclusively with its own resources. For both zones, only 30% revealed that there are institutions to promote activity in the region, and according to a fish farmer from Piauí:

'The lines of credit are usually not suitable for the activity, as the accepted guarantees are immovable properties that are not necessary for the development of the activity (fish farming in net cages) and the deadline to pay the financing is short; 12 months are not sufficient to have the return that allows settling the transaction with the earnings from the activity'.

This scenario was reflected in low scores for the indicator of availability of financial resources in the institutional context in both zones, which will be presented below. However, even in the governance dimension, the score of the frequency of compliance indicator with trade agreements was significantly higher for the SMCB TPZ (0.979) compared with Boa Esperança (0.333); the default in trade relations was reported as a problem in the marketing of tilapia for 66% of the northeastern producers and only 2% for producers from Goiás.

The upgrading dimension presented the greatest contrast between TPZs. The scores of the technological improvement and technological level indicators were the most relevant to understand the difference between the zones. For the first indicator, out of the 10 technologies³⁴ listed to producers, 65% of SMCB's TPUs reported using at least nine of them, while in Boa Esperança, 63% of the producers did not adopt any of the 10 technologies listed.

Comparatively, the technological level indicator presented an even greater difference. It should be clarified that this indicator was operationalised from the identification of the use of five technologies classified as having the greatest productive impact among the 10 technologies listed. Of these five technologies, 79% of the SMCB TPUs adopted at least two of them, while in the Boa Esperança zone, this proportion was 33%. In other words, in addition to quantitatively adopting more technologies, the SMCB TPZ also proportionally adopts technologies with higher impact on increased production.

³⁴ (1) Polyculture; (2) Recirculation; (3) Bioflocos; (4) Automation of harvesting, classification or feeding; (5) Management software; (6) Aerator; (7) Vaccine; (8) Medicines; (9) Prebiotic and probiotic; (10) Genetically improved lineage.

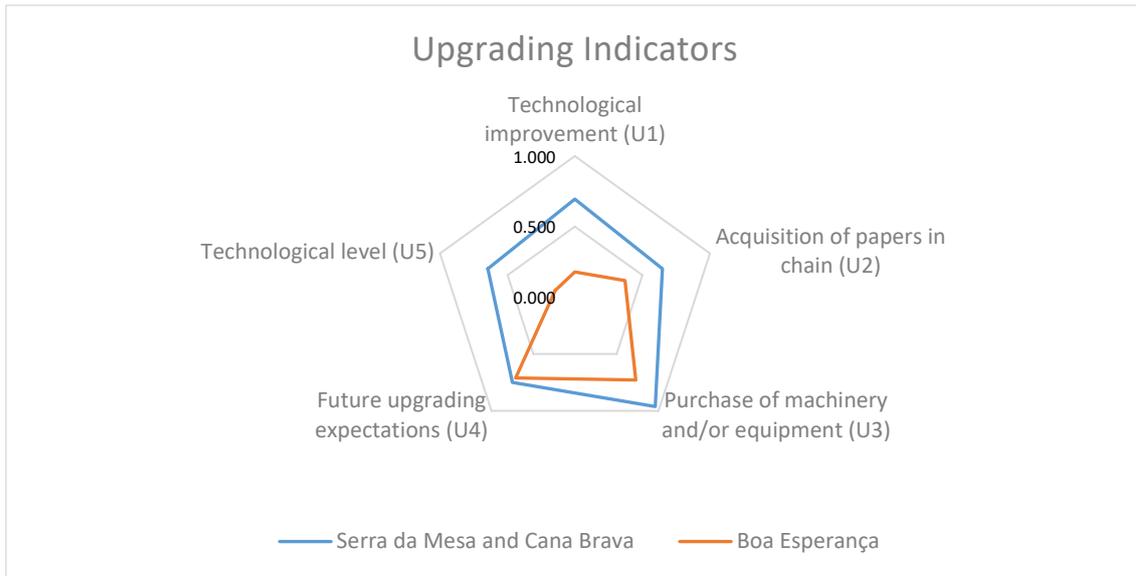


Figure 10. Indicators of upgrading dimension.

From the institutional perspective, as already pointed out earlier for both zones, only 30% of the units surveyed revealed that there were institutions to promote activity in the region³⁵. Regarding the indicator of access to financial resources, 34% of producers in Boa Esperança pointed out that there were difficulties in accessing credit lines when they requested them. Conversely, 94% of producers SMCB revealed that, generally, there is some pending documentation or missing guarantee that hinders or prevents access to resources available in the region.

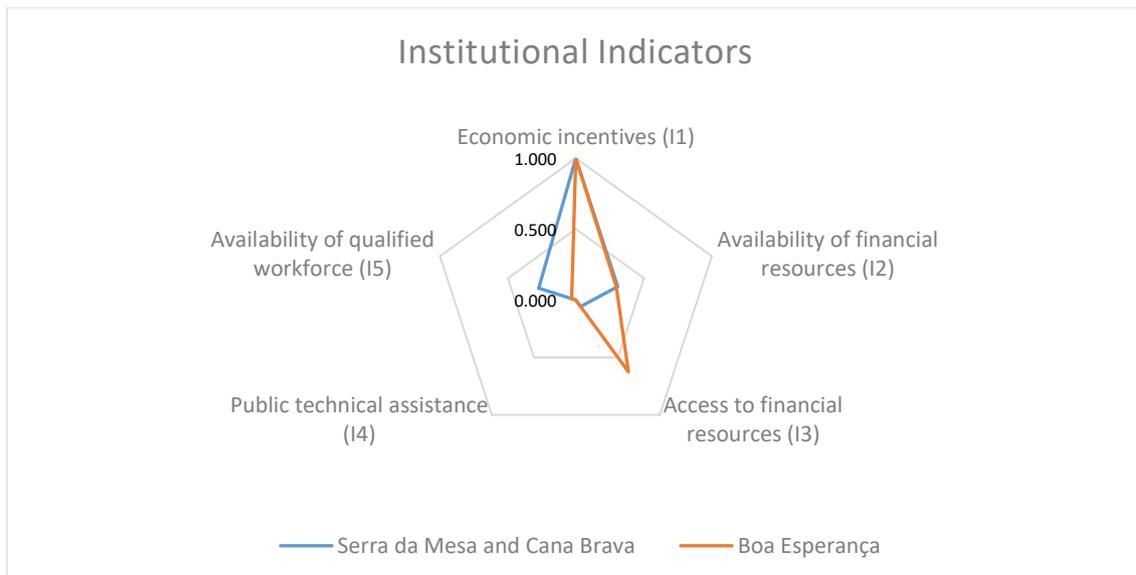


Figure 11. Indicators of institutional dimension.

³⁵ The remaining 70% were distributed among productive units that did not know how to answer the question or indicated that there were no promotional institutions.

For the institutional indicator of technical assistance, there was no difference between the zones. All the TPUs interviewed indicated that they did not receive any type of public technical assistance. Finally, the indicator of labour availability had a relatively low score for both zones; lower than 0.250. This was due to the fact that 92% (Boa Esperança) and 72% (SMCB) considered the difficulty in obtaining labour as having a high negative impact on the performance of the activity.

4.2 Consolidated production zones

Figure 12 illustrates a comparison of the results obtained for the dimensional indexes of the consolidated production zones. In this first observation, we can already identify that there is a greater difference in the results compared with the first group. In these terms, it is important to highlight that there was a statistically significant difference between the means of the indexes for all categories of analysis except for governance.

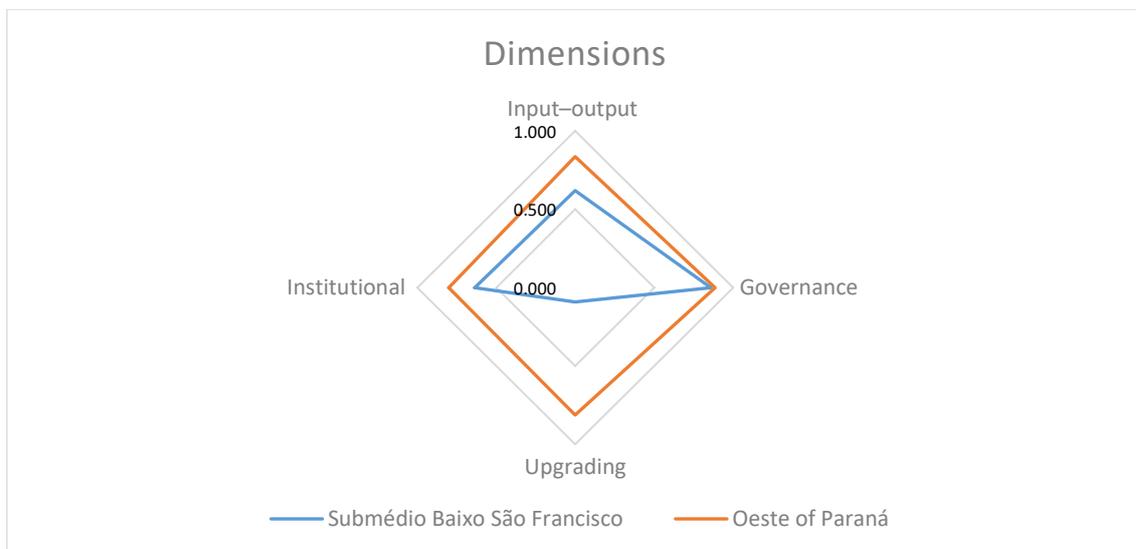


Figure 12. Means of dimensional indexes for consolidated zones.

In the I-O dimension, the indicators of labour productivity, processing capacity, network of inputs and equipment were significantly higher for the Oeste-PR TPZ.

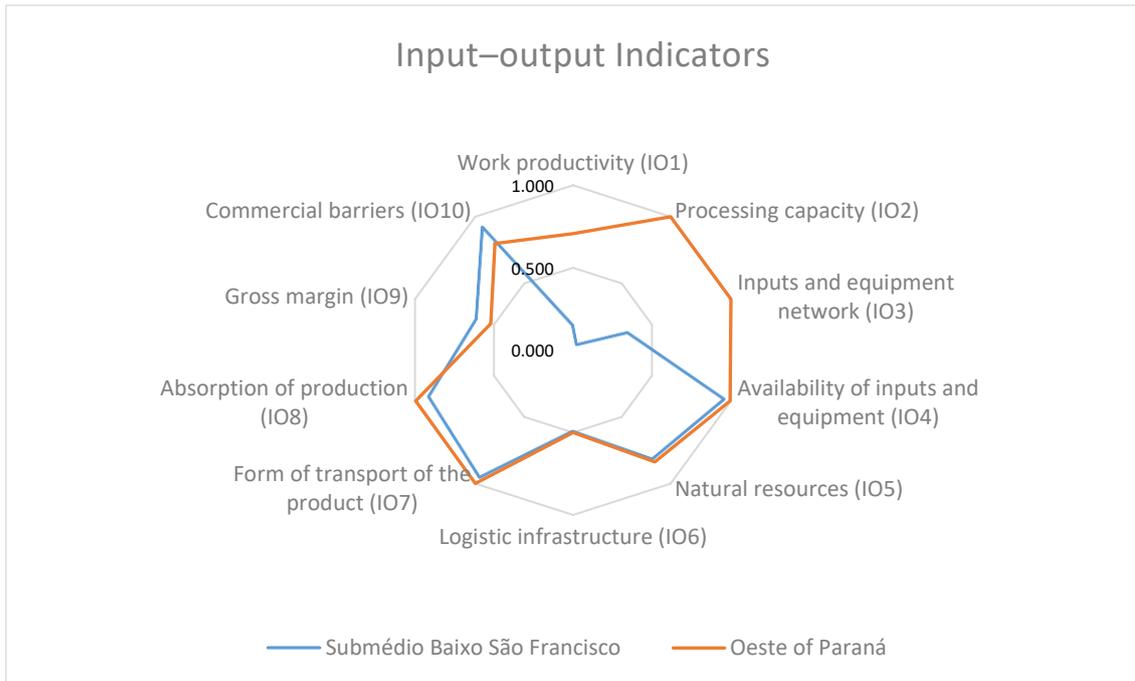


Figure 13. Indicators of input-output dimension.

Regarding the governance dimension, the indicator that presented the most significant difference between the zones was that of compliance with trade agreements. The default for payment in commercial relations was reported as a problem in the marketing of tilapia for 62% of the SMBSF TPUs. Conversely, only two properties from Oeste-PR indicated the occurrence of such an event, that is, less than 0.01%.

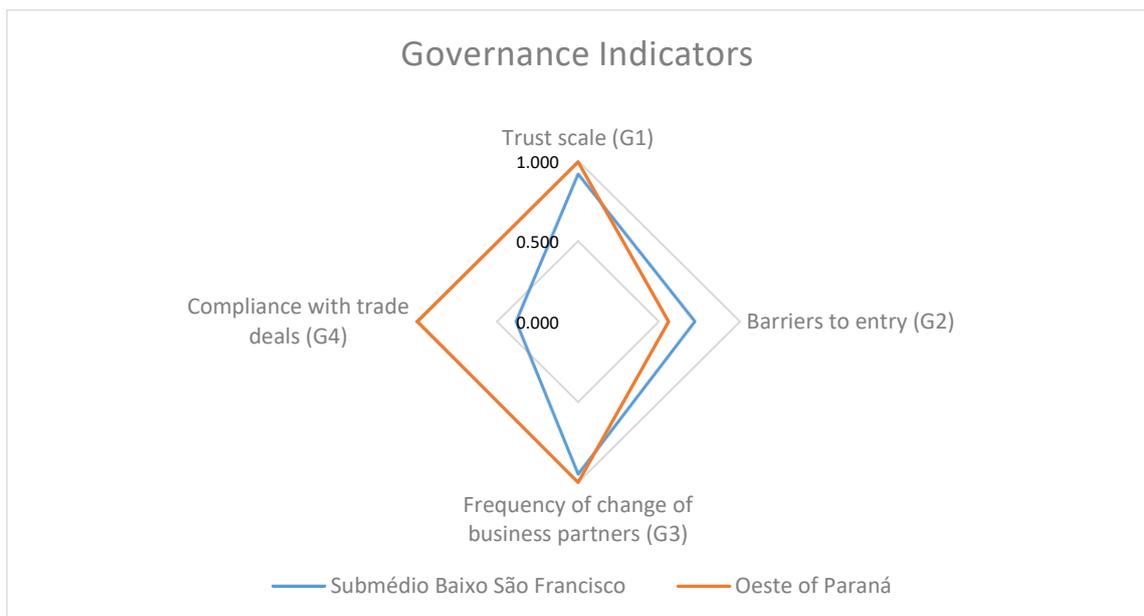


Figure 14. Indicators of governance dimension.

For the emerging group, the upgrading dimension presented the greatest difference between the zones. As for technological improvement, more than 90% of the Oeste-PR TPUs, all integrated in the form of cooperatives, have shown in recent years that they have adopted 5 of the 10 technologies listed. Conversely, only one unit from the northeast zone applied at least five of the technologies. Generally, this reason was the same for the indicator of acquisition of papers in chain. Considering the six activities listed, more than 90% of the TPUs from the south adopted at least half of these papers, while in the northeast only two incorporated two papers.

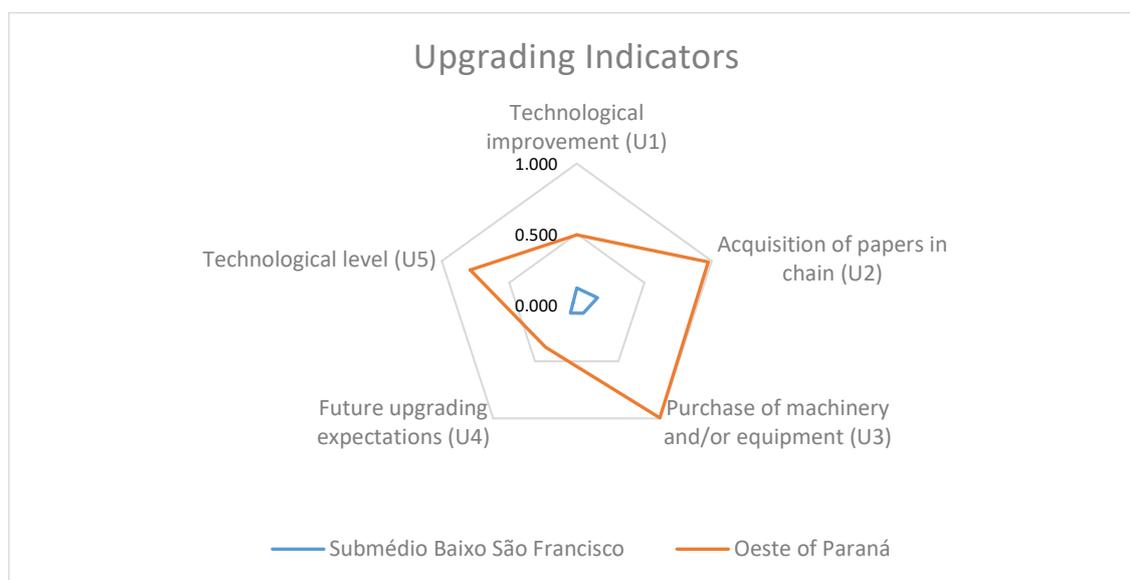


Figure 15. Indicators of upgrading dimension.

Analyzing the five selected technologies with the greatest productive impact, the zones also presented distinct results. In the SMBSF, 90% of the TPUs have not adopted any of these production technologies in recent years. While in the Oeste-PR, more than 90% adopted four of these technologies, all of which were in an integration system.

With regard to the acquisition of machinery and equipment, only one TPZ producer in Oeste-PR revealed that he had not purchased any of these items in the last five years. Conversely, only 8% of the SMBSF production units reported having purchased machinery or equipment during this period. Finally, expectations of future adoption of technologies and/or papers in chain, as well as the acquisition of machines and equipment, measured by the indicator of upgrading expectations, were higher for TPZs Oeste-PR (0.375) compared with SMBSF (0.076).

Finally, the institutional dimension also pointed out moderate differences between the productive zones. First, it was identified that there were no tax incentives for fish farming

activities in the states and municipalities where the SMBSF TPUs operate, something that occurs in the state of Paraná. Furthermore, northeastern producers pointed to a fragile availability and difficult access to financial resources—a reality that is completely different from that experienced by the production units of the south.

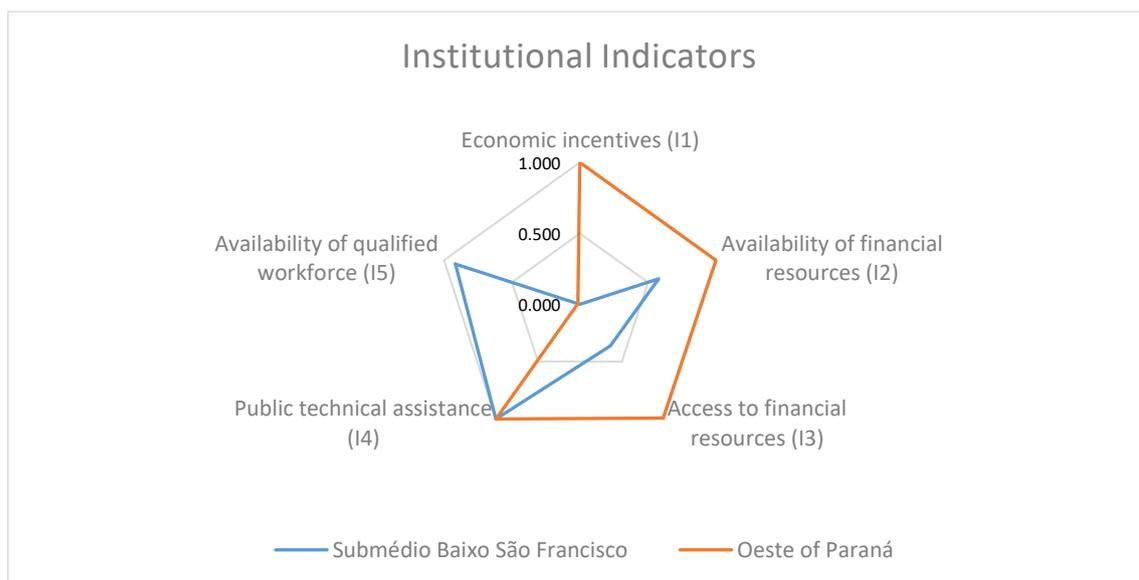


Figure 16. Indicators of institutional dimension.

However, observing the institutional indicator of labour, the northeastern scenario seems better than the southern scenario. Note that more than 90% of the production units in Oeste-PR indicated that obtaining skilled labour was a problem with high impact on the activity. In the northeast, 88% of the TPUs indicated that this factor did not have any impact on the activity.

5. Discussion of Results

As presented in the previous section, the upgrading dimension presented the greatest difference between the production zones considering the two groups, emerging and consolidated. In this section, we initially started from this dimension to discuss the results of the research and advanced to the other dimensions in search of a broader understanding of the configurations of the tilapia production zones researched. Given the relative paucity of research of this nature related to aquaculture in Brazil and Latin America, we sought to establish some links between this study and others frequently linked to the value chains of Asia and Africa.

Hu et al (2019) identified that fish farms in Bangladesh that were small scale and that delayed adopting modern inputs possibly faced restrictions on the local credit market, thus depending on their own resources to invest in the activity. In the case of Brazil, there is no evidence in the literature that restrictions on access and availability of credit for the activity are related to the size or level of upgrading of the TPUs. Note that there was no significant correlation measured by the Spearman coefficient for any of these variables, considering 463 units of the four zones. The fact is that the two emerging zones and SMBSF suffered from the same problem, even with different means of upgrading levels and size of fish farms. In fact, Barroso et al (2018) points out that the difficulty in accessing credit in Brazil is a general reality of aquaculture activity.

Based on complementary reports to the subject provided by the TPUs, the hypothesis raised in this present research is that the restriction to the promotion of activity in Brazil has a crucial relationship with institutional aspects. Concerning the availability of credit, the shortage can be influenced by a timid action by the State, via promotional banks, as well as by a relative lack of knowledge of the activity by the banking sector as a whole.

Concerning the access to credit, deriving from this limitation of knowledge or even of interest of the financial sector for the activity, the credit lines often offered to fish farmers come with requirements such as guarantees and deadlines to pay the funding costs, which are foreign to the activity itself because most of them are formatted and originally intended for other activities, such as poultry and pig farming. Finally, perhaps the greatest factor that limits access to credit is compliance with environmental and water use laws and standards, particularly in farms located in federal reservoirs. These two limiting components of access to funding were the same as identified by Barroso et al (2018) as bottlenecks for the development of the activity in several tilapia production zones in Brazil.

Kumar, Engel and Tucker (2018), in a literature review, upon analyzing factors guiding the adoption of technology in aquaculture, indicate that the size of fish farming was considered an important characteristic that influences the adoption of technologies. Possibly because of a greater availability of one's own financial resources for investment and management associated with larger production units. The data of this present research partially reinforce this argument, considering that there was a significant positive correlation ($p < 0.05$) between the size of the

fish farms³⁶ and the improvement indicators (0.82) and technological level (0.89)³⁷; however, we cannot argue that this occurred directly by the capacity to finance and/or manage the activity in relatively larger fish farms.

In the literature review, the authors also highlighted two other aspects that were considered as indicators of the institutional dimension, namely, the availability of qualified labor and support by extension service. According to Kumar, Engel and Tucker (2018), these two elements are critical in enabling farmers to increase their knowledge on new technologies. It is interesting to note that in this present research, the conclusion regarding the role of extension service in the adoption of technologies is not so clear.

Both emerging zones, which presented different levels of upgrading, do not receive public technical assistance by extension services. Furthermore, in general, they reported that access to technology is not a barrier (SMCB) or is a barrier of little impact (Boa Esperança) to the establishment of fish farming in the region. Conversely, consolidated production zones with different levels of upgrading receive public technical assistance and did not consider access to technology as impacting the development of the activity.

This scenario leads us to conclude that, within these research productive zones, either public technical assistance has a marginal effect on access and application of technologies—which we believe is plausible—or the producers' perception of the technological domain is overvalued, giving them a distorted perception of their technological knowledge, which is also possible. It is also possible there is a role of private technical assistance, either through consultants or through technicians from input companies (e.g. fish feed), in the transfer of technology to fish farms that was not adequately investigated in the surveys.

This last hypothesis will be discussed considering governance and infrastructure configurations of the productive zones where fish farmers, suppliers of inputs and buyers operate. In SMBSF, there is only one fish processing plant, a multinational company, that does not buy fish from producers in the region, using—in processing—only those produced by themselves. The only effect of production overflow is the supply of processing waste to the only feed plant located in the production zone. In Goiás, there are three suppliers of inputs and three fish processing plants that serve the production zone, and in Boa Esperança, there is only one supplier of inputs and no fish processing plant.

³⁶ The categorisations of fish farm sizes were defined from the position measures (quartiles) of the production data of 463 units. It is considered that small properties are those with 10t/year or less, medium properties have production greater than 10t/year and less than 155t/year and large properties have production above or equal to 155t/year.

³⁷ Additionally, we also identified a significant positive correlation (0.83) ($p < 0.05$) between labor productivity (ton/worker/year) and technological level for 463 TPUs.

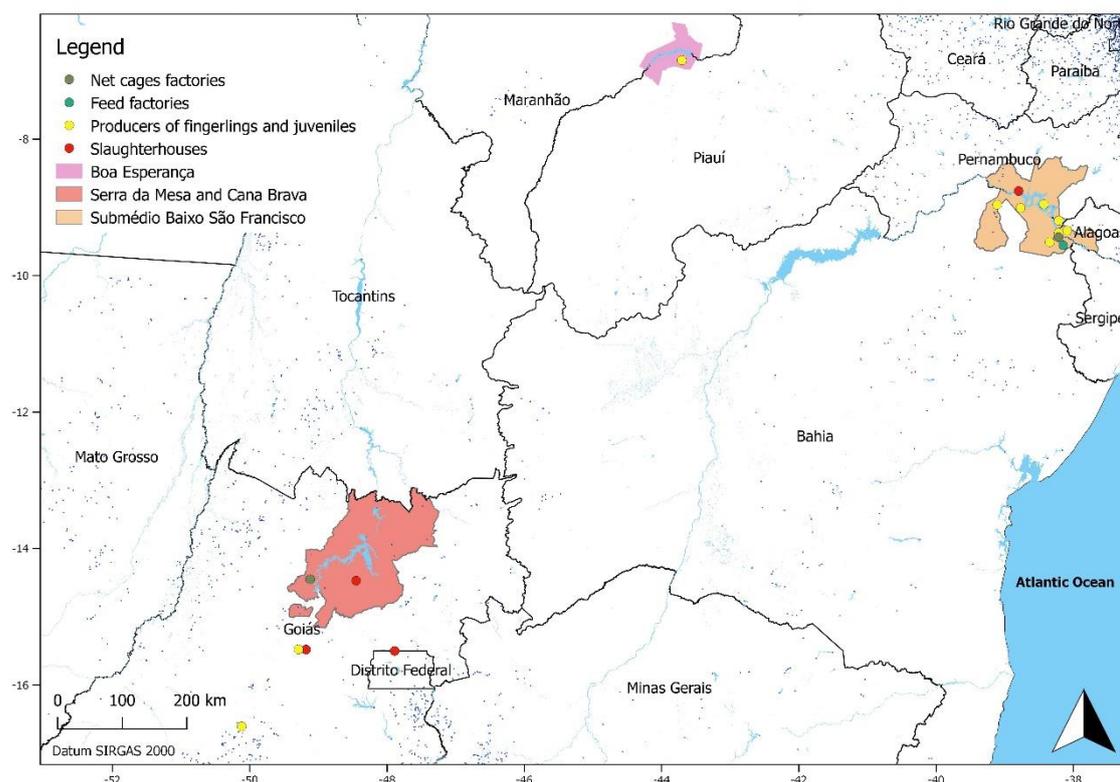


Figure 17. Input–output structure in selected poles.

In this context, the literature in aquaculture indicates that suppliers of inputs have a relevant role in promoting productivity and modernisation because farms mainly incorporate innovations induced by these actors. It also identifies that vertically integrated firms have a leading role in removing technology bottlenecks (Bergesen and Tveterås, 2019; Kumar, Engel and Tucker, 2018; Yi, Reardon, Stringer, 2018).

However, we highlight that even in SMCB, where 98% of TPUs sell their production totally or partially to processing plants and/or fishmongers/farmers' market vendors in the region. In general, there is no verticalisation of production with the industry in these three zones. Something quite distinct from what is observed in the Oeste-PR. Conversely, there is in SMCB—unlike the northeastern zones—a much more active role in promoting the care of the TPUs by the companies supplying inputs. In parallel to this, there is generally a well-structured private technical assistance services network around the SMCB zone. For instance, particularly in this TPZ, there is a tilapia production company with more than 10 years of operation, which in addition to marketing products, promote training programs to employees of TPUs both in aspects related to cultivation as well as those associated with property management.

There is also another peculiarity of this zone, which potentially had a positive impact on the measurement of levels and technological improvements. There is a proximity, both physical and commercial, of the zone with one of the largest national suppliers of fingerlings

and juveniles—currently linked to a Norwegian multinational company, a global leader in animal genetics. This relationship in some way facilitates both the availability and access to technologies considered to be cutting edge for the activity in the country.

Hul et al (2019) pointed out that the development of networks of inputs and outputs surrounding fish farms is a key element for the policy of modernisation and development of aquaculture chains. Ponte et al (2014) identified that the dominant drivers in value chains with their different driving degrees played a more influential role in upgrading trajectories compared with the dominant coordination mechanisms in aquaculture chains. An exception is made to the captive form of governance, which seems to have fostered some degree of upgrading. The authors mention retailers, fast food networks and importers of products with higher added value as important drivers that stimulate, to varying degrees, all types of upgrading.

Based on these reflections, we highlight that at the level of the TPUs, the upgrading process in the productive zones of the northeast (Boa Esperança and SMBSF) can be stimulated by strategies, both public and private, that structure other links in the value chain. Additionally, we point out that in the Brazilian case, it is quite plausible that the differences identified in upgrading between TPZs were strongly driven by companies downstream and upstream from the TPUs. This form of relationship with buyers and suppliers (governance) had a strong influence on the upgrading of the zones, reinforcing what is observed in the literature (Bergesen and Tveterås, 2019; Giuliani, Pietrobelli and Rabellotti, 2005; Golini et al; 2018; Hul et al, 2019; Humprey and Smith, 2002; Kaminski et al, 2018; Kumar, Engel and Tucker, 2018; Ponte et al 2014).

Although Asian literature points to upgrading in aquaculture as a response to international dominant drivers, in the Brazilian value chain this impulse comes mainly from domestic drivers (i.e. Processing plants, Supermarkets), given that its international commercial connection is practically embryonic. This different scenario is very close to the one identified by Kaminski et al (2018) for African aquaculture, given that both chains are less developed worldwide compared with Asian chains.

If upgrading plays a key role in enabling tilapia producers to capture the economic benefits of added values, it is necessary to better understand what these benefits are and how they are distributed in this segment of the chain. As Ponte et al (2014) points out, upgrading may involve activities that do not necessarily increase the value of the product, such as adoption of different management models, access to new markets, increased efficiency and compliance with social and environmental standards, which in a way reduces the risk of activity for producers and enhances local, social and environmental benefits.

In this perspective, it is important to analyse thoroughly, especially at the level of small producers, what are the real benefits of their insertion into the GVC considering the different aspects of upgrading. Additionally, we must understand the role of different governance configurations in the chains with special attention to the role of leading companies as an element that limits or facilitates the achievement of these gains related to the phenomenon of upgrading.

In this study, we can make some remarks taking as reference the value chain of tilapia in Brazil. If we analyse the average prices paid by the main marketing channels used in the four zones, we observe that in the one where there is a greater verticalisation of the tilapia production, Oeste-PR, with exclusive sale to processing plants, the average price paid was US\$ 0.80/kg. In the SMCB zone, where this channel is used by most (98%) TPUs³⁸, the average value was US\$ 0.96/kg.

In the productive zones of Boa Esperança and SMBSF the average prices were US\$ 1.81/kg and US\$ 1.18/kg, respectively. For the first, here is a higher prevalence of commercialisation via middleman and direct sales, while in the second zone it is more frequent to sell to fishmongers, farmers' market vendors and middlemans. This scenario points out that the TPUs selling tilapia to channels other than slaughterhouses received on average 70% higher final earnings. Conversely, we argue that possible verticalisation, with production channelling to processing plants, would be associated with benefits related to a reduction in marketing risk. Note that in the Oeste-PR zone, the entire sale was destined for the industry, and in the SMCB zone, a significant part of the sale went to these actors. In 2018, the occurrence of payment default was reported by only one unit from Paraná and two units from Goiás, less than 2% of the total. These ratios were 62% and 66% for the zones of Boa Esperança and SMBSF, respectively.

If, on the one hand, these hypotheses of lower average value received and lower risk of payment default, for integrated TPUs, can be strongly limited by price levels and default frequency restricted to the one-year time window. We still believe it is plausible that this governance configuration will play an important role in reducing the risks associated with the market (i.e. lower payment default, guarantee of sale, etc.) and the production itself through technological standardisation, supervision and management of the quality—including sanitary—of the products.

In this line of thought, Bush (2018) points out that when conducting a study comparing the shrimp and salmon chain, a high risk of activity and a low capacity for coding information

³⁸ It is important to note that unlike the Oeste-PR, the TPUs in this zone do not use this channel exclusively. But in conjunction with fishmongers / farmers' market vendors.

by farmers drive leading companies to adopt captive or hierarchical forms, which in turn provide greater supervision of production, stability in supply and better quality management³⁹. Apparently, there seems to be a strengthening of this coordination as supplier capacities increase and their production risks decrease, as has been observed for the salmon industry.

As a consequence, Bush (2018) points out that hierarchical forms of coordination in aquaculture are more likely to comply with international certifications. We believe not only that risks and capabilities define the adoption of different forms of governance by leading companies but also that these risks and capabilities are modified over time by the very dynamics of the forms of governance in which the TPUs are immersed.

Kaminski et al (2018) reinforces that the verticalisation (hierarchical governance) of aquaculture companies in Zambia, which goes beyond the simple integration of fattening practices, is primarily a risk management strategy by companies to control quality and improve the functionality of activities developed. Jespersen et al (2014) identified that as the Vietnamese *pangasius* chain consolidates, there is a tendency of prevalence of hierarchical forms of governance where captive governance is the most significant in countries such as Bangladesh, China and Thailand.

There is still no evidence for Brazil that governance structures, of the captive or hierarchical type, are a trend or are shaping the value chain of aquaculture, as is the case in Zambia or Vietnam. However, we can highlight that there is an entry in the country of large companies from other agri-food chains, mainly for exporting, that have been using this governance structure since 1970, especially in the South of Brazil. This is also the case with Brazilian pork chains (fourth largest producer and exporter worldwide) and poultry (second largest producer and world leader in exports, in 2019) (USDA, 2020; Zen et al, 2014). For instance, one of the most important agro-industries in the south, with more than 60 years of experience in pig and poultry production, incorporated tilapia farming just over 10 years ago and has become the largest tilapia processing industry in Latin America.

With regard to these chains, the farmers' integrating governance structures mark their historical trajectories. Despite the different contexts of the regions in the country, it can be stated that the prevalence of these coordination models is quite relevant, estimated at about 90% for poultry farming. This model has grown the most in pig farming, driven by export activity, and there is also a trend of migration from the market structure to captive. The Brazilian

³⁹ In a study on farmer–buyer relations in the Brazilian pork chain, Martins, Trienekens and Omta (2019) argue that besides meeting official regulatory requirements, vertical relations under contractual (captive) coordination provide additional information on quality and productivity by producers to buyers compared with market governance models.

literature points out the strict vertical coordination as important element for the development of both the chains, reflecting on issues such as biosafety, health and quality management (Guareski et al, 2019; Guimarães et al, 2017; Neves et al, 2016; Zen et al, 2014).

We believe that this background, both organisational and technological, from other Brazilian food chains can be of great value for tilapia value chain, and for aquaculture in general. According to Kaminski et al (2018), this relationship provided the development of the first fish farms in Zambia and still promotes inter-chain upgrading, even if not in such a comprehensive manner. Asche, Cojocararu and Roth (2018) argue for the Norwegian salmon industry that the transfer of knowledge and processes from the poultry industry have contributed and can further contribute to the development of the former, which is already the most efficient seafood chain in the world.

Finally, in addition to the issues discussed, it is important to highlight that the institutional environments⁴⁰ of the Brazilian production zones can be improved, especially for those emerging zones. Although this topic in general remains under-researched and connections between the institutions and other elements that compose the GVC analyses are still not well elucidated. The GVC literature recognises the importance of institutions (domestic and external) both for the insertion of countries in global chains and for analyzing the governance and upgrading frameworks of these chains (Dollar and Kinder, 2017; Dollar, Ge and Yu, 2016; Eckhardt and Poletti, 2018; Kumar, Engel and Tucker, 2018; Lim, 2016; Neilson and Pritchard, 2009; Ponte et al, 2014).

The results of the research for the institutional dimension indicate that there is room for improvement in all zones. In relation to the role of the government, but not restricted to it⁴¹, greater attention is needed on the availability and access to financial resources and the provision of technical assistance to the TPUs, as well as the process of adequacy to environmental standards and using and granting public water access, which is a difficulty reported by many, are acknowledged bottlenecks of the chain (Barroso et al, 2018).

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 (Granovetter, 1985; Granovetter, 1992). In this context, future implementations of international marketing standards may come on a collision course with the complexity of local, social practices and norms that

⁴⁰ See Davis and North (1971).

⁴¹ Miller and Atanda (2011) present in the case of Nigerian aquaculture the important role played by international organisations (FAO and World Bank) and NGOs in some topics in this area. Jespersen et al (2014) highlight the role of private and international technical assistance, as well as of NGOs, in the process of institutional strengthening for the adaptation of international export standards in Asian countries.

govern production, which ultimately may exclude smaller TPUs from the aquaculture chain. This potentially complex⁴²reconciliation between international⁴³ and domestic standards is an institutional arrangement that must be developed and thought out in an open, inclusive and urgent way (Bremer et al, 2016; Bush, 2018; Mialhe et al, 2018).

As noted by Jespersen et al (2014), improving the quality of national institutional structures in more sophisticated aquaculture countries, such as Asia, has facilitated the fulfilment of the increasing demands of global buyers. This issue is an important element for the internationalisation of the global southern chains still in the early stages of development. This reinforces the importance of synergy between the Brazilian aquaculture chain and those internationally consolidated and successful agri-food chains.

Finally, are presented some warnings and recommendations in addition to what has been discussed, which are important for the development of the chain in the production areas. Frequent reports were made concerning marketing difficulty by 90% of SMCB interviewees. Some units surveyed pointed out, as a solution, the creation of an association or cooperative to minimise the problem. This is something we believe to be coherent in view of the possibility of marketing larger volumes and opening up new markets. Improving the quality of highways and roads of emerging productive areas is something that deserves attention because for both zones the evaluation of this infrastructure was between poor or very bad. Concluding this first category, Boa Esperança currently faces what may be a potential risk for its development, which is the concentration of feed production in the region by a single company.

For the category of consolidated zones, we warn of the challenge of obtaining qualified labour as a negative impact factor for Oeste-PR, which can be because of two elements. The first is the competition, by the labor production factor, with other larger and more consolidated chains, as is the case of poultry and pigs, or even with other industries (e.g. clothing, mechanical). The second may be associated with the phenomenon of discontinuity of family generations in agricultural activities and the rural exodus of young people to urban areas of the region. Although Barroso et al (2018) did not identify the workforce as a limiting factor for the development of the productive area, even pointing out the return of the younger generation to the activities, with a higher technical qualification, Zilli, Bargato and Zen (2005) and Zen et al (2014) point out this phenomenon as impacting the availability of poultry farming labour in the South of Brazil, something that potentially may also be occurring for the TPUs of this region.

⁴² Bremer et al (2016) gave an overview of this obstacle by discussing sustainability patterns in aquaculture production in Bangladesh.

⁴³ Food safety, traceability, environmental and social impacts.

Finally, although it occurs on a smaller scale, the marketing problem repeats itself for some SMBSF TPUs. The shortage of demand and quality of tilapia were reported as bottlenecks; curiously, the solution for some of them was the same as in the SMCB zone. However, there is a caveat in the case of SMBSF, given that the tilapia produced by its TPUs does not undergo any type of processing and is sold with low added value to distant markets in an average radius above 248.55 miles. Thus, the establishment of an association or cooperative that processes this product, in addition to adding value, can leverage the reach of new markets, thus alleviating the imbalance between supply and demand. However, we know that this is not a simple task for both zones, especially for SMBSF. According to Barroso et al (2018), the latter culturally presents a low rate of participation in productive organisations.

6. Final Considerations

Although we believe that the value chain of tilapia culture in Brazil can coexist under different forms of governance with actors of different sizes and explore different market niches, as in the case of Asia (Jespersen et al, 2014), we understand that based on this overview of tilapia culture in Brazil more integrated governance structures (hierarchical and/or captive) that occur in other food sectors of the country (pigs and poultry) indicate more promising paths for the development of the value chain, reinforcing the conclusion of Bush (2018). These structures point to better upgrading trajectories, better management of the risk associated with the activity in general and a higher probability of compliance with international eco-certifications. The research also highlights that, in productive configurations where these integrated forms are not fully dominant, active technical assistance and competent suppliers can be an important factor in boosting the technological development of the TPUs.

Additionally, we point out some relevant issues for the development of the four TPZs surveyed and give special attention to the institutional environment in which the chain is immersed, highlighting, for example, regardless of the dominant form(s) of governance, the future challenge of the prevalence of a domestic institutional structure that discuss local complexities with international marketing standards. In this sense, we point out the important role that the experiences of other more developed agri-food chains, nationally and internationally, can play in overcoming this and other potential future technological and organisational obstacles.

Although the tilapia culture chain in Brazil is currently essentially oriented to the domestic and regionalised market, we believe that there is a significant potential for

international growth, including coexisting with the current structures that meet the current demand. A study of this nature is significantly important, both to diagnose *ex ante* the strengths and weaknesses of this chain, in view of a potential process of global insertion, and to evaluate *ex post* its possible results and impacts.

We consider a limitation of this research the fact that it does not contemplate other links in the value chain, which limits a broader analysis, especially in the dimensions of governance and upgrading. By not extending research to other segments (i.e. inputs and processing), the analysis of power relations between firms can be limited, which is a central issue for the governance dimension.

We also understand, in view of the continental dimensions of Brazil, that despite the good spatial dispersion and representativeness of the TPUs surveyed, the country as a whole has a heterogeneity of socio-productive relations, which in turn also limits the extrapolation of these results. However, taking into account these limitations, we highlight that the research makes an important contribution to studies of a quantitative nature and at the level of the firms for the field of research and is a pioneering research in Latin America.

As contributions to future work, we can point to the need to better investigate, at the level of the firms, what the real net gains from insertion into GVC and their effects of overflow and bending at the local and regional level, considering economic, social and environmental aspects. Finally, we also point out the need to continue efforts to create a better understanding of the role of institutions in the configurations and performances of GVC, especially in the Global South.

Acknowledgements

This work was supported by Federal Institute of Education, Science and Technology of Tocantins, Campus Palmas. Also by BRSAqua Project, coordinated by Embrapa Fisheries and Aquaculture, and financed by BNDES (Brazilian Economic Development Bank) and MAPA (Ministry of Agriculture, Livestock and Food Supply), in partnership with CNPq (National Council for Scientific and Technological Development).

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5 CONCLUSIONS

This thesis initially presented a framework of elements that broadly reflects the dimensions of GVC analysis, and proposed that these elements be observed from a historical and trend perspective, because he believes that value chains, more or less globalized, are becoming increasingly mutant and vulnerable to shocks, as in the case of the current Covid-19 pandemic.

The historical perspective is important not only to analyze the effects of shocks on globalized chains, but also to analyze chains in the process of global insertion. Both to diagnose *ex ante* the strengths and weaknesses of this, in view of a potential process of global insertion, and to evaluate *ex post* its possible results and impacts.

Parallel to this, the research brought the approaches of GVC and SCP closer together, pointing out mutual benefits for both. On the one hand, GVC introduces for another approach the global value chain phenomenon and its wide range of analytical elements. On the other hand, the tradition of investigating the causal relationships between macro and microeconomic elements of SCP model establishes important structural foundations for quantitative and firm-level research in GVC field.

The research had the merit of pointing out the use of the GVC framework for the analysis of firms and productive zones belonging to value chains until then little or not inserted globally. As well as those shorter chains, where the transformations and aggregation of value are relatively smaller. Demonstrating that the analytical tool of the approach can also be useful to analyze chains with such characteristics, which opens the way to expand the objects of study in the field. It also presented fuzzy logic as a novel methodological approach for GVC. Emphasizing its ability to process often nonlinear and subjective elements present in GVC analysis. Despite the barriers to its use, it indicates that fuzzy logic opens doors for the continuity of quantitative and firm-level research in the field.

Using a database of over four hundred TPUs distributed in four TPZs, the research concluded some key questions about this Brazilian aquaculture chain. Such as the important role that input suppliers, associated with active technical assistance, can play in the issue of technological development. The potential benefits of operating, at the level of TPUs, in a logic of more verticalized governance models, as well as the possible gains of an approximation of that with other national chains already internationalized, such as poultry and pigs. It also reinforced the recognition of compliance with environmental and using and granting water

standards as a bottleneck that afflicts the entire chain. Finally, pointed out key and particular issues for the development of the chain in each of the four productive zones surveyed.

Regarding the limitations of this research, emphasis was placed on the fact that it was developed from a single segment of the chain (tilapia producers), without extending to the other links. This made it impossible to include analyses of the Geographic Scope and Stakeholders dimensions. It also limited, for example, a broader analysis of the governance and upgrading dimension, since by surveying the industries (inputs and processing) it would be possible, for example, to better understand the power relations, which are so important for this dimension, both from the perspective of the producers and of the chain as a whole.

These limitations in themselves already indicate contributions and suggestions for future research. However, throughout the thesis it is recurrent as a contribution the concern to promote an expansion of the range of studies of a quantitative and micro nature in the field in order to advance in a better understanding of the GVC phenomenon. It is important to reinforce the relevance of deepening studies of aquaculture chains, especially in the Global South, given that it is a chain with fast growth worldwide and with a potential impact on relevant issues such as food security and sustainable development, especially on this side of the hemisphere.

In the sphere of government action to alleviate bottlenecks in the chain, some points deserve highlighting. Greater attention is needed to the access and availability of financial resources and technical assistance to TPUs, as well as to the process of adequacy to environmental standards and of using and granting public access to water. It is also important to improve the quality of highways and roads, and encourage the installation of more slaughterhouses, producers of fingerlings and juveniles, feed factories and net cages factories, especially in emerging productive zones.

Finally, in the producers' sphere the productive coordination in a verticalized form (i.e., cooperatives) is a promising path for develop of the chain. For producers who are not in this kind of system it is important to understand the importance of technical assistance for the upgrading. In productive zones where this type of system does not prevail, despite the recognized low rates of participation in productive organizations, it is important to stimulate the creation of cooperatives or associations in order to minimize problems related to upgrading, marketing and processing of tilapia.

APPENDICES

APPENDIX A – Tables of Article 2

Table A.1

Inference rules for relational context.

Rule Number	Inference Rules
1	IF < (Conf is H) and (FMudPar is H) and (CumpAcord is H) > THEN < (Relational VH)>
2	IF < (Conf is H) and (FMudPar is H) and (CumpAcord is L) > THEN < (Relational H)>
3	IF < (Conf is H) and (FMudPar is L) and (CumpAcord is H) > THEN < (Relational H)>
4	IF < (Conf is L) and (FMudPar is H) and (CumpAcord is H) > THEN < (Relational H)>
5	IF < (Conf is M) and (FMudPar is H) and (CumpAcord is H) > THEN < (Relational H)>
6	IF < (Conf is H) and (FMudPar is M) and (CumpAcord is H) > THEN < (Relational H)>
7	IF < (Conf is M) and (FMudPar is H) and (CumpAcord is L) > THEN < (Relational M)>
8	IF < (Conf is H) and (FMudPar is M) and (CumpAcord is L) > THEN < (Relational M)>
9	IF < (Conf is M) and (FMudPar is M) and (CumpAcord is L) > THEN < (Relational M)>
10	IF < (Conf is M) and (FMudPar is L) and (CumpAcord is H) > THEN < (Relational M)>
11	IF < (Conf is L) and (FMudPar is M) and (CumpAcord is H) > THEN < (Relational M)>
12	IF < (Conf is M) and (FMudPar is M) and (CumpAcord is H) > THEN < (Relational M)>
13	IF < (Conf is L) and (FMudPar is L) and (CumpAcord is H) > THEN < (Relational L)>
14	IF < (Conf is H) and (FMudPar is L) and (CumpAcord is L) > THEN < (Relational L)>
15	IF < (Conf is L) and (FMudPar is H) and (CumpAcord is L) > THEN < (Relational L)>
16	IF < (Conf is M) and (FMudPar is L) and (CumpAcord is L) > THEN < (Relational L)>
17	IF < (Conf is L) and (FMudPar is M) and (CumpAcord is L) > THEN < (Relational L)>
18	IF < (Conf is L) and (FMudPar is L) and (CumpAcord is L) > THEN < (Relational VL)>

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

Table A.2

General causal mechanism between indicators and institutional environment

Context	Indicators	Limits of institutional environment	
		Worst scenario	Best scenario
	Trust scale	worst rating	best rating
Relational	Frequency of change of business partners	high occurrence	non-occurrence
	Compliance with trade deals	non-occurrence	occurrence

	Quality of infrastructure	worst rating	best rating
Economic	Availability of financial resources	non-occurrence	occurrence
	Access to financial resources	restricted	unrestricted
	Manager's level of education	illiterate	post graduate
Social	Women's participation in management	non-occurrence	occurrence
	Availability of qualified workforce	high impact	non-impact
	Environmental legislation	high impact	non-impact
Local	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.3
Summary of rules used for both FIS.

Relational		Economic		Social		Local	
IF	THEN	IF	THEN	IF	THEN	IF	THEN
H-H-H	VH	VH-H-H	VH	VH-H-H	VH	H-H-H	VH
H-H-L	H	H-H-H	VH	H-H-H	VH	L-H-H	H
L-H-H	H	VH-L-H	H	VH-L-H	H	M-H-H	H
H-L-H	H	VH-H-L	H	VH-H-L	H	H-L-H	H
M-H-H	H	H-L-H	H	H-L-H	H	H-M-H	H
H-M-H	H	H-H-L	H	H-H-L	H	H-H-L	H
M-H-L	M	M-H-H	H	M-H-H	H	H-H-M	H
H-M-L	M	L-H-H	H	L-H-H	H	L-M-M	M
M-M-L	M	VH-L-L	M	VH-L-L	M	L-M-H	M
M-L-H	M	M-L-H	M	M-L-H	M	L-H-M	M
L-M-H	M	M-H-L	M	M-H-L	M	M-L-M	M
M-M-H	M	VL-H-H	M	VL-H-H	M	M-L-H	M
L-L-H	L	H-L-L	L	H-L-L	L	M-M-L	M
H-L-L	L	M-L-L	L	M-L-L	L	M-M-M	M
L-H-L	L	L-L-H	L	L-L-H	L	M-M-H	M
M-L-L	L	L-H-L	L	L-H-L	L	M-H-L	M
L-M-L	L	VL-L-H	L	VL-L-H	L	M-H-M	M

L-L-L	VL	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	18		20		20		27

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

APPENDIX B – Questionnaire applied with tilapia production units

1 Polo/Reservatório: _____

1.1 Município: _____

2 Há quantos anos atua na piscicultura |_____| anos

3 Qual seu sexo? () Masculino () Feminino

4 Qual a sua idade? |_____| anos

5 Qual seu nível de escolaridade?

() Sem Escolaridade

() Ensino fundamental (1º grau) Incompleto

() Ensino fundamental (1º grau) completo

() Ensino médio (2º grau) Incompleto

() Ensino médio (2º grau) completo

() Superior Incompleto

() Superior completo

() Pós graduado(a)

6 Atualmente qual a sua produção anual de **Tilápia**? |_____| Ton

7 Contando com você, qual o número total de pessoas envolvidas na produção? |_____|

8 Algum fator ambiental tem impactado sua produção?

() Sim () Não

8.1 Assinale, qual(is):

() *Seca* () *Baixa qualidade de água* () *Mexilhão dourado* () *Predador* () *Plantas aquáticas*

() *Outro(s)* _____

9 Houve ou há ausência de fornecedores de insumos ou equipamentos no polo?

() Sim () Não

10 Como julga a qualidade das estradas do polo (rodovias e vicinais)?

() Muito Boas

() Boas

() Regulares

() Ruins

() Muito Ruins

11 Ao transportar a tilápia faz uso de?

() Gelo () Caixa de isopor () Caixa isotérmica () Caminhão refrigerado

12 Qual a distância em que estão localizados os principais consumidores finais do seu peixe?

() Até 100 km () 100 a 300 km () 300 a 600 km () mais de 600 km

13 O mercado onde você vende atualmente, absorve toda a sua produção de tilápia?

() Sim () Não

14 Do total da sua produção quanto é vendido para cada tipo de comprador? (caso não venda para algum dos tipos de compradores, deixe ele em branco)

Atravessador ou intermediário: |_____| %

Supermercados: |_____| %

Feirantes e/ou Peixarias: |_____| %

Frigoríficos: |_____| %

Venda direta para consumidor final: |_____| %

15 Qual o preço pago por cada tipo de comprador? (caso não venda para algum dos tipos de compradores, deixe ele em branco)

Atravessador ou intermediário: R\$/kg |_____|

Supermercados: R\$/kg |_____|

Feirantes e/ou Peixarias: R\$/kg |_____|

Frigoríficos: R\$/kg |_____|

Venda direta para consumidor final: R\$/kg |_____|

16 Assinale a frase abaixo que melhor define a relação entre você e seus compradores?

() “Vendo meu peixe sem me preocupar com os meus parceiros pois temos uma relação comercial sólida e de confiança”

() “Por mais que eu os conheça, algumas vezes verifico pessoalmente as negociações para me certificar de que tudo está ocorrendo como deveria”

() “Em todos os negócios que fazemos tenho que sempre me certificar pessoalmente que as coisas estão ocorrendo da forma correta, infelizmente nossa relação de confiança é muito baixa”

17 Quanto às principais dificuldades para alguém que queira instalar uma piscicultura na região? (Julgue a dificuldade, caso não entenda ser uma dificuldade assinalar como 0)

0 - não é uma dificuldade

1 - baixa

2 - média

3- alta

() Alto investimento

() Dificuldade com mão de obra

() Alto custo da terra

() Dificuldade na obtenção de licenças ambientais

() Dificuldade em obter cessão de águas da união

() Insegurança (roubos)

() Risco ambiental (qualidade de água, banzeiro, seca, etc.)

() Acesso à tecnologia

Outros

18 Você troca de compradores com qual frequência?

Frequentemente As vezes Quase nunca

19 Acredita que uma eventual mudança de parceiro gera algum um custo de tempo e/ou dinheiro?

Sim Não Não sei responder

20 Qual seu conhecimento sobre os seguintes elos da cadeia produtiva (exemplo: custos de produção, negociações e tecnologias utilizadas)?

Alevinagem Alto Razoável Baixo

Ração Alto Razoável Baixo

Mercado Alto Razoável Baixo

21 Nos últimos anos, assinale qual(is) tecnologia(s) adotou na sua propriedade (*pode assinalar mais de uma alternativa*)

Policultivo

Recirculação

Bioflocos

Automatização da despesca, classificação ou arraçamento

Software de gerenciamento

Aerador

Vacina

Medicamentos

Pré e probiótico

Linhagem melhorada geneticamente

Outros(as) | _____ |

21.1 Se não adotou alguns dessas tecnologias, pretende pôr algum(s) em prática nos próximos anos?

Sim Não

22 Qual(is) atividade(s) que eram de outras pessoas e que você passou a realizar por conta própria? (*pode assinalar mais de uma alternativa*)

Fabricação de ração

Alevinagem

Processamento do pescado

Venda no atacado ou varejo

Transporte

Gelo

Outras | _____ |

22.1 Se não adotou essas atividades, pretende pôr em prática alguma(s) nos próximos anos?

Sim Não

23 Comprou alguma máquina ou equipamento utilizados na atividade nos últimos 5 anos?

Sim Não

23.1 Se não comprou, pretende fazer compras desse tipo nos próximos 5 anos?

Sim Não

24 Para você, o acesso e entendimento das leis e normas relacionadas à piscicultura é?

Difícil Razoável Fácil

25 Caso necessite de financiamento para a piscicultura, existe na região disponibilidade de recursos financeiros via bancos, agência de fomento, cooperativas de crédito, etc?

Sim Não Não sei responder

26 Ainda em relação a esses recursos financeiros, falta alguma documentação da propriedade e/ou da produção que dificultaria ou impediria o seu acesso a um financiamento?

Sim Não Não sei responder

27. Encontra dificuldade ao comercializar sua produção?

Sim Não

27.1 Qual(is) a sua(s) principal(is) dificuldade(s) na comercialização?

Preço baixo Falta de comprador Calote Falta de processamento
 Pouco volume Outros _____

28 Acredita que a ação conjunta das instituições (ensino, pesquisa, assistência técnica, fomento, associações, sindicatos, etc.) pode impulsionar mudanças e alavancar o crescimento no polo?

Sim Não Talvez

29 Espaço para comentários adicionais

APPENDIX C - Tables of Article 3

Dimension	Indicators	Limits of business environment	
		Worst scenario	Best scenario
Input–output (IO)	Work productivity (IO ₁)	-	+
	Processing capacity (IO ₂)	-	+
	Inputs and equipment network (IO ₃)	-	+
	Availability of inputs and equipment (IO ₄)	occurrence	non-occurrence
	Natural resources (IO ₅)	+	non-occurrence
	Logistic infrastructure (IO ₆)	worst rating	best rating
	Form of transport of the product (IO ₇)	worst rating	best rating
	Absorption of production (IO ₈)	non-occurrence	occurrence
	Gross margin (IO ₉)	-	+
	Commercial barriers (IO ₁₀)	+	non-occurrence
Governance (G)	Trust scale (G ₁)	worst rating	best rating
	Barriers to entry (G ₂)	high impact	non-impact
	Frequency of change of business partners (G ₃)	+	-
	Compliance with trade deals (G ₄)	non-occurrence	occurrence
Upgrading (U)	Technological improvement (U ₁)	-	+
	Acquisition of papers in chain (U ₂)	-	+
	Purchase of machinery and/or equipment (U ₃)	non-occurrence	occurrence
	Future upgrading expectations (U ₄)	have no expectations	all expectations
	Technological level (U ₅)	-	+
Institutional (I)	Economic incentives (I ₁)	non-existent	exists
	Availability of financial resources (I ₂)	non-occurrence	occurrence
	Access to financial resources (I ₃)	restricted	unrestricted

Public technical assistance (I ₄)	non-existent	exists
Availability of qualified workforce (I ₅)	high impact	non-impact

Table C.1. General causal mechanism between indicators and business environment. Note: - designates an inverse relationship between the magnitude of the indicator and the business environment. + designates a direct relationship between the magnitude of the indicator and the business environment

Rules	If							Then
	Input-output	op	Gorvenance	op	Upgrading	op	Intitutional	Bussines Environment
1	Low	AND	Low	AND	Low	AND	Low	Very Low
2	Low	AND	Low	AND	Low	AND	Medium	Very Low
3	Low	AND	Low	AND	Low	AND	High	Low
4	Low	AND	Low	AND	Medium	AND	Low	Very Low
5	Low	AND	Low	AND	Medium	AND	Medium	Low
6	Low	AND	Low	AND	Medium	AND	High	Low
7	Low	AND	Low	AND	High	AND	Low	Low
8	Low	AND	Low	AND	High	AND	Medium	Low
9	Low	AND	Low	AND	High	AND	High	Medium
10	Low	AND	Medium	AND	Low	AND	Low	Very Low
11	Low	AND	Medium	AND	Low	AND	Medium	Low
12	Low	AND	Medium	AND	Low	AND	High	Low
13	Low	AND	Medium	AND	Medium	AND	Low	Low
14	Low	AND	Medium	AND	Medium	AND	Medium	Medium
15	Low	AND	Medium	AND	Medium	AND	High	Medium
16	Low	AND	Medium	AND	High	AND	Low	Low
17	Low	AND	Medium	AND	High	AND	Medium	Medium
18	Low	AND	Medium	AND	High	AND	High	Medium
19	Low	AND	High	AND	Low	AND	Low	Low
20	Low	AND	High	AND	Low	AND	Medium	Low
21	Low	AND	High	AND	Low	AND	High	Medium
22	Low	AND	High	AND	Medium	AND	Low	Low
23	Low	AND	High	AND	Medium	AND	Medium	Medium
24	Low	AND	High	AND	Medium	AND	High	Medium
25	Low	AND	High	AND	High	AND	Low	Medium
26	Low	AND	High	AND	High	AND	Medium	Medium
27	Low	AND	High	AND	High	AND	High	High
28	Medium	AND	Low	AND	Low	AND	Low	Very Low
29	Medium	AND	Low	AND	Low	AND	Medium	Low
30	Medium	AND	Low	AND	Low	AND	High	Low
31	Medium	AND	Low	AND	Medium	AND	Low	Low
32	Medium	AND	Low	AND	Medium	AND	Medium	Medium
33	Medium	AND	Low	AND	Medium	AND	High	Medium
34	Medium	AND	Low	AND	High	AND	Low	Low
35	Medium	AND	Low	AND	High	AND	Medium	Medium
36	Medium	AND	Low	AND	High	AND	High	High
37	Medium	AND	Medium	AND	Low	AND	Low	Medium
38	Medium	AND	Medium	AND	Low	AND	Medium	Medium
39	Medium	AND	Medium	AND	Low	AND	High	Medium
40	Medium	AND	Medium	AND	Medium	AND	Low	Medium
41	Medium	AND	Medium	AND	Medium	AND	Medium	Medium
42	Medium	AND	Medium	AND	Medium	AND	High	Medium

43	Medium	AND	Medium	AND	High	AND	Low	Medium
44	Medium	AND	Medium	AND	High	AND	Medium	Medium
45	Medium	AND	Medium	AND	High	AND	High	High
46	Medium	AND	High	AND	Low	AND	Low	Low
47	Medium	AND	High	AND	Low	AND	Medium	Medium
48	Medium	AND	High	AND	Low	AND	High	Medium
49	Medium	AND	High	AND	Medium	AND	Low	Medium
50	Medium	AND	High	AND	Medium	AND	Medium	High
51	Medium	AND	High	AND	Medium	AND	High	High
52	Medium	AND	High	AND	High	AND	Low	Medium
53	Medium	AND	High	AND	High	AND	Medium	High
54	Medium	AND	High	AND	High	AND	High	Very High
55	High	AND	Low	AND	Low	AND	Low	Low
56	High	AND	Low	AND	Low	AND	Medium	Low
57	High	AND	Low	AND	Low	AND	High	Medium
58	High	AND	Low	AND	Medium	AND	Low	Low
59	High	AND	Low	AND	Medium	AND	Medium	Medium
60	High	AND	Low	AND	Medium	AND	High	High
61	High	AND	Low	AND	High	AND	Low	Medium
62	High	AND	Low	AND	High	AND	Medium	Medium
63	High	AND	Low	AND	High	AND	High	High
64	High	AND	Medium	AND	Low	AND	Low	Low
65	High	AND	Medium	AND	Low	AND	Medium	Medium
66	High	AND	Medium	AND	Low	AND	High	High
67	High	AND	Medium	AND	Medium	AND	Low	Medium
68	High	AND	Medium	AND	Medium	AND	Medium	Medium
69	High	AND	Medium	AND	Medium	AND	High	High
70	High	AND	Medium	AND	High	AND	Low	Medium
71	High	AND	Medium	AND	High	AND	Medium	Medium
72	High	AND	Medium	AND	High	AND	High	Very High
73	High	AND	High	AND	Low	AND	Low	Medium
74	High	AND	High	AND	Low	AND	Medium	Medium
75	High	AND	High	AND	Low	AND	High	Medium
76	High	AND	High	AND	Medium	AND	Low	Medium
77	High	AND	High	AND	Medium	AND	Medium	High
78	High	AND	High	AND	Medium	AND	High	Very High
79	High	AND	High	AND	High	AND	Low	High
80	High	AND	High	AND	High	AND	Medium	Very High
81	High	AND	High	AND	High	AND	High	Very High

Table C.2. Inference rules for Bussines Environment Fuzzy Index