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Role of freshwater fish aquaculture on the food security of Latin America and Caribbean region

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List of abbreviations

ACF	Auto- and Cross- Covariance and -Correlation_Function
ADF	Augmented Dickey Fuller Test
AqP in LAC FwP	Aquaculture Production in LAC Freshwater fish Production
CAISAN	Interministerial Chamber of Food Security and Nutrition
EECA	East Europe and Central Asia
FAO	Food and Agriculture Organization
FwAqP in LAC FP	Freshwater fish Aquaculture Production in LAC Fish Production
FwE in LAC TFfE	Freshwater fish Exports in Total LAC Fish Food Exports
FwI in LAC TFfI	Freshwater fish Imports in Total LAC Fish Food Imports
FwP in_LAC FfP	Freshwater fish Production in LAC Fish Food Production
INCOPESCA	Costa Rican Institute of Fish and Aquaculture
IRF	Impulse Response Function
LAC	Latin American and Caribbean
MAPA	Ministry of Agriculture, Livestock and Supply
MENA	Middle East and North Africa
OSPESCA	Organization of fishing and aquaculture sector of Central America
PHR LAC	Poverty Headcount Ratio in Latin America and Caribbean
PoU LAC	Prevalence of Undernourishment in Latin America and Caribbean
SADER	Secretary of Agriculture and Rural Development
SEGALMEX	Mexican Food Security
SEPSA	Executive Secretary of Agricultural planning
SESAN	Secretary of Food and Nutritional Security
SICA	Integration system of Central America
STP	Technical Unit of Planning
UTSAN	Technical Unit for Food Security and Nutrition

VAR	Vectors Auto Regressive
WFP	World Food Program
WTO	World Trade Organization

1. INTRODUCTION

Fish production has been the fastest growing food industry in the world for the last 40 years, and is expected to remain so in the near future, contributing to the food security of more than 10% of the world population (Béné et al., 2015), In fact, the world fish supply has effectively been growing faster than the world's population (FAO, 2012b), and its environmental impact is low, considering that the carbon footprint of this source of animal protein is lower compared to other animal production systems (Béné et al., 2015). Furthermore, fish in aquaculture systems are very efficient converters of feed into high-quality food; for instance, poultry converts about 18% of their consumed food and pigs about 13 %, whereas is around 30 % in the case of fish; on the other side, the production of 1 kg of beef protein requires 61.1 kg of grain, on its side the production of 1 kg of pork protein requires 38 kg of grain, while fish only requires 13.5 kg (Hasan & Halwart, 2009).

The most significant change in the global fish production during the previous four decades has been the growth of aquaculture; as the world demand of freshwater and marine foods (seafood) rose, the production farmed increased (Gephart et al., 2020), and recently is recognized the aquaculture potential to be more competitive and eventually replace some of the capture fisheries supplies (Bostock et al., 2016).

Aquaculture encompasses a range of species, cultivation methods, and processing standards, resulting in diverse social, economic, nutritional, feed composition, and environmental outcomes (Bostock et al., 2016; Gephart et al., 2020); for decades has been the world's fastest growing food production industry (Roubach et al., 2015; Tveterås et al., 2012). It is projected to remain the fastest growing food commodity sector, and soon become even more central in the future food security of the world population (Béné et al., 2015). The largest expansion of aquaculture to 2030 is expected in India, Latin America and Caribbean, and Southeast Asia (Kobayashi et al., 2015).

Poverty reduction strategies are strongly connected with food security management, and aquaculture became a potential solution for cheaply and easily providing animal source foods to poor and food-insecure populations around the world (Kobayashi et al., 2015). It supplies half of the fish consumed by humans (Golden et al., 2017), and has contributed to the reduction of poverty directly, and indirectly by providing food, income, and employment for producers and other value chain actor households, increasing food security, rural economic, social development, diversification toward niche markets, and local food production (Béné et al., 2016; Burns et al., 2014; Valenti et al., 2018). However, international food security experts and decision-makers seem unaware of the potential that fish can play in the fight against malnutrition (Béné et al., 2015).

Seafood is considered a sustainable animal-source food and is acknowledged as a major nutrient-dense animal source food for a significant proportion of the nutritionally vulnerable people (Béné et al., 2016). Nevertheless, the geography of fish as a source of protein is also significant in the food security and nutrition discussion, almost three quarter of the countries where fish is an important source of animal protein are poor and food-deficient (Béné et al., 2015) .

With 11.6 million tons harvested from freshwater capture fisheries, and 51.4 million tons from freshwater aquaculture in the world, freshwater ecosystems are important sources of food fish, and have accounted for about 40% of all fish destined for human consumption, with growth rates higher than other food producing sectors. At the beginning of the millennium, the freshwater's share was 57% of the global aquaculture production, and by 2019 its production represented 61.2% of the aquaculture sector in the world (FAO, 2023).

In Latin America and Caribbean, the aquaculture development has been quite different from other regions, since the marine production still dominated the sector with 41.9%, by 2019, followed by freshwater aquaculture with 27.4%, according to data from FishStat J (FAO, 2023). Nevertheless, freshwater production gained importance due to its social and economic benefits. The contribution of aquaculture to the economy of the region has grown substantially in the last 10 years. It provides employment to more than 200,000 people directly and approximately 500,000 indirectly. More than 100,000 rural families in the region depend directly or indirectly on aquaculture for their livelihood, including food for private consumption (FAO, 2021b).

On the other hand, it is important to consider that the increase of freshwater production in a sustainable way will be a major challenge for aquaculture (Perschbacher, 2017), since it has been found that factors such as land area, population increase, market demand, and renewable freshwater have associations with freshwater aquaculture production at countries level (Boyd et al., 2012).

Freshwater aquaculture is concentrated in Asia, which accounts for 89% of farmed aquatic supply (FAO, 2020). However, Latin America's freshwater aquaculture sector registered a growth, which is remarkable even in global comparison, as can be observed in Figure 1. The growth of this sector in the region was even higher than in Asia, since 2000 (FAO, 2023); its annual production grew approximately 20%: from 186,000 tons in 1990 to 1.3 million tons in 2016 (FAO, 2021b). Between the period 2007-2009 and 2017-2019 Latin-American production grew by 95% (FAO, 2023).

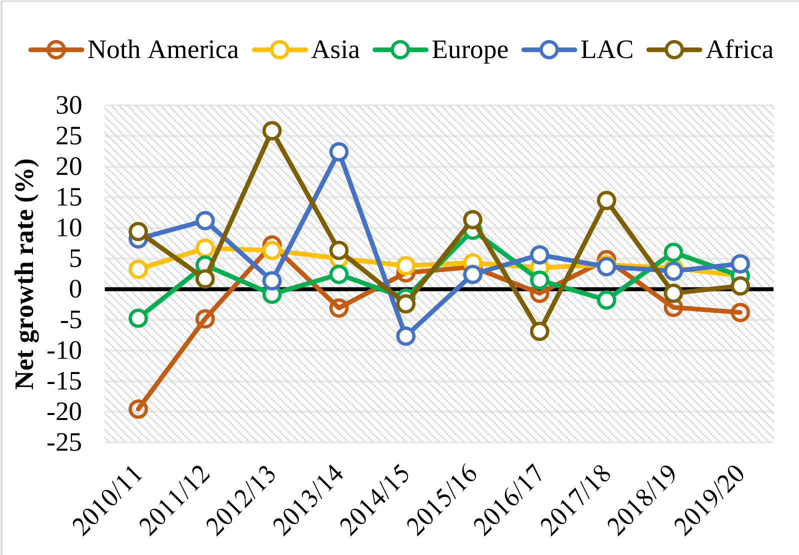


Figure 1. Growth rate of freshwater aquaculture production from 2010 to 2020

Source: elaborated by the author from statistical data of FishStat J. (FAO, 2023).

The exponential rise of the freshwater aquaculture production in the LAC, in the last ten years, focused on the fish farming increasing of Tilapia, Cachama, and Rainbow Trout, reducing the production of species such as Cyprinidis, Pacu, and Silver Carp. The dominance of the species is influenced by aspects like cost, volume, marketability, easy reproduction, fast growth and hardiness (Neori & Nobre, 2012); since these low trophic-level species are more profitable, even though their revenue per kg is low, due to their low production cost and the large demand (Knowler et al., 2020), and examining this dynamic of production can be seen that Latin American aquaculture is moving towards species concentration; the share of Tilapia in total production has increased from 51 % to 58% in the last ten years (FAO, 2023).

The share of aquaculture in the freshwater fish production of the region has passed from 35.83% at the beginning of the century to 65.60 % by 2021 (FAO, 2023). Nonetheless, most of the aquaculture production in LAC is for export markets, with industrial-scale production of only a few species (Wurmann et al., 2022). By 2021, 37.95% of the total fish food exported by LAC were freshwater fish commodities.

The region is trying to diversify its aquaculture production, considering that has been the largest fish exporter region (World Bank, 2013), particularly with promising native species in response to strong domestic demand (Wurmann et al., 2022). However, the operations still focus on traditional production systems; technological limitations are still hampering further growth throughout the region and the development of new production systems will still require 5 to 15 years or more (Wurmann et al., 2022).

In terms of fish consumption, during the last 50 years, the annual growth average rate of total food fish consumption (3.1%) outpaced all other animal proteins, except poultry (Wurmann et al., 2022). Fish (combining capture fisheries and aquaculture) has been the main contributor to the 61% increase of per capita consumption of animal protein in the world, for the period 1969–2009; regarding animal protein availability, with 18.2 kg per capita per year, fish is providing 115% more protein per capita than pig, 133 % more than poultry, and 189% more than beef (Béné et al., 2015).

Some refer to this growth trend of fish consumption because of fish prices have been less volatile than terrestrial food prices and becoming more competitive (Tveterås et al., 2012). Literature estimates that the per capita fish consumption will remain at around 18 kg per year in 2030 (Béné et al., 2015); however, fish consumption is influenced by other factors such as regional demographic characteristics, availability, climate, market penetration, transportation, and infrastructure (Wurmann et al., 2022). It is important to highlight that more than half of countries had mean intakes of two or more servings seafood per week, by 2018; however, seafood intake remained low in many South Asian, Latin American and Caribbean, and Middle Eastern and North African countries (Miller et al., 2022).

The LAC region had the lowest average annual per capita fish consumption rate in the world despite areas where fish consumption rates are relatively high such as the Amazon, some of the Caribbean islands, Guyana, coastal of Peru and Chile, most countries in the LAC region prefer meat such as beef, pork, and chicken to fish. Nevertheless, in the latest decades America was identified in the fourth position of per capita fish consumption, just ahead of Africa; the consumption has slightly grown from around 15 kg/person/year (2010-2012) to 17 kg/person/year (2020/22) (OECD/FAO, 2023).

The freshwater aquaculture production of LAC experienced considerable growth with several emerging species (Valenti et al., 2021), as well as the fish consumption per capita has been increasing, in 2017 was 10.5 kg/year with 6.7 million tons live weight equivalent (Wurmann et al., 2022).

Per capita fish consumption in Latin America has been increasing faster than the large traditional markets, at 1.3 %, but the region started from a lower base, therefore LAC still has the lowest per capita seafood consumption in the world. Wurmann G., (2017) predicts that total fish consumption will grow by 18 % in the current decade and 33% in the LAC region by 2030. This would represent the highest regional per capita growth rate in the world and will need to be largely fueled by the increasing availability of aquaculture products (Wurmann et al., 2022), since by 2018 the LAC's per capita fish availability was 9kg, far from its per capita meat availability of 61.1 kg (OECD & FAO, 2021).

Regarding the contribution of the freshwater aquaculture sector to the food security of the region, the economic and social significance has increased in at least the top five aquaculture producing countries in South America, and it is expected that its importance will keep growing. Countries with less developed aquaculture industries still need to demonstrate that this activity will have a meaningful impact on their development while improving food security (Wurmann et al., 2022).

Latin America and Caribbean region has been facing challenges in the management of food security; despite the strategies and prevention efforts was identified that LAC countries decrease in food security (from 51% to 43%) and increased in moderate (13% to 16%) and severe (14% to 19%) food insecurity (Nugroho et al., 2022; Rezende Machado de Sousa et al., 2019), reflecting that, during the last twenty years, the region has not executed medium- and long-term operative programs (Smith et al., 2017).

In the analysis of the undernourishment in 14 Latin American countries by Nugroho et al. (2022), was found that despite the food production index increase, this did not carry to a reduction in the number of undernourished people in the region, since there are factors as physical and economic food access, population increase, food production losses, infrastructure, and consumer behavior; besides it was identified that the increased food production of the region is used to fulfil global food and biofuel market demands (Dyson, 1999). Biofuel and renewable resource policies have boosted the global trade of products as maize, sugarcane, and oil crops (Rosegrant et al., 2013).

This tendency has been reflected in the main agricultural commodities exported by Latin American countries such as Brazil and Argentina, led by soya beans, soya beans oil, and corn; and in Colombia with sugar cane and the rise of the palm oil sector (Growth Lab, 2022). Cubillos et al., (2021) showed how the palm oil commodities gained participation in the Colombian's agriculture export in the last decade, increasing its exports participation from 3% in 2011 to 12.2% in 2019, specifically toward the European market, despite that palm oil prices decreased during that period. The export volume of palm oil in 2018 was 252% higher than in 2011, growing faster, even than traditional agriculture products such as bananas and coffee, and carrying to the reduction of diversification of agriculture products exported.

The decrease of export diversification presented in the region did not affect its freshwater aquaculture production, and in spite of fish does not appear as a main export agriculture commodity in the Latin America countries, the region has been keeping the tendency of fish exporter, with countries as Chile, Ecuador, Colombia, Honduras, Costa Rica, Perú and Panamá, on which predominate production for exports (Sosa-Villalobos et al., 2016).

On the other hand, the study of Nugroho et al., (2022) found that the imports dependency ratio became an important element in the reduction of undernourishment in Latin America, the countries become more reliant on external food sources because of consumption patterns and price volatility, highlighting cereal as the primary source of calories in the region (FAO, 2017). This overview reflects the need for inclusion, in the analysis and the design of food security programs, components such a social-economic indicators and international food trade, this last one affects food security directly through the impact on food availability, and indirectly through the effects on food accessibility and stability (Magrini et al., 2014). Trade and trade policies influence the profits of food producers and the food costs for consumers, affecting world and domestic food prices (Magrini et al., 2014).

Significance of the study

LAC is the largest fishmeal producing region in the world, accounting for about 40 % of world's fishmeal supply, considering that, globally, less than 20% of total fish produced is currently used for fishmeal; World Bank (2013) projected fishmeal production of Latin America in 2030 will be slightly more than that of all of Asia. Fish not consumed as food is processed into fishmeal or other non-food use, such as pharmaceutical input, feed of aquaculture, livestock or other animals (OECD/FAO, 2023).

The aquaculture sector in LAC has been analyzed mainly at global level, even together with capture fisheries sector, limiting the information specifically on the aquaculture development, impacts, and its contribution to the regional food security; as consequence, there is scarce acknowledgment on the specific role of aquaculture sectors, such as freshwater aquaculture, narrowing its consideration by the policy makers in the design food security policies (Burns et al., 2014).

Being the freshwater fish aquaculture a nascent activity to produce fish commodities and food, at the moment there is a lack of knowledge and recognition of the social and economic contribution of this sector to the region development; it has impeded the integration of this, and the whole fishing sector, in the national food security and nutritional policies and programs. Being fish more included in countries' nutritional programs focusing on tackling micronutrient deficiencies (Béné et al., 2015). The absence of nutrition policy focus on fisheries and aquaculture represents an untapped opportunity to ensuring sustainable healthy diets (Thilsted et al., 2016).

The aim of this research is to provide wide details of the freshwater fish aquaculture contribution to the food availability and food access in LAC, analyzing it from economics aspects as international trade, fish price, and the role of fish as animal protein source in the region. The last main component of this analysis was the integration of the sector in national policies, considering that policies have the capability to cover sustainable aquaculture development, benefitting all scales of production, and stimulating better interaction (Wurmann et al., 2022). Thus, the social and economic analysis of the freshwater fish aquaculture developed in this thesis involves the identification of the integration level of this economic sector in the food security policy of the region's countries.

Regarding food security, studies have analyzed the influence and consequence of economic indicators such as poverty (Allee et al., 2021; Iddrisu & Alagidede, 2020), food inflation (Fujii, 2013; Monsivais et al., 2010; Rodriguez-Takeuchi & Imai, 2013), and food balance (Arsenault et al., 2015; Liu et al., 2019), however the impacts of macroeconomic fluctuations on food insecurity have remained scantily explored (Erokhin & Gao, 2020), which was considered to evaluate in this research.

The results of this thesis provide data and statistics of the fish commodities and freshwater fish aquaculture relevance in LAC, the fish sector particularities to contribute to the food security and poverty reduction of the region. The study is done through analysis of indicators as production share, fish balance trade, and prices tendencies, considering other animal protein of the region (bovine, swine, poultry, and goat), and assessing the influence of an external factor (crude oil prices) on the fish and other animal protein prices, as element of the food access in LAC.

For the animal protein prices analysis, is proposed a methodology with cointegration and causality methods, extending the scope of the assessment to two (2) more developing regions Middle East and North Africa (MENA), and East Europe and Central Asia (EECA). This provided better understanding of the fish role and prices tendencies.

At last, the aspects tackled in this study supports the closure of research gaps identified in the building of theoretical framework, for instance:

1) Scarce knowledge of the aquaculture sector's role in the regional economy and food and nutritional security.
2) The absence of measure and articulation of poverty in aquaculture studies.
3) Studies on aquaculture and food security mainly developed at a global level.

2. OBJECTIVES OF THE THESIS

The research was structured for the achievement of one (1) main objective through the development of three (3) stages, defined as specific objectives, which provided inputs to establish the freshwater fish aquaculture status and elements of the sector's development on the food availability and food access of the region. In order to determine the role of the freshwater aquaculture sector, as an animal protein source, provide details on integration level of relevant public policies, driver forces of the sector, and the influence of macroeconomic factors on fish commodities projections.

Main objective

Determine the contribution of the fish sector and freshwater fish aquaculture to the food security, economic development, and poverty reduction of the Latin America and Caribbean region.

Specific objectives

1) To identify the role of freshwater aquaculture sector, as animal protein source, in the food availability and food access of LAC, and its integration level with the food security policies of the top 10 largest producer countries of LAC.
2) Determine the most influential drivers forces associated to the freshwater fish aquaculture development in LAC, that support poverty alleviation and food security of the region, during 2000-2019.
3) To establish the emerging role of fish products as an animal protein source in LAC by 2030.

Hypotheses

The hypotheses considered for each of specific objectives are based on the scope, methods, and the statistical analysis performed in each objective.

Specific objective 1: **Policy integration:**

- Hypothesis 1 (H_1): The development of freshwater fish aquaculture in LAC has been supported with the integration of fishing and aquaculture sector on the Food Security national policies.

Specific objective 2: **Multiple regression model for Prevalence of undernourishment**

- Hypothesis 2 (H_2): Share of aquaculture production in LAC freshwater fish production is the fish driver force that most impacts the reduction of undernourishment.
- Hypothesis 3 (H_3): Share of freshwater fish production in the food balance trade of LAC influence positively on the prevalence of undernourishment.

Multiple regression model for poverty headcount ratio

- Hypothesis 4 (H_4): Share of aquaculture production in LAC freshwater fish production is the fish driver force that most impacts the reduction of poverty headcount ratio.
- Hypothesis 5 (H_5): Share of freshwater fish production in the food balance trade of LAC influence positively on the poverty indicator.

Specific objective 3: **Co-integration - Phillips and Ouliaris Unit Root**

- Hypothesis 6 (H_6): Oil prices have long-run influence on animal protein prices.

Granger Causality

- Hypothesis 7 (H_7): Oil prices have short -term influence on animal protein prices.

Instantaneous Causality:

- Hypothesis 8 (H_8): There is instantaneous causality of oil prices on the animal protein prices.

3. LITERATURE REVIEW

3.1. Background of the food security approach

Food security emerged during the world food crisis of 1974, as a right to not be undernourished. Neoliberal policies and technocratic conceptions of economic growth and free trade influenced this concept as a development goal (R. Merino, 2020). Since then, the definition of food security evolved from a focus by economists on national availability of staple food, with seasonal dimension, it became to consider socio-economic disparities influence on guarantee freedom from hunger (FAO, 2015). By the 1990s the perception of food security had expanded to include not only the access to affordable and nutritious food, but affirmed cultural food preferences as a basic human right (Ríos García et al., 2015). It enables humans to have physical, economic, and socially acceptable access to a safe and nutritious diet (IICA, 2009).

Food security gradually and consistently enlarged to involve not only the food availability and food production (sufficient, safe and nutritious food) but also its expansion to ensure explicitly and accessibility (physical and economic access) to food, simultaneously; integrating stability (food supplied for all people all times) and utilization (use of food, providing energy and essential nutrients) (Al Jaafreh O. & Nagy I., 2020; Sassi, 2018). The food security approach "prioritizes trade-oriented goods, imports, and intensive agriculture while promoting poverty-alleviation policies" (R. Merino, 2020).

A food system is made up of the environment, people, institutions, policies, and processes through which food is produced, processed, and brought to the consumer (Hundertwasser, 2013), and those who create and enforce food safety regulations need to understand each other's perspectives better (Martin & Perkin, 2016). Developing food supply chains in agriculture could be one of the keys for higher value-added activities and income of the participants along the chains (Ron Vaskó et al., 2022).

Adequate management and response to food problems need a contextualized analysis including causal interdependencies, information on climatic aspects, but also on agricultural and socioeconomic indicators (FAO, 2012a), which can be useful in the decision-making process of the stakeholders involved. To ensure the countries' food security, there were strategies such as the stability of prices for necessities, increasing national food production based on smallholder agriculture, and supporting small farmers with seed assistance, labor-intensive programs (Darma & Darma, 2020), equipping and infrastructure in rural areas (Smith et al., 2017), predictable trading systems, by making the international food system more efficient, and trade policies on export and import restrictions (Matthews, 2014).

International trade affects food security directly, through the impact on food availability, and indirectly through the effects on food accessibility and stability (Magrini et al., 2014). Literature on economic development and policy studies has focused on evaluating specific outcomes from food security policies, nevertheless, is necessary a wider perspective since macroeconomic factors, such as poverty, unemployment and balance trade, play a strong role in the improvement of food security (Smith et al., 2017). Trade and trade policies influence the profits of food producers and the food costs for consumers, mainly because of their effect on the world and domestic food prices (Magrini et al., 2014). The dynamics of food security were not dependent only on the food balance sheets, but on the ability of countries to maintain food consumption through domestic food production, and financing food imports (Vasa et al., 2020).

3.2. Bibliometric analysis

Considering the wide literature available on the topics of food security, nutrition, aquaculture, and the other fields and approaches connected with this research, it was developed a bibliometric analysis, to assess the scientific production through performing analysis and science mapping, identifying the most important themes associated, the evolution of scientific production, most relevant sources, authors and documents. It was performed co-words (co-occurrence) and citation analysis. This last one reflects intellectual linkages between publications, it enables the most influential publications in a research field to be ascertained, while co-words can be used to forecast future research direction in the field, it is suitable to predict forthcoming trajectories (Donthu et al., 2021).

This bibliometric analysis was done with Bibliometrix R package through the Biblioshiny application, and the visualization for the network analysis was complemented with the software VOS viewer. The database to extract the literature was Web of Science, with selected keywords from a systematic literature review and own studies of the food security and freshwater aquaculture, thus, the search criteria used the following structure: ((freshwater aquaculture OR aquaculture OR fisheries) AND (food security OR nutrition security) AND (management OR impact OR trade OR market behavior OR consumption OR undernourishment OR economy OR sustainability)).

The literature collected has a timespan from 2000 to 2022, and it is formed by 1590 documents, from which 1271 are articles and the rest are among reviews, book chapters, and proceeding papers. Regarding authors, the average per document is 3.92, co-authors per document is 5.43, and the collaboration index is 4.18.

The documents came from 469 sources (journals, books, etc.), led by marine policy (175 articles), followed by fish and fisheries (49), frontiers in marine science (47), sustainability (46), fisheries research (40), aquaculture (36), Plos One (35) and ecology and society (22). For the H index that measures productivity and citation impact of the publications, the main journals are Marine policy, fish and fisheries, Plos one, and aquaculture.

In the evolution of scientific production was identified an exponential and constant growth of studies and publication on these themes since 2008, when the publications associated were 5 to 2021 with 279 articles (annual growth rate: 22.11%), this let identify the increased interest and global relevance of these fields.

3.2.1. Citation analysis

It was identified that the most influential authors are connected mainly to institutes in United States, United Kingdom, Australia, Canada, and China, which are the main producers of publications on food security, aquaculture, and fisheries. Brazil is the only country in Latin America located in the top 15 of scientific production in these fields. However, regarding citations Colombia appears in position 9 as the most cited country from Latin America (664 quotes), followed by Brazil (602 quotes).

The analysis of authors considers four indicators to identify their influence, the number of publications, times cited, year of first publication, and H index. The H index is based on the set of the scientist’s most cited papers and the number of citations that they have received in other publications (Aria & Cuccurullo, 2017).

Table 1 presents the 18 most relevant authors in the fields searched, where stand out Allison EH, Sumaila UR, Pauly D, Cheung WWL, Thilsted SH with more than 20 publications, who can be considered experts in addressing fish consumption, malnutrition, food security and fisheries management.

Table 1. Impact of the most relevant authors in the research field

	Authors	number of publications	Times Cited	H index	First publication
1	ALLISON EH	29	2733	22	2007
2	SUMAILA UR	28	884	16	2004
3	PAULY D	24	2083	18	2005
4	CHEUNG WWL	21	1138	13	2012
5	THILSTED SH	21	1049	13	2013
6	BELTON B	19	863	15	2010
7	ZELLER D	19	846	12	2012
8	LITTLE DC	18	786	14	2010
9	COOKE SJ	17	537	11	2011
10	COWX IG	15	513	10	2011
11	HOBDAY AJ	15	923	11	2013
12	BENE C	14	1346	12	2007
13	BELL JD	13	835	10	2009
14	COHEN PJ	13	278	6	2012
15	GEPHART JA	13	237	7	2014
16	TROELL M	13	953	11	2013
17	ANDREW NL	12	1288	9	2007
18	FULTON EA	12	808	10	2011

Source: Biblioshiny – Bibliometrix R tool based on methods from Aria & Cuccurullo (2017)

Nevertheless, it is important to highlight authors with less publications such as Hobday AJ, Bene C, and Andrew NL have a strong impact in terms of citations, which are higher than other authors. These authors tackle topics on fish consumption (Béné et al., 2015), food security and nutrition (Béné et al., 2016), which are important to consider in the literature of this research.

About the time of authors' production can be observed that the most influenced authors have publications in these fields of no more than 15 years, being updated analysis and studies as can be observed in Figure 2 their scientific production started to increase in the recent years.

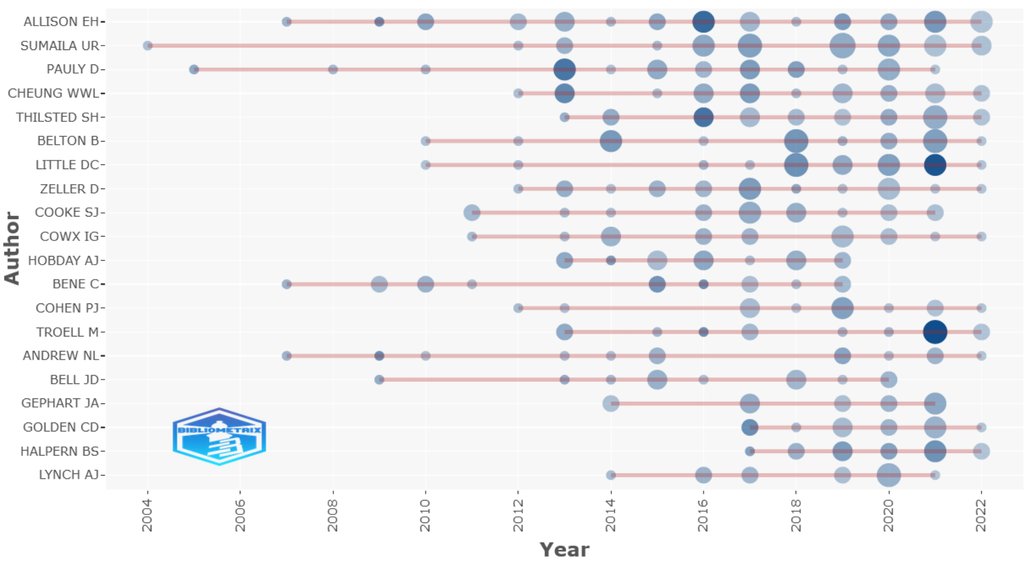


Figure 2. Author's scientific production over the time

Source: Biblioshiny – Bibliometrix R tool based on methods from Aria & Cuccurullo (2017)

The 10 most influential publications on the fields from 2000 to 2022, regarding local citations, are studies that gather capture fisheries and aquaculture's contribution to food security, nutrition, households (Kawarazuka & Béné, 2010) and national economies (Belton & Thilsted, 2014; Béné et al., 2016; Thilsted et al., 2016); besides challenges on the aquaculture rise (Beveridge et al., 2013), crops and animals' protein production to feed the global population (Béné et al., 2015; Charles et al., 2010), and climate vulnerability assessment of fish exports countries (coast and inland landing fisheries) (Allison et al., 2009). Among the stand-out publications, there are articles that only concentrated the analysis on marine fisheries as well, regarding physical access to fish for food, consumption (Bell et al., 2009), and role in marine fisheries management (Harper et al., 2013).

On one side, these publications do not have a specific analysis of freshwater aquaculture or the aquaculture sector; and on the other side, most of the studies tackle the fisheries field on a global level, not a deep assessment of regions.

Table 2. The 10 most relevant publications in the food security and fisheries field

Journal	Title	Authors	Year	Local Citations	Global Citations
World Development	Contribution of Fisheries and Aquaculture to Food Security and Poverty Reduction: Assessing the Current Evidence	C. Béné et al.	2016	141	324
Marine Policy	Planning the use of fish for food security in the Pacific	J. D. Bell et al.	2009	127	285
Science	Food Security: The Challenge of Feeding 9 Billion People	H. Charles et al.	2010	101	5580
Fish And Fisheries	Vulnerability of national economies to the impacts of climate change on fisheries	E. H. Allison et al.	2009	94	656
Springer- Food Secur.	Feeding 9 billion by 2050 – Putting fish back on the menu	C. Béné et al.	2015	92	320
Food Policy	Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era	S. H. Thilsted et al.	2016	72	150
Springer – Food Secur.	Linking small-scale fisheries and aquaculture to household nutritional security: an overview	N. Kawarazuka and C. Béné	2010	70	129
Fish Biology	Meeting the food and nutrition needs of the poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculture	M. C. M. Beveridge et al.	2013	59	172
Marine Policy	Women and fisheries: Contribution to food security and local economies	S. Harper, et al.	2013	58	146
Global Food Security	Fisheries in transition: Food and nutrition security implications for the global South	B. Belton and S. H. Thilsted	2014	58	121

Source: adapted by the author from results of Biblioshiny – Bibliometrix R tool based on methods from Aria & Cuccurullo (2017).

As can be seen in the previous Table 2, the influential publications do not present a concentration on journals, since the 10 articles are related to 8 journals; all of them are from a near period, the oldest document is from 2009; and it is highlighted the expert authors Christophe Béné, and Edward H. Allison, who participated, each of them, in 3 of the most relevant publications. In relation to Latin American authors or institutions associated with the publications, only in the first ranked article, the author Christopher Béné registered association with the International Center for Tropical Agriculture (CIAT) of Colombia; in the other relevant publication there is no participation of LAC's institutions.

The last component of this analysis' section is the thematic evolution; was identified the main research areas and their evolution during the time, detecting conceptual subdomains through the titles of articles cited by the author of the article being indexed. In the period analyzed (2000-2022) was found that initially, the publication focused on 3 main concepts (Food security, Management, and Impacts), followed by far for the concept of sustainability, to evolve in the last years (from 2019) to 6 research areas (Fisheries, Food security, Impacts, Conservation, Model and Performance), observing those areas as impacts moved to a strong connection to conservation and models, presenting tendencies of analysis on efficiency and use of resources. Whereas management diversified its concept to the specific aspects of food security, impacts, and conservation.

Figure 3. presents the thematic map, which organizes in four quadrant typologies the most relevant terms of the fields analyzed. Themes in the upper-right quadrant are known as the motor themes, they are characterized as high centrality as density, meaning that they are the most developed and relevant for the research field. In this typology were located 2 cluster of themes, one as the most developed in literature and high relevance (small scale fisheries, fisheries management, and artisanal fisheries). And the other cluster has less development degree but presents the highest relevance, this cluster gathers the themes of Food security, Aquaculture, and Sustainability, which are the main approaches of this thesis project.

At this point can be identified that despite the most relevant publications do not focus specifically on the aquaculture sector but analyze this and capture fisheries together for fisheries management. Aquaculture is one of the highest concerns of the fishing sector, gained importance for its exponential growth in recent times, and the content of the most relevant research publications on the field include the component of aquaculture.

The upper-left quadrant is known as the highly developed and isolated themes or niche themes, they have a high density with good development of the themes, however, they have limited importance for the field (reflected in the low centrality location), with low relevance for external links. In this quadrant are the themes of nutrition, inland fisheries, and poverty, which are analyzed for specific study cases and regions.

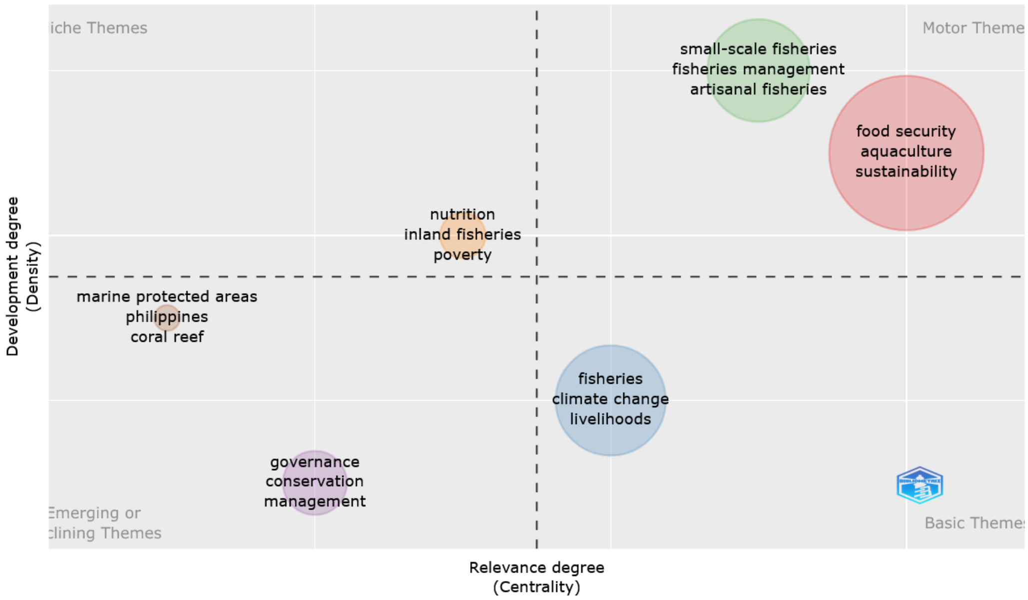


Figure 3. Thematic map

Source: Biblioshiny – Bibliometrix R tool based on methods from Aria & Cuccurullo (2017).

Regarding the lower-left quadrant, it is known as emerging or declining themes. They have both low centrality and density; therefore, the themes are considered weakly developed and marginal; for this analysis, these terms are governance, conservation, and management, the last one was observed that gain relevance in the most important publication of the field.

Finally, the lower-right quadrant, known as basic and transversal themes, presents those characterized by high centrality and low density. These themes (Fisheries, Climate change, and Livelihoods) are important and concern general transversal topics from different areas of the research fields.

3.2.2. Co-words analysis

Once identified the relevant authors, publications, and themes in the fields of this research, the analysis is complemented with the co-occurrence (words) assessment, this technique let's examine the actual content of the publication itself (Donthu et al., 2021), identifying future relationship among the topics to understand better the clusters thematic, visualizing the conceptual structure in a network of words.

In the following Figure 4, can be observed the clusters and connections consolidated from the publications developed in the research fields. Food security, management, impacts, fisheries and aquaculture are the main 4 clusters structured, around which are connected the most relevant topics of the fields, that gather social development, environmental, policy, resource management, economic aspects, among others. Management and Food security are the clusters with the highest concurrency and influence; in the case of food security, it has been strongly connected in the publications with the other 3 main clusters, and the topics of small fisheries, poverty, livelihood, and communities, however, is important to highlight the highest connection between food security and aquaculture, reflecting that have been more researched the relationship between these areas.

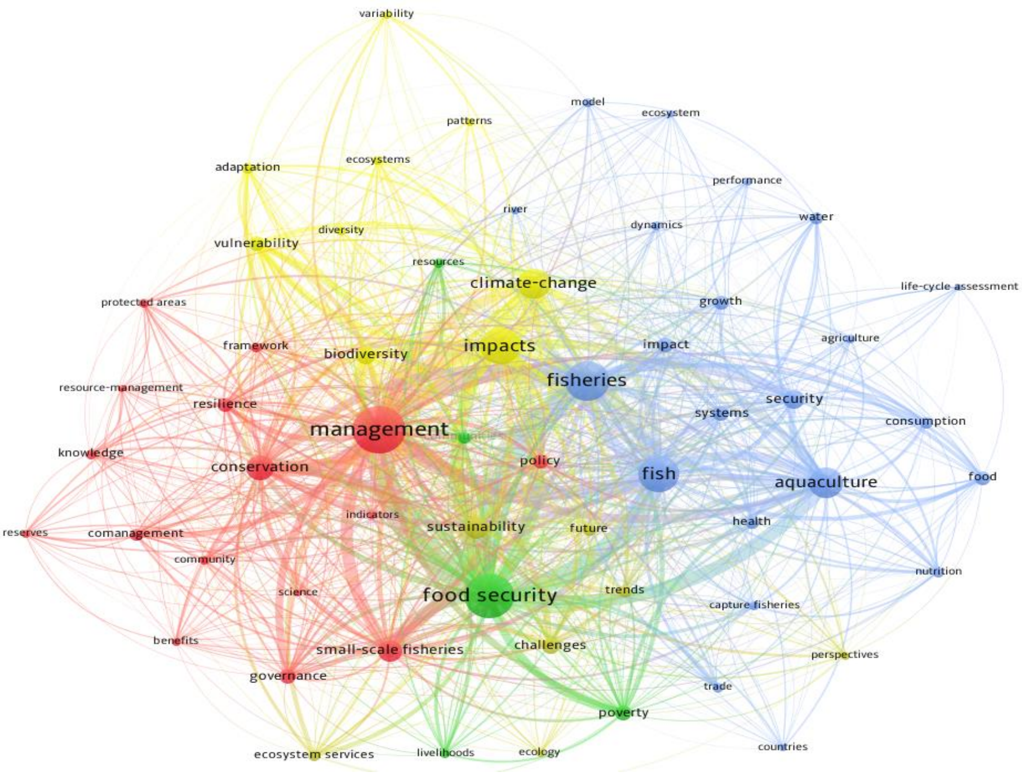


Figure 4. Visualization network of the co-occurrence analysis

Source: Processed data by author in VOS viewer based on method from van Eck N. J. & Waltman L., (2010).

The cluster of management has the widest links with all sectors, the principal items of this group are conservation, small-scale fisheries, policy, resilience, community, and governance. In the case of the impacts cluster, the climate change item has the second strongest occurrence and links, however, this cluster does not only focus on sustainability and biodiversity aspects, but tackles issues like poverty, adaptation, trade, and growth.

Fisheries and aquaculture shape a large network, highlighting the biggest items fisheries, fish and aquaculture, which have the strongest connection with the other components of the cluster such as consumption, security, nutrition, trade, health, and systems.

The results of the bibliometric analysis reflected the most relevant authors, publications, and journals that are considered in this research to identify the sort of methodologies and analysis connected with food security and freshwater aquaculture development. On the thematic evolution and visualization network, these let identified and defined the main areas for this research, selecting the motor themes of Food security and aquaculture, complemented with the most influence clusters items as well (management and impacts).

3.3. Content analysis of the aquaculture sector and food security literature

Recently, aquaculture development has been influenced by approaches such as Blue Growth, the Circular Economy, and the Bioeconomy (Bostock et al., 2016; Merino et al., 2012). Studies of aquaculture's role in society include factors such as integration with the environment, socioeconomics management and governance; while regarding sustainable aquaculture industry there are factors like technology, recirculation systems, managing biological life cycle, aquatic animal health, and welfare.

The most relevant publication identified (Béné et al., 2016) highlighted several studies that attempt to address the relationship between aquaculture and food security within a global context, with drivers such as population growth, fisheries governance reform, and climate change. However, it is observed that those studies identified are dominated by the assessment of environmental drivers, such as climate change and biodiversity, while aspects as economic development and trade are not deeply tackled.

One of them (Allison et al., 2009), which is among the most relevant publication, applied the indicators based approach to assessing the vulnerability of capture fisheries in developing countries to the climate change, focusing on a country level, because policies are formulated and implemented at this scale, several global indicators are available only at national scale, and this assessment provides them a broad view of vulnerability patterns.

Among the indicators considered by Allison et al. (2009), in the analysis of employment and economic dependence, five of them from FAOSTAT, are of interest to this thesis, since can be considered and adapted in capture fisheries as in the aquaculture sector: number of fishers; export value proportion (%) of total export value; proportion (%) of the economically active population involved in the fishery sector; tons of production; and fish protein as a proportion of all animal protein (% g person).

On their side (Rice & Garcia, 2011), develop the analysis of the influence of climate changes and biodiversity drivers on freshwater and marine fisheries, considering the global projections to 2050 for human population growth and food production. While Thilsted et al. (2016) through a proposal of multi sectoral policy solution highlighted the opportunities of the capture fisheries and aquaculture sector for future challenges in fish production and consumption. Modern portfolio theory was implemented by Troell et al. (2014) as framework to define the extent to which growth in aquaculture and the diversification of food production systems will enhance the resilience of the food system to factors such as climate change, applying correlation among food production activities. These are methods implemented to environmental impacts, however, can be adapted to assess economic factors to the food availability and access.

Life-Cycle Assessment (LCA) is a method for measuring multiple environmental impacts, used by methods (Hilborn et al., 2018) to evaluate major food production; results on greenhouse gasses production per portion of the protein was lowest for mollusk aquaculture and small pelagic fisheries; salmon aquaculture, chicken production, and large pelagic and whitefish fisheries also emitting less than 1.0 kg CO_2-eq per 40 g of protein. Regarding aquaculture activities, although emissions may have global impacts, eutrophication and water use impacts can be more detrimental at the local level.

The classification of production methods was greatly restricted by the limited data available from LCAs, demonstrating the need for a far greater number of LCAs and more comparative evaluations of products such as milk, egg, pork, chicken, and beef production in different (Hilborn et al., 2018).

Apart from this, in search of the most relevant publication on the aquaculture sector, few studies were found on the specific relationship between this one and food security; Beveridge et al. (2013) analyzed this association in Asia and Sub-Saharan Africa, considering technical and policy factors, and claiming the importance of accessibility of poor communities to aquaculture products; presented several references to support that fisheries and aquaculture can improve household food directly through fish consumption and increasing purchasing power from the sale of fish, nevertheless, there is a lack of statistical data to confirm it.

In the following Table 3. there is the list of the most influential publication for the aquaculture sector, identifying the analysis of this sector at the country and global level, tackling aspects such as tendencies of fish consumption, social welfare, and environmental resources. Another feature is that the relevant research on these areas focus on developing regions (Asia, Africa, “global south”) and developing countries, in which Bangladesh excelled.

The aquaculture studies at the national level tend to focus on the household relationship, export value chains, and the use of diverse approaches (Béné et al., 2016); like Kawarazuka & Béné, (2010) identifying the potential pathways on consumption, incomes, and distribution (enhancing the economic status of women) between small-scale fisheries and household nutritional security.

Table 3. The 8 most relevant publications in aquaculture sector

Journal	Title	Authors	Year	Local Citations	Global Citations
World Development	Is Aquaculture Pro-Poor? Empirical Evidence of Impacts on Fish Consumption in Bangladesh	Toufique & Belton	2014	50	109
Food Policy	Improving developing country food security through aquaculture development—lessons from Asia	Ahmed & Lorica	2002	49	120
Fish And Fisheries	Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy, and environment	Jennings et al.	2016	31	130
Global Food Security	Not just for the wealthy: Rethinking farmed fish consumption in the Global South	Belton et al.	2018	31	97
Food Policy	Faltering fisheries and ascendant aquaculture: Implications for food and nutrition security in Bangladesh	Belton et al.	2014	29	66
Aquaculture	Can aquaculture benefit the extreme poor? A case study of landless and socially marginalized Adivasi (ethnic) communities in Bangladesh	Pant et al.	2014	18	47
World Development	Give a Man a Fishpond: Modelling the Impacts of Aquaculture in the Rural Economy	Filipski & Belton	2018	17	37
Global Food Security	Prospects and challenges of fish for food security in Africa	Chan et al.	2019	17	45

Source: adapted by the author from results of Biblioshiny – Bibliometrix R tool based on methods from Aria & Cuccurullo (2017).

It was observed that in spite of the majority of studies are oriented to analyze the conditions in developing regions, the scientific knowledge published on the aquaculture sector came from researchers and institutions associated to the United States, United Kingdom, Australia, and China. From Latin America the first country that appears in the list of aquaculture scientific production is Chile, in position 14, followed by Brazil (15), which in comparison to the other Latin American countries have more research development in this sector, nevertheless being Chile one of the biggest marine aquaculture producers, its studies are mainly focused on this specific sector, whereas for freshwater aquaculture was found study cases of the development at a local level, not country or regional analysis.

In the case of citation in the publication of aquaculture sector, Colombia becomes the first Latin American country in the ranking scale, since has few relevant studies but in association with institutes of England and USA that generated more impact and relevant results; while the other four LAC's countries are significantly far with fewer citations.

Table 4. Scientific production and the most cited countries in aquaculture publications

	Country	Scientific Production
1	USA	467
2	UK	289
3	Australia	178
4	China	131
5	Canada	125
6	Bangladesh	109
7	Malaysia	108
8	Italy	69
9	Sweden	63
10	India	61
14	Chile	49
15	Brazil	43
34	Mexico	14
41	Peru	10
56	Colombia	5
65	Argentina	2
70	Panama	2

	Country	Total Citations
1	USA	2724
2	UK	1861
3	Canada	1656
4	Australia	1455
5	Italy	761
6	Bangladesh	736
7	Colombia	659
8	China	633
9	Malaysia	554
10	India	408
19	Brazil	144
33	Chile	38
57	Mexico	4
62	Peru	1

Source: adapted by the author from results of Biblioshiny – Bibliometrix R tool based on method from Aria & Cuccurullo (2017).

This overview lets identify that the LAC region is lagging in aquaculture research, behind countries of Asia and Europe. Furthermore, as can be observed in Figure 5 Latin America and Caribbean has a low research collaboration among the countries of the region, the connection is higher with USA, European, and Asian countries; this situation could be one of the aspects of the few studies and lack of acknowledgement about the relevance and impacts of this sector in the region, and the slow aquaculture technologies development and production systems innovation.

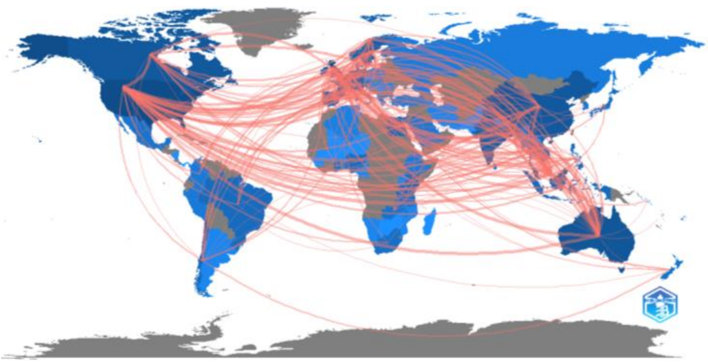


Figure 5. Countries' collaboration map on aquaculture field research

Source: Biblioshiny – Bibliometrix R tool, based on method from Aria & Cuccurullo (2017)

3.4. Nutritional security

This concept is constantly present in the studies since aquaculture is considered a supporter of the nutritional need of vulnerable nations (Golden et al., 2017). The majority of studies founded have been conducted in Asia, mainly Bangladesh (Arsenault et al., 2015; Belton et al., 2014; Bogard et al., 2017; Kibria & Haque, 2018), and the analysis often lack reference to broader diets. Far less is known about species consumed in other parts of the developing world, especially in Africa (Béné et al., 2016).

In addition, Béné et al. (2016) mentioned that little emphasis has been placed on understanding the variability and importance of nutrients in fish produced in different contexts, such as capture compared to culture, or farmed under different conditions. It is an important aspect due to fish consumption does not necessarily mean that the nutritional status of that person will systematically improve.

Fish is considered more nutritious than staple foods, such as cereals, providing, in particular, high levels of animal protein, essential fatty acids and micronutrients (Kawarazuka & Béné, 2010). Fish commodities are a diverse and valuable source of protein; fish muscle contains 16–21% protein, and is a prominent resource in many communities (Day et al., 2022). By 2032 food fish consumption is projected to reach 21.2 kg per capita globally, and aquaculture production is projected to account for 55% of total fish production, compared with 50% in 2020-2022 (OECD/FAO, 2023).

Gephart et al. (2020) proposed research with a qualitative scenarios approach to determine aquaculture's futures and their role in nutrition security, valuing the social significance of food, and supporting livelihoods. These authors described that the concept of nutrition-sensitivity has been extended to fisheries and aquaculture, defined as a food system that supports public health outcomes through the production of diverse seafood, provides multiple, rich sources of essential, bioavailable nutrients, and supports equitable access to nutritionally diets that meet food preferences for all populations, without compromising ecosystem functions, other food systems, and livelihoods.

This systems approach is connected with the concept of nutrition-sensitive food production, emerging in response to perceptions that the global food system has been successful at increasing productivity to meet the caloric needs of a growing population but has been less successful at supplying a healthy and nutritious diet (Gephart et al., 2020).

The impact of aquaculture on Nutritionally Vulnerable Nations (NVN) has been evaluated by Golden et al. (2017), through the analysis of aquaculture production, aquaculture exports, total seafood exports, and percent of exports directed to 41 NVN, with the aim of determining if aquaculture supports the needs of poor and food-insecure populations via domestic production or trade, or indirectly via purchase of nutritionally rich dietary substitutes.

To assess the criterion of the direct contribution of aquaculture they used the FAO global commodities production and trade database provided by FishStatJ for statistics on annual production, imports, and exports of fisheries commodities. This assessment of the aquaculture's direct contribution via trade is constrained by data limitations, since international trade statistics, different from FAO, do not distinguish between wild caught and aquaculture products, thus, precise estimates of aquaculture imports are difficult.

Among the results, Golden et al. (2017) claimed that it is unlikely to contribute to human nutrition in vulnerable groups, as most exported aquaculture consists of high-value species for international markets. However, they also mentioned if aquaculture production within NVNs is largely exported, for instance, more than 50% of production by volume goes to international markets, those incomes, from the sale of aquaculture production, must enable these nations to purchase nutritionally rich dietary substitutes, thus indirectly benefit NVNs, with incomes from the trade of domestic aquaculture to purchase alternative nutrient foods.

Contrary, having a domestic-oriented aquaculture production system does not necessarily mean that nutritionally vulnerable subpopulations have access to these aquaculture products; even when aquaculture is consumed domestically by those in need, the biomass of wild capture fish can be compensated, but the nutritional shortfall might still exist (Bogard et al., 2017).

On their side, Burns et al. (2014) developed a qualitative and quantitative content analysis of publications linked to aquaculture and human health, considering the determinants of health (poverty, food security, food production sustainability, and gender equality), the type of aquaculture activity (shrimp, shellfish, freshwater finfish, saltwater finfish, or aquatic plant), the research methodology, the region and country of the research. From this analysis, the authors found the three most common themes: Farmer income, environment, and employment.

Regarding farmer income, employment and food security they found that aquaculture often has positive impacts, but the ones on environments and shared resources can be negative, and gender equality is considered in a small proportion of publications; therefore, future research should bring a gender perspective to the aquaculture sector.

On the other hand, most attention of the contribution of aquaculture has been directed toward positive impacts on human development, such as the improvement of livelihoods and reduce poverty, while most criticism has been directed toward conflict over shared resources and damage to common environments (Burns et al., 2014). Therefore, the context is essential to determine aquaculture's impacts and it would be inappropriate to lump all production types and settings together. Studies found on food security and food sustainability have been directed toward developing consistent and comparable analysis, however, a limitation was that the evaluation methods were not used in many publications, and when were used frequently are poorly described (Burns et al., 2014).

Driving forces, Pressures, State, Impacts, Responses (DPSIR) Cause-Effect was one of the methodologies found for the multiple scale analysis of the relation of aquaculture - fisheries with food production, focusing on technological development. Little & Bunting (2016) identified the key drivers of technical change as electrical and potable water supplies, infrastructure and urbanization tend.

IMPACT is another methodology for global, multi-market and economic model that covers a wide range of agricultural commodities, developed at the International Food Policy Research Institute (IFPRI). The main objective of this model is provided forward projections. Kobayashi et al. (2015) mentioned that there are studies that developed assessments with the IMPACT model on 45 agricultural commodities and16 fish species categories, beginning its projections in 2000 and carrying forward to 2030. Kobayashi et al. (2015) assesses five scenarios and relied on three sets of data compiled FAO Fisheries and Aquaculture Statistics (FishStat) for fish production, FAO Fisheries and Aquaculture Statistics for food balance sheets (FAO FIPS FBS) for fish consumption and trade, and a combination of FishStat J, Oil World, IFFO data for production and trade of fishmeal and fish oil. One of the limitations was the lack of disaggregate data for fish consumption and trade.

About the results of the model, Kobayashi et al. (2015) concluded that the projections were consistent with the available data from other institutes. Projections results and available data for quantities of fish supply and demand at the global and regional levels were connected and close fit, whereas in the case of price data was not possible.

Regarding the contribution of fisheries and aquaculture to food security and the reduction of poverty, Béné et al., (2015) identified four factors in the analysis of the fisheries sector: the fishmeal and fish oil in aquaculture; fish loss, considering that global discard of fish was estimated to be around 7.3 Mt in 2005, while small-scale fisheries generated less wastage (discards) with about 2 Mt a year. The third factor considered was sustainability, with the reduction of overfishing by the global fisheries to be more productive; and the last factor livelihood support, because the fisheries and aquaculture sector have an important role in low income and emergent countries. Between 660 and 820 million people (fishers, fish-farmers, fish traders, workers in fish processing factories, and their families) depend on fish related activities as a source of income (HLPE, 2014).

In another study, Béné et al., (2016) evaluated the existing evidence by identifying two mainly clusters: the contribution of fish to nutrition, and the effect of fish consumption on human health. Finding that areas of research still lack the level of disaggregated data or an appropriate methodology to reach consistent conclusions.

The analysis reveals that the influences of major drivers such as decentralization, climate change, demographic transition (fish consumption improves with consumer's increasing wealth and incomes), global and household economy are still insufficiently documented and therefore poorly understood; besides the links between aquaculture and poverty alleviation are still unclear. And the clusters of fish nutrition, and fish consumption linked to health were identified as the best developed in the research literature (Béné et al., 2016). Topics regarding the impacts on food security and aquaculture and national economies presented a moderate research quality and less studies in comparison with other clusters.

Another interesting result of Béné et al., (2016) is on cross-cutting issues, highlighting that research fields that are tackled in this thesis, as fish trade with food security and poverty alleviation present large studies but with inconsistent and moderate quality. At the global level, literature emphasizes the increasingly critical importance of aquaculture to fill the gap between fish demand and supply. Only a few case studies evoke the possibility that income and employment created by aquaculture can benefit low-income households participating in specific, often rural, aquaculture activities in developing regions, showing the benefits to household livelihoods through aquaculture development (Béné et al., 2016).

3.5. International fish trade

One of the common topics found in the literature on food security and aquaculture relationship is the international fish trade analysis, considering it from three (3) perspectives, the fish trade contributes to poverty alleviation, to the economic growth, and to the food security.

Regarding the contribution to poverty alleviation and economic growth (Béné et al., 2016) mentioned that one of the main results is that exploiting rising demand in export markets is an important way of wealth generation in the regions, but the analysis are uncritical, relying on global data sets of foreign exchange revenues from fish trade, rather than evidence of the effects of these revenues on the national economy or the livelihoods of their populations. Domestic trade and export trade between developing countries is significantly less well explored.

At national-level studies (Boyd et al., 2012; Jennings et al., 2016; Kawarazuka & Béné, 2010; OECD, 2016; Raftowicz & Le Gallic, 2020) focused on demonstrating incomes for national governments from fisheries activities, however, there is no evidence that the revenues are redistributed and support the reduction of poverty in developing countries.

Béné et al. (2016) highlighted that the perspective of contribution to food security has been developed by studies at local and global levels, however, they do not offer methodologies with combined data that allows understanding the issue comprehensively and rigorously, as consequence, the quality of evidence is low, and unsettled discussions of results. These authors described, as well, a polarized vision of the international fish trade impacts since some studies claim that it contributes to improving the food security of developing countries through fish export revenues, while others claim that the international fish trade threatens food security at the local level, and those studies do not demonstrate a correlation between fish export revenues and import of food, or improvement in food security at national or local levels.

3.6. Policy analysis

Ensuring the successful and sustainable development of global aquaculture is an urgent agenda, and policies should provide an enabling business environment that fosters efficiency and further technological innovations in aquaculture feeds, genetics and breeding, disease management, product processing, and marketing and distribution (Kobayashi et al., 2015). Fish production is projected to growth by 12% in the next decade. The slowdown in the expected growth reflects the impact of policy changes in China, toward sustainable fisheries, the higher costs for fuel inputs, climate impacts. Slow progression of aquaculture production, projected to account more than 50% of total fish production, achieving productivity gain and technological improvements related to spatial planning, breeding, feed and management (OECD/FAO, 2023).

Research on fisheries and aquaculture activities should consider in their objectives to provide knowledge for the integration of fish into the overall debate and future policy about food security and nutrition (Béné et al., 2015), since future of aquaculture development depends, in part, of regional policies (Bostock et al., 2016).

It was identified that future scenarios are methods frequently used for the analysis of the possible impact of policies and economic measures. Furthermore, analyses of scenarios in aquaculture have used supply and demand models to project production and consumption levels based on observed patterns of consumption and price elasticities of demand (Kobayashi et al., 2015). Regarding food security was observed in the literature that the prospective scope in the analysis of emerging scenarios is common to 2030 because of the Sustainable Development Goals, or to 2050 considering UN global food and population projection. On their side, Béné et al. (2016) set an evaluation of the capacity of fish to contribute to feeding 9 billion people in 2050 and beyond.

FAO (2020) applied the projections for fisheries and aquaculture development to determine the emerging issues toward 2030, finding trends in world fish production, consumption, trade, growth, and prices. Besides, for the analysis of fisheries policies was developed a methodology from (Koehn, 2019) to identify the level of integration of food security and nutritional policies in the national fisheries policies and the indicators considered in these fields.

Future assessment with a version of the exploratory-strategic scenario methodology have been used to analyze nutrition-sensitive, the influence of driver forces in the aquaculture development and food system, as a description of future possibilities, based on consistent relationships, current diet patterns, trade environments, and governance contexts (Gephart et al., 2020). The scenarios focused on contrasting situations faced by aquaculture and food sectors, such as international trade and macroeconomic interaction with sustainability, health, human development, environment, and equitable distribution of seafood.

In the study developed by Gephart et al., (2020), their results of the qualitative scenarios reflected that aquaculture production continues to grow, and there is an opportunity to use policies, market instruments, and consumer education to guide the development toward more nutrition-sensitive and healthy environmental futures, encouraging the inclusion of this kind of assessment in fisheries and aquaculture research.

3.7. Fish prices

The impact and tendencies of global food price have been widely studied because of the effects on households' livelihood in developed and developing economies; the increasing global food price generally makes households' daily food baskets more expensive, and resource-poor households adopt various strategies to mitigate the rising price effect, such as replacing expensive foods with cheaper alternatives (Birhanu, 2023). Trade can help to improve availability and access to food and agricultural commodities, and contribute to the stability and food security (OECD/FAO, 2023), with the management of climate change effects and food supply challenges.

The pricing of aquaculture products is a multifaceted issue that encompasses the entire value chain, from the acquisition of inputs to the delivery of the final product to consumers. The costs associated with each stage of the value chain, along with a margin for profits, collectively determine the product's price. The integration of sustainable practices, particularly in the selection of feeds and farming methods, further influences the cost structure and environmental sustainability of aquaculture production (Bostock et al., 2016; Luna et al., 2022). Factors such as climate change and socio-political scenarios, will significantly impact future price trends for fish, fuel, electricity, and fish feed ingredients (Kreiss et al., 2020).

Price is the dominant factor as conventional supply and demand economics predicts that demand falls as prices rise, whilst the incentive and then ability of producers to supply the market fall as prices fall, therefore the competitiveness of aquaculture commonly involve analysis of production and sales prices; and because of the significant variability over time is highlighted the need for relatively long term financial planning and assessments (Bostock et al., 2016). The aquaculture industry's competitiveness is intricately linked to effective price analysis, addressing factors as price variability and economic and environmental context is essential for the sustainable growth of aquaculture (Pasch & Palm, 2021).

The profitability of the aquaculture sector has been examined considering the price factor as well; Framian BV (2009) analyzed the EU's aquaculture on the structure of production (segments and types of farms) and the economic performance in terms of prices, number of companies (legal status), employment, and international trade. Other studies (Guillen et al., 2015) include variables such as turnover, which comprises all market sales of goods and services supplied to third parties; The EBIT (earnings before interest and taxes), measure of a firm's profitability that excludes interest and income tax expenses; and the number of employed persons.

As one of the most important factors or drivers of aquaculture development, price is complex to analyze in relation to food security. The expansion of aquaculture has caused the price of farmed fish to grow more slowly than other animal foods source, even this growth reigned in increases in the price of captured fish (Belton & Thilsted, 2014). The controlled growth in the price of farmed fish maintains affordability, accessibility, and contributes to food security.

Growth in aquaculture prices is projected to be significantly lower than previous decades; markets will continue to be characterized by the traditional competition between aquaculture and livestock for fishmeal, and between aquaculture and dietary supplements for direct human consumption for fish oil. This last one is expected to mainly be used in aquaculture, but direct human consumption will remain an important market, where prices are generally higher (OECD/FAO, 2023).

The increase of aquaculture competitiveness, as a result of technical and management innovations that reduce the cost of production, has held down fish prices, so that they are far less affected by price volatility than terrestrial foods. With this scenario could be interpreted that fish consumption rise and improve the access of the poor population to this animal protein, since for instance semi-intensive freshwater aquaculture, with its low price and limited international markets, has become an increasingly important source of animal protein in some developing countries in Asia (Golden et al., 2017), however, few studies can confirm that commercial aquaculture systems have led to price reductions, and in turn, increased the fish food access by the poor people (Toufique & Belton, 2014; Troell et al., 2014).

3.8. Analysis of macroeconomic impacts (crude oil prices) on food prices

The primary objective of agribusiness is to ensure food security for the global population at affordable prices (Kleyn & Ciacciariello, 2021). The demand growth for animal products is driven by demography, urbanization and changes in diet in the poorer countries (Caillavet et al., 2019).

Analysis of macroeconomic impacts on food prices has been widely analyzed considering mainly food production index, identifying long-term, and positive relationships between crude oil and meat prices (Zingbagba et al., 2020). Rising food prices has been correlated with the increase of poverty in the short run, as most poor households spend their budget on food (Ivanic & Martin, 2018). A change in food price is usually a signal of possible changes in households' food security in the developing world (Kalkuhl et al., 2016); poor urban/non-farm households with a high share of food expenditures are the most vulnerable to food price hikes (Anríquez et al., 2013).

The impact of oil price index on agricultural commodities has been reported to prices of products as corn, soybeans, wheat, eggs, meat, milk, and oilseeds (Fowowe, 2016; Melichar & Atems, 2019; Roman et al., 2020; Zmami & Ben-Salha, 2019); however, there are no studies documented about the impact specifically on animal protein commodities. Studies on food price increases mainly focus on staple food crops such as maize, wheat, and rice; empirical evidence on livestock products (Birhanu et al., 2023). This gap in research highlights a need for more focused investigations into how fluctuations in oil prices influence the cost and availability of animal protein products.

From the literature review on this field, the most relevant studies found on the food prices analysis are briefly described in Table 5, highlighting the scopes, variables, methods, and results of the literature cluster.

Table 5. Relevant studies on Food prices analysis and influence of oil price as macroeconomic factor

Paper	Objective	Methods	Results
Assessing the effect of oil price on world food prices: Application of principal component analysis (Esmaeili & Shokoohi, 2011)	influence of the macroeconomic variables (crude oil prices, consumer price index, food production indexes and GDP) on food prices around the world between 1961 and 2005. Examined food prices of 7 major products: eggs, meat, milk, oilseeds, rice, sugar, and wheat.	• Scree test and the proportion of variance method for determining the optimal number of common factors. • Granger causality test.	• Food production index has the greatest influence on the macroeconomic index and that the oil price index has an influence on the food production index.
Does Oil Price Drive World Food Prices? Evidence from Linear and Nonlinear ARDL Modelling (Zmami & Ben-Salha, 2019)	Aggregated and disaggregated analyses of the impact of the Brent and WTI oil prices on international food prices (Food price index, meat price index, dairy price index, cereals price index, vegetable oils price index, and sugar price index); between January 1990 and October 2017.	• linear and nonlinear autoregressive distributed lag (ARDL) models.	• Asymmetries, since the overall food price is only affected by positive shocks on oil price in the long run. • Asymmetry presents for some other agricultural commodity prices in the short run since they respond only to oil price decreases.
The impact of diesel price on upstream and downstream food prices: Evidence from São Paulo (Zingbagba et al., 2020)	Modelling upstream and downstream diesel price shocks along the nutritional high-value food supply chain. Data: monthly average prices of meat, eggs, dairy and fats & oil products sold in São Paulo, from July 2001 to December 2013	• Vector Error Correction approach estimates short-run and long-run dynamics in producer and retail prices of meat, eggs, dairy and fats &oil due to changes in the average monthly price of diesel. • Granger causality analysis; Unit root test - Cointegration test	• The response of food prices to diesel price shocks shows a positive response of both upstream and downstream prices of egg and dairy products, while the opposite direction occurs in the fat and meat markets. • The price of diesel predicts retail price only in the egg market.
The Linkages between Crude Oil and Food Prices (Roman et al., 2020)	Linkages between crude oil prices and food price indexes (dairy, meat, oils, cereals, and sugar) and provide an empirical specification of the direction of the impact. The data series covers the period between January 1990 and September 2020.	• Augmented Dickey–Fuller test • Granger causality test - The cointegration test - Vector autoregression model - Vector error correction model	• There are long-term relationships between crude oil and meat prices. The linkage of crude oil prices occurred with food, cereal, and oil prices in the short term.
Time-frequency causality and connectedness between international prices of energy, food, industry, agriculture and metals (Tiwari et al., 2020)	Analyze the lead-lag relationship between the price indices of energy fuels and each of food, industrial inputs, agriculture raw materials, metals, and beverages. The period of the study is 1990m1 to 2017m5.	• Wavelet coherency and phase-differences: to explore the price-correlation dynamics. • Spillover indices to analyze the connectedness among the set of the price indices under consideration.	• There are important and significant relations between the fuel and food prices, the fuel and industrial prices, and the fuel and metal prices. • The volatility spillover results indicate that the agricultural sector is the most affected by shocks from the other markets.
Do oil prices drive agricultural commodity prices? Evidence from South Africa (Fowowe, 2016)	Effects of oil prices (Brent) on agricultural commodity prices (maize, sunflower and soybeans) in South Africa. Data: weekly data for agricultural commodity prices and oil prices over the period January 2, 2003 to January 31, 2014.	• Cointegration tests to determine if there is a long-run relationship between the variables. • Causality tests to ascertain the dynamic relationships between oil prices and agricultural commodity prices.	• No evidence of a long-run relationship between oil prices and agricultural commodity prices in South Africa. Nonlinear causality tests showed no evidence that agricultural commodity prices in South Africa respond to oil prices.

Paper	Objective	Methods	Results
Tail dependence risk and spillovers between oil and food prices (Hanif et al., 2021)	Nonlinear dependence dynamics, downside and upside risk spillovers between oil prices and world food prices index (dairy, cereals, vegetable oil, and sugar). Data: Monthly series modelled span from January 1990 to February 2018.	• Static and dynamic bivariate copulas, • Value- at-Risk (VaR) and conditional VaR (CoVaR) methods.	• Lower and upper tail dependence is observed between oil prices and cereals, vegetable oil, and sugar prices. • Upside and downside asymmetric risk spillovers from individual food commodities to oil, and from oil to food commodities.
Modelling the symmetrical and asymmetrical effects of global oil prices on local food prices: A MENA region application (Hadj cherif et al., 2021)	To investigate the symmetrical and asymmetrical influence of oil prices on food prices, in the Middle East and North Africa region during the period 2000–2020. Panel data of food prices, for 14 countries, and annual time series data of the global oil price, inflation rate, the degree of trade openness, and urbanization levels are chosen as control variables.	• Linear and nonlinear models of the autoregressive distributed lag (ARDL). • Data stationary test • Food prices in the MENA region are transformed by consumer prices indices to actual values for the base period (2015 = 100).	• The positive impact on oil exporters—due to higher oil revenues—is greater than importing nations, leading to an increased demand for food. • Short-term asymmetric behavior due to the heterogeneous response within the oil-importing and oil- exporting samples. While in the long term, the asymmetric effect is positive, indicating that food prices increase regardless of fluctuations in oil prices.
Cross-Correlations in Meat Prices in Brazil: A Non-Linear Approach Using Different Time Scales (Quintino et al., 2021)	Analyze the cross-correlation between meat prices in Brazil, (cattle, swine and chicken) including analysis of maize, soya beans, oil, and the Brazilian exchange rate. from 2011 to 2020	• Detrended cross-correlation analysis coefficient (DCCA)	• Swine and chicken prices showed a positive and strong correlation over time, and cattle showed some positive correlation with chicken only in the short run. • For more spaced time scales (days), the changes in the degree of correlation were significant only in the long run for swine and cattle.
Global crude oil market shocks and global commodity prices (Melichar & Atems, 2019)	Relationship between shocks to the global crude oil market and commodity prices. (Non-Energy index, namely Metals and Minerals, Agriculture, and Fertilizers)	• Augmented Dickey–Fuller (ADF) test • VAR model	• Asymmetric responses in commodity index prices to endogenous oil price shocks, with oil demand shocks leading to higher energy and non-energy commodity index prices.
The relation between petroleum product prices and crude oil prices (Ederington et al., 2021)	Empirical examination of the relation between real spot Brent oil prices and real spot petroleum product prices, specifically gasoline and heating oil prices. Based upon weekly price data spanning a 30-year period ending in April 2019	• Granger causality running for both non-stationarity of the series, and separately conditional heteroskedasticity. • Multivariate model	• No evidence of Granger causality from product prices to oil prices is found for the full sample period nor the period up to the end of 2005

Source: Elaborated by author

3.9. Animal protein sector in developing regions

World meat consumption continues to grow at one of the highest rates among major agricultural commodities; meat trade was led mostly by expansion of poultry and bovine shipments. Increased demand for meats will mostly stem from large economies in Asia, crude oil exporting countries in Latin America, where income gains are expected to be significant; poultry meat will lead this anticipated growth as the cheapest and most accessible source of meat protein, overtaking pig meat as the largest meat sector by 2030; meat imports are expected to grow in developing countries (OECD/FAO, 2012).

LAC is the largest net exporter of agriculture and fisheries commodities, amongst all the regions. Exports have been integral to its agricultural growth, reducing exposure to the macroeconomic instability within the region and improving resilience to exogenous shocks. The share of exports in the total agricultural production is expected to reach 50% by 2032, increasing its share on global exports to almost 18% as well. Brazil is the biggest exporter of the region, nevertheless there are other important exporter countries such as Mexico, Argentina and Peru (OECD/FAO, 2023).

In LAC region, agriculture and fish production account for 8% of total GDP; the prolonged period of high prices further benefitted agricultural performance, sustained its share in GDP, however is expected that sector's share will decline below 7% by 2032; drought in Brazil and Argentina could accelerate this decline. The outlook of OECD/FAO (2023) mentioned that the region provides 16% of global livestock production; poultry is expected to grow the fastest, to account for just over 60% of additional meat production by 2032; bovine and swine are expected to grow by 0.9% and 1.2% respectively; bovine will account for 22% of meat production in 2032; and fish production comprises just 11% of total value in the region, and this share is expected to decline in 9% by 2032; aquaculture is expected to contribute 30% of the total fish production.

The region's land abundance contributes to strong crop production growth; despite slower growth in livestock production, the region will continue to be a large contributor to global production. Nevertheless, as part of the effects associated with COVID pandemic and the Ukrainian crisis, LAC experienced greater increase in the prevalence of food insecurity compared to other regions of the world, rising from 31.7% to 40.6%, between 2019 and 2021, external situations that generated high inflation, rise in fertilizer and food costs (Word Food Program, 2023).

The third (3rd) specific objective developed in this study was extended to two developing regions, to obtain a wide scenario of the animal protein affordability presented in LAC. Middle East and North Africa (MENA) and East Europe and Central Asia (EECA) were the regions considered in this thesis for the component of animal protein analysis.

East Europe and Central Asia

EECA region is an important exporter of fish products, with Poland and Russia the major contributors. The region is expected to have the slowest production growth, mostly driven by Central Asia and Eastern Europe, but tighter regulation related to environmental sustainability and animal welfare will place downward pressure on yield improvements (OECD/FAO, 2023). Russia has been a top meat importer, however recently it has experienced sustained growth in Swine and poultry sector; Boost productivity is an important factor in the EECA fish sector, in order to growth in as animal protein source (OECD/FAO, 2012).

Europe and Central Asia contribute more than 40% of livestock product exports globally and almost 90 % of this volume came from the European Union. meat exports are projected to decline by 16%, mainly in swine commodities, remaining stable poultry and bovine shares. The share of primary agriculture, forestry and fish production in GDP is less than 2 % in European Union, and 13 % in Central Asia. (OECD/FAO, 2023)

EECA region became a net exporting region of agriculture commodities in 2008; the limited domestic demand, due to stagnating population and per capita consumption (OECD/FAO, 2023), being Russia and Ukraine important to maintain the net exporting position, should be considered the impacts of the current political conflict, is expected to generate slowdown in the short term.

Compared to 2020-2022 base period, the net value of agriculture and fish production is expected to have a low growth of 7% by 2032, this entails an expansion of 22 % in Central Asia, and 11% in Eastern Europe. Whereas output from Western Europe rises by less than 2% by 2032 (OECD/FAO, 2023), Growth from Eastern Europe is expected to be led by Turkey (26%) and Russia (9%), followed by Kazakhstan.

The meat products will constitute 24% of total protein availability in EECA, by 2032, with a rise of poultry and minor declines in swine, bovine and goat. Fish consumption is expected to rise by 5%. The relative importance of animal products in terms of both consumption and production is also reflected in feed; total feed use is only expected to expand with 4% reduction in western Europe offset by gains of 12% and 25% respectively in eastern Europe and central Asia.

Middle East and North Africa

About MENA region, this is amongst the largest net food importers in the world, largely due to the challenging production environment resulting from its natural resource limitation. Self-sufficiency rates are low for most commodities, exposed to global trade system, logistic problems and political conflicts as the one between Russia and Ukraine (OECD/FAO, 2023). By 2032, imports are expected to rise for almost all commodities though generally at a faster rate for meat and dairy than plant-based products.

It is expected that food imports per person will be highest in Saudi Arabia and other Middle East area. Particularly in near east and north Africa, the production of livestock and fish commodities is expected to grow significantly, although from a low base; livestock is expected to grow faster over the coming decade in response to rapid population increase and urbanization (OECD/FAO, 2023).

Meat production is projected , by OECD/FAO (2023), to grow in MENA region, by almost 2.4 Mt in 2032, mostly derived from poultry. This one comprises 59% of total meat production, driving most of the increase in livestock production, whereas bovine meat represents a turnaround from an historic contraction .

3.10. Freshwater fish aquaculture in Latin America and the Caribbean

Fish accounted about 16% of the worldwide intake on animal protein, and 6% of all protein consumed (OECD/FAO, 2012). Globally, less than 20 % of total fish produced is currently used for fishmeal and fish oil production, and the proportion is expected to remain unchanged into 2030. LAC is the largest fishmeal-producing region, accounting for about 40% of world's fishmeal supply. In fact, in Latin America, reduction demand accounts for about three-quarters of their fish use. The projected fishmeal production of Latin America in 2030 is slightly more than that of all of Asia (World Bank, 2013).

For the period 2012-2022 OECD and FAO projected that fish sector would experience high prices, and production costs, due to growing prices of fishmeal and other feeds. The demand for fishmeal will likely become stronger, given the expansion of the global aquaculture; during 2010–2030 period, prices in real terms are expected to rise by 90 % for fishmeal (World Bank, 2013). The same report highlighted that with higher fishmeal traded, species substitution in production is expected, and animal protein source as well.

World production of fishmeal is expected to expand over the next decade with the proportion of fishmeal obtained from fish residues as the main driver (OECD/FAO, 2023). World trade of fish product (fish for human consumption and fishmeal) was expected to grow strongly, higher than other meat products, with fish exports increasing by 34% by 2021 (OECD/FAO, 2012).

As was mentioned before the freshwater aquaculture sector in the LAC region has several potential opportunities to become one of the most important economic activities, enhancing the food security and contributing to the reduction of poverty and undernourishment. Nevertheless, considering the features of the aquaculture development in the region, as consumption, production system developments, diversification, fish trade, additionally to the scarce studies and publication on the field (Wurmann, 2017). LAC has to face several challenges to improve food and nutrition security through freshwater aquaculture products, and promote them as an economic driver for local economies.

Among the contributions of this aquaculture to rural areas in LAC are the provision of self-employment and cash incomes, allowing people to diversify their cash income activities, due to most of small-scale fish farmers in the region are also agricultural farmers (Wurmann et al., 2022).

Table 6. Latin America and Caribbean data of protein supply and fish contribution in 2017

	Per Capita Supply	Protein Supply			Fish Contribution To	
		Fish protein	Animal protein	Total protein	Animal protein	Total protein
	Kg	g per capita per day			%	%
LAC	10,5	3,0	42,9	83,7	7,0	3,6
World excl. China	15,9	4,7	30,4	76,7	15,6	6,2

Source: (FAO, 2020)

In spite of the low growth of fish consumption in the region, trends in the domestic markets and production system, there are reports and projections, such as FAO (2020), that describe emerging issues to 2030, reflecting the continuous growth of aquaculture production in LAC with variations in the range of species and products; highlighting that the regions where is expected the most expansion are Africa (up 48 %) and Latin America (up 33 %). About food fish supply will increase in all regions, while per capita fish consumption is expected to decline in in sub-Saharan Africa, raising concerns in terms of food security there (FAO, 2020).

The development of this aquaculture sector in LAC has followed the trend that the majority of world farmed fishes are freshwater omnivores and herbivores, even the consumer preference of the region is for low-level species as well. This situation and the international market demand have led that the LAC's production growth in the last decade was mostly on species from Cichlidae and Characidae family. The region kept 88% of its species production on low levels, concentrating on species from 2.0 to 3.0 trophic level (herbivores, detritivores, and omnivores), as can be detailed in Figure 6. This chart presents the state of 3 indicators (species production, unit value, and trophic level), reflecting the distribution of the freshwater aquaculture production in the region by 2019.

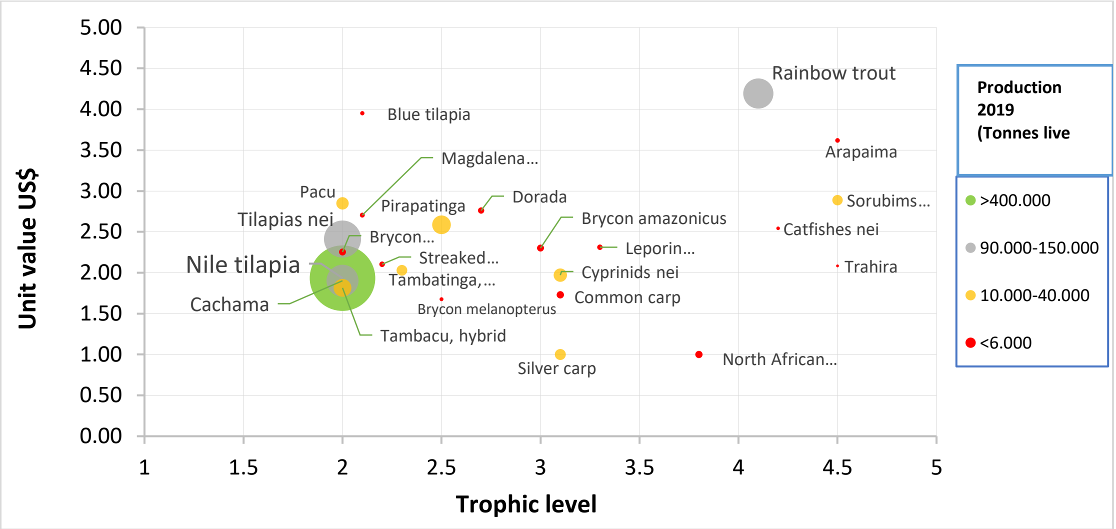


Figure 6. Species distribution of the freshwater fish aquaculture production of LAC in 2019, in terms of tons, trophic level, and unit value

Source: elaborated by the author from statistical data of FishStat J database (FAO, 2023) and Fishbase, (2021).

The three (3) factors presented are essential for the growth of the aquaculture sector and the integration to the food security strategies of the countries in the region, since the supply, nutrition and protein demands are linked with the trophic level of fish species produced. In terms of food access, the price of species produced and the level of diversification influence both sides (producers and consumers).

Aquaculture has changed the availability of certain food-fish types, species and nutrients consumed via fish. Freshwater species, in particular cyprinids and tilapines, increasingly dominate food-fish supplies, and this may have marginal effects on protein supplies per unit food-fish, (Belton & Thilsted, 2014).

Can be observed the species concentration of the LAC's production in Nile Tilapia, other varieties of Tilapia, and Cachama, consequence of the market demand and the influence factors of low trophic level species production such as cost, marketability, easy reproduction, and fast growth. Therefore, the production systems in the region have specialized in this production with freshwater pond aquaculture (extensive to semi-intensive), intensive freshwater flow-through, partial recirculation systems (mostly tanks, raceways, and small ponds) and small cage systems. Farming methods have a further effect on fish lipid content and composition, intensification of production methods tends to increase fat levels (Belton & Thilsted, 2014).

Another feature of the LAC production is the short gap between the price of low and high trophic level species; in other regions as Europe, there is a wide difference from the unit value of the low-level European species to the highest ones, the range of value is concentrated mainly from US$ 1.09 to US$8.18, while in the LAC was from US$ 1.5 to US$ 3.0 (FAO 2021a). Farmed fish price affects access by poor consumers while the size at which fish is harvested influences both access and use (Beveridge et al., 2013).

3.11. Challenges – gaps

Capture fisheries and aquaculture have a complementary role to play in increasing fish availability and access (Thilsted et al., 2016). The two sectors, therefore, have highly complementary roles to play in ensuring that fish remains available and accessible to poor consumers (Belton & Thilsted, 2014). However, gathering both to analyze the impacts of the sector does not allow to identify and understand deeply their states and roles in the food security management.

The existing literature reveals scattered but increasing evidence of the role of fish to nutritional security (Kawarazuka & Béné, 2010), however, studies related to the contribution of capture fisheries or aquaculture sectors to food security or economic development have been developed mainly at global or macro-level (Béné et al., 2016). Benefits of aquaculture to local food security are recognized but have not been sufficiently documented (Little & Bunting, 2016), mainly in the LAC region, where there is a lack of acknowledgment of the role of aquaculture sector in the regional economy and food and nutritional security. Most research of aquaculture (75%) was focused in Asia, with limited research from Africa (10%) and South America (2%) (Burns et al. 2014).

Literature on economic development and policy studies has focused on evaluating specific outcomes from food security policies, nevertheless, is necessary a wider perspective since macroeconomic factors, such as poverty, unemployment and trade balance, play a strong role in the improvement of food security programs (Smith et al., 2017).

Béné et al. (2016); Bostock et al. (2016) described key gaps in the definition of fisheries and aquaculture in the future sustainable food security

- Components of capture fisheries and aquaculture are not completely accounted in national statistics, particularly in developing countries, few rigorous socio-economic analyses have been conducted on the impact of commercial aquaculture activities on low-income households.
- In aquaculture, many questions remain concerning who benefits, and at what costs to whom. There is a gap related to knowledge of causal relationships between aquaculture

development and food security, economic growth, and impacts on poor people. Such research should be feasible as the sector is concentrated around a limited number of fish species and products. Researchers can help resolve inconsistencies and reduce uncertainties.

- Gender equality is considered in a small proportion of publications; therefore, efforts are required to bring a gender perspective to future research, but a limitation is the availability of data.
- Freshwater aquaculture production systems depend on a combination of market demand, diversification activities, water demand, and recognition of environmental services, integrating freshwater recirculation systems because of competition in markets.
- Poverty is not clearly conceptualized, articulated, or measured in fisheries and aquaculture studies. There is a lack of concrete evidence of how fish production, trade, and consumption translate into developmental benefits and reduce poverty. Studies focus mainly on production impacts.

  It is required to put greater emphasis and more evidence on the distributional benefits and how aquaculture effectively contributes to poverty alleviation, economic growth, food and nutrition security.
- The rising demand brings strong market competition, particularly with imported fish food, keeping prices low, and there is a challenge to create adequate access to finance for working capital.

Regarding the data of the aquaculture sector, the lack of reliable data on small-scale fisheries and the reliability of national and intra-regional trade data in most of the developing areas complicate the research development (Béné et al., 2016). Furthermore, the variety of concepts linked to fisheries production and used in studies could generate the wrong interpretation of the scope; for instance, seafood and blue food as well are concepts that gather fish products. There is no consensus on underlying concepts or one single, universal indicator, to address a single category for fish products in studies and policies (Naylor et al., 2021).

4. MATERIALS AND METHODS

4.1. Role of the freshwater aquaculture sector, as an animal protein source, in the food availability and food access of the LAC region

The contribution of fish to household food and nutrition security depends upon access and availability; this last one for food-fish has recognized a function of production, whereas the greatest influence on access to food is price, largely determined by markets and incomes trade (Beveridge et al., 2013). In this research the two components of food security are analyzed considering the following aspects:

- Food availability: The role of freshwater aquaculture is analyzed at regional and country level, through indicators on production, fish trade (exports – imports), and the identification of production methods.
- Food access: Analysis (regional and country-level) considering the indicators of fish trade, and prices.

The food security approach "prioritizes trade-oriented goods, imports, and intensive agriculture while promoting poverty-alleviation policies" (R. Merino, 2020); being the trade sector an essential component, this research details the analysis on the value of trade, share, and the quantity (volume) of the imports and exports of the freshwater fish aquaculture products, since the tendency in one of the trade indicators does not always reflect in the same way in others; therefore, it is necessary to include these three factors in the analysis of export commodities to better understand the overview (Cubillos et al., 2021).

The databases considered are FAO Fisheries and Aquaculture Statistics (FishStat) for fish production (values and volume), imports, export, (values and volume), and commodities food balance sheet in the FAO yearbook (FAO, 2021a).

4.2. Identifying the integration level of the freshwater aquaculture and food security in the public policies of the top 10 largest producer countries of LAC

To develop this was adapted a methodology proposed by Koehn (2019) determining the level of integration of freshwater aquaculture in the food security policy of each of the ten (10) LAC's countries, and the level of integration of food security in the aquaculture policies of these countries as well; implementing a content analysis of the national documents, and considering the scale presented in Table 7 to determine the integration level.

Table 7. Scale for the assessment of the level of integration in the national policies.

Level	Description
Low	Only several mentions of the fields object of analysis
Moderate	The fields are included among the objectives of the policy
High	The Fields are included in objectives, with specific details and action items needed

Source: adapted by author from (FAO, 2020)

4.3. Influential drivers of the growth of freshwater aquaculture in LAC that contributes to the reduction of poverty and food insecurity in the countries of the region

The links between aquaculture and poverty alleviation are complex and still unclear; the absence of good conceptual models produce inconsistent results at national level (Béné et al., 2016). It is necessary to determine if aquaculture supports the needs of poor and food-insecure populations via domestic production or trade, or indirectly via purchase of nutritionally rich dietary substitutes (Golden et al., 2017).

The term driver forces, considered in this research, has been widely used in the fish sector studies (Allison et al., 2009; Béné et al., 2016; Gephart et al., 2020; Rice & Garcia, 2011). The analysis of this component is developed with a cross-sectional time-series data analysis (panel data), from 2000 to 2019, considering the availability of regions' data on the freshwater aquaculture drivers: fish production, fish food export-imports; the last ones associated with apparent consumption and trade data (World Bank, 2013). From these drivers were identified the most influential ones on poverty alleviation and undernourishment of the region.

The analysis of driver forces was done with multiple regression analysis, which is implemented to predict a dependent variable from two or more independent variables; with this regression is possible to forecast the scores on cases for which measurements have not yet been obtained or might be hard to obtain (Field, 2017). The regression equation can be used to classify, rate, or rank new cases. Multiple regression is developed for each aspect (poverty alleviation, and undernourishment), to identify the most influential drivers of freshwater fish aquaculture in each aspect.

In the Table 8 is presented the summary of fish indicators considered as independent variable for the two multiple regression models, moreover, the expected influence that the author considers the fish variables probably would present on the dependent indicators, according to the hypotheses established (H_2, H_3, H_4, H_5). One of the dependent variable for the regression is Prevalence of Undernourishment (PoU), defined as proportion of the population whose habitual food consumption is insufficient to provide the dietary energy levels required to maintain a normal active and healthy life (FAO, 2014).

The second dependent variable is Poverty headcount ratio at $2.15 a day (2017 PPP) as dependent variable. This indicator is the percentage of the population living on less than $2.15 a day at 2017 purchasing power adjusted prices. As a result of revisions in PPP exchange rates, poverty rates for individual countries cannot be compared with poverty rates reported in earlier editions (World Bank, 2022a).

Table 8. List of variables for multiple regression analyses

Variable	Unit	Source	Expected Influence
Dependent variable			
Prevalence of undernourishment in LAC	% of population	World bank	
Poverty headcount ratio at $2.15 a day (2017 PPP) in LAC	% of population	World bank	
Independent variable			
Share of aquaculture production in LAC freshwater fish production	(Aquaculture production/ Total Freshwater fish Production) *100	FishStatJ	Negative
Share of freshwater fish aquaculture production in LAC fish production	(Freshwater fish aquaculture production / Total Fish Production) *100	FishStatJ	Negative
Share of freshwater fish production in LAC fish food production	(Freshwater fish production / Total fish Food Production) *100	FishStatJ	Negative
Share of freshwater fish exports in Total LAC fish food exports	(Freshwater fish exports/ Total Fish Food Exports) *100	FishStatJ	Positive
Share of Freshwater fish imports in Total LAC fish food imports	(Freshwater fish imports/ Total fish food imports) *100	FishStatJ	Positive

Source: elaborated by author

The regression included multiple correlation coefficients such as R and R-squared. The last one shows the proportion of the variation in the dependent variable explained by the independent variables. ANOVA sig., in multiple regression helps to assess the overall significance of a model, if $P<0,05$ the model is significant (Field, 2017).

For the analysis of driver forces was established four (4) hypotheses; on one site hypothesis H_2 establishes that share of aquaculture production in the LAC freshwater fish production is the driver force that most impacts the reduction of undernourishment. Whereas hypothesis H_3 stated that shares of freshwater fish aquaculture production in the food balance trade of LAC influence positively on the prevalence of undernourishment.

Regarding the influence on poverty headcount ratio, hypothesis H_4 presents percentage of aquaculture production in LAC freshwater fish production as the most influential driver force on this poverty indicator. And hypothesis H_5 establishes that freshwater fish production shares in the food balance trade of LAC positively influences this dependent variable.

4.4. Emerging role of fish commodities as an animal protein source in LAC by 2030, and comparative analysis with developing regions

The consumption of animal products is a crucial issue for global food security; the rise in the standard of living allowing access to sources of animal protein (Caillavet et al., 2019). The growth in the consumption of animal products is greater than the growth rate of the population (Steinfeld et al., 2006), and due to the social inequality in the consumption of animal products the level of income plays on the one hand between countries on a global scale (Sans & Combris, 2015). Furthermore, the consumption of meat highlights conflict between two development goals: food security and biodiversity conservation (Rentsch & Damon, 2013).

It was developed an analysis of food security from the food access approach, through the assessment of the crude oil prices influence on the trade of animal protein commodities (import-export prices and volume), in LAC region, and two developing regions (Middle East and North Africa (MENA), and East Europe and Central Asia (EECA).

Through statistical analysis of cointegration and causality, in the software R Studio, was determined the cointegration of oil crude prices with the export- import prices of animal protein commodities (fish, bovine, swine, poultry, and goat), during 2000 to 2021, for each of the largest traded countries analyzed, to identify commodities and trade flow with the highest and lowest impact by crude oil prices fluctuations. Table 9 presents the variables and sources considered in this research, for each animal protein, and crude oil prices as independent variable.

Table 9. Variables details for animal protein analysis

Variables	Category	Source
Dependent variables		
Meat of **bovine** animals; fresh, chilled or frozen.	Import and export ➢ Quantity: Weight in kilograms ➢ Trade value: USD	UN Comtrade FAOSTAT
Meat and edible offal of **poultry** fresh, chilled or frozen.	Import and export ➢ Quantity: Weight in kilograms ➢ Trade value: USD	UN Comtrade FAOSTAT
Fish fillets, fish meat; fresh, chilled or frozen.	Import and export ➢ Quantity: Weight in kilograms ➢ Trade value: USD	UN Comtrade FAOSTAT
Meat of **swine**; fresh, chilled or frozen.	Import and export ➢ Quantity: Weight in kilograms ➢ Trade value: USD	UN Comtrade FAOSTAT
Meat of **sheep or goats**; fresh, chilled or frozen.	Import and export ➢ Quantity: Weight in kilograms ➢ Trade value: USD	UN Comtrade FAOSTAT
Independent variable		
Global Crude Oil Prices	USD per cubic meter	Crude oil prices (ourworldindata.org)

Source: elaborated by author

The data of production volume and trade value, for the animal protein commodities during the period analyzed (2000 – 2021), were obtained mainly from UN Comtrade database and complemented with FAOSTAT.

It was defined the recent top five (5) of the largest exporters and importers countries in the three developing regions, based on trade value and volume. Table 10 detailed the countries per animal protein commodity and per region, which were considered in this research. The complete list of countries considered in each region, for this filter, is presented in **Appendix 3**.

Table 10. Top 5 of the largest exporter and importer of animal protein commodities in the countries per developing region

		Bovine	Poultry	Swine	Fish	Goat
Latin America and Caribbean	**Export**	Brazil Argentina Mexico Uruguay Paraguay	Brazil Argentina Chile Dominican Rep Uruguay	Brazil Mexico Chile Argentina Paraguay	Chile Argentina Uruguay Peru Ecuador	Uruguay Chile Argentina Mexico Colombia
	Import	Chile Mexico El salvador Brazil Uruguay	Mexico Chile Guatemala Peru Colombia	Mexico Chile Colombia Argentina Uruguay	Brazil Mexico Colombia Peru Argentina	Brazil Mexico Trinidad & T Jamaica Bahamas
Middle East and North Africa	**Export**	UAE Egypt Saudi Arabia Jordan Kuwait	UAE Saudi Arabia Tunisia Oman Jordan	UAE Oman Egypt Bahrain Morocco	Morocco Oman Tunisia Mauritania Saudi Arabia	UAE Saudi Arabia Jordan Bahrain Oman
	Import	Egypt Jordan Saudi Arabia UAE Kuwait	Saudi Arabia UAE Kuwait Qatar Oman	UAE Oman Bahrain Lebanon Egypt	Saudi Arabia UAE Kuwait Lebanon Oman	UAE Saudi Arabia Qatar Jordan Oman
Eastern Europe and Central Asia	**Export**	Poland Belarus Lithuania Ukraine Hungary	Poland Turkey Hungary Ukraine Russia	Poland Hungary Russia Czechia Slovakia	Poland Turkey Russia Croatia Lithuania	Russia Romania Bulgaria North Macedonia Slovakia
	Import	Russia Bulgaria Czechia Bosnia Croatia	Russia Kazakhstan Czechia Romania Slovakia	Poland Czechia Romania Hungary Russia	Poland Russia Lithuania Ukraine Belarus	Russia Croatia Bulgaria Poland Romania

Source: Author

The statistical analysis and econometrics methods used are detailed in Figure 7, describing the four (4) sections considered from the data treatment until the cointegration and causal analysis.

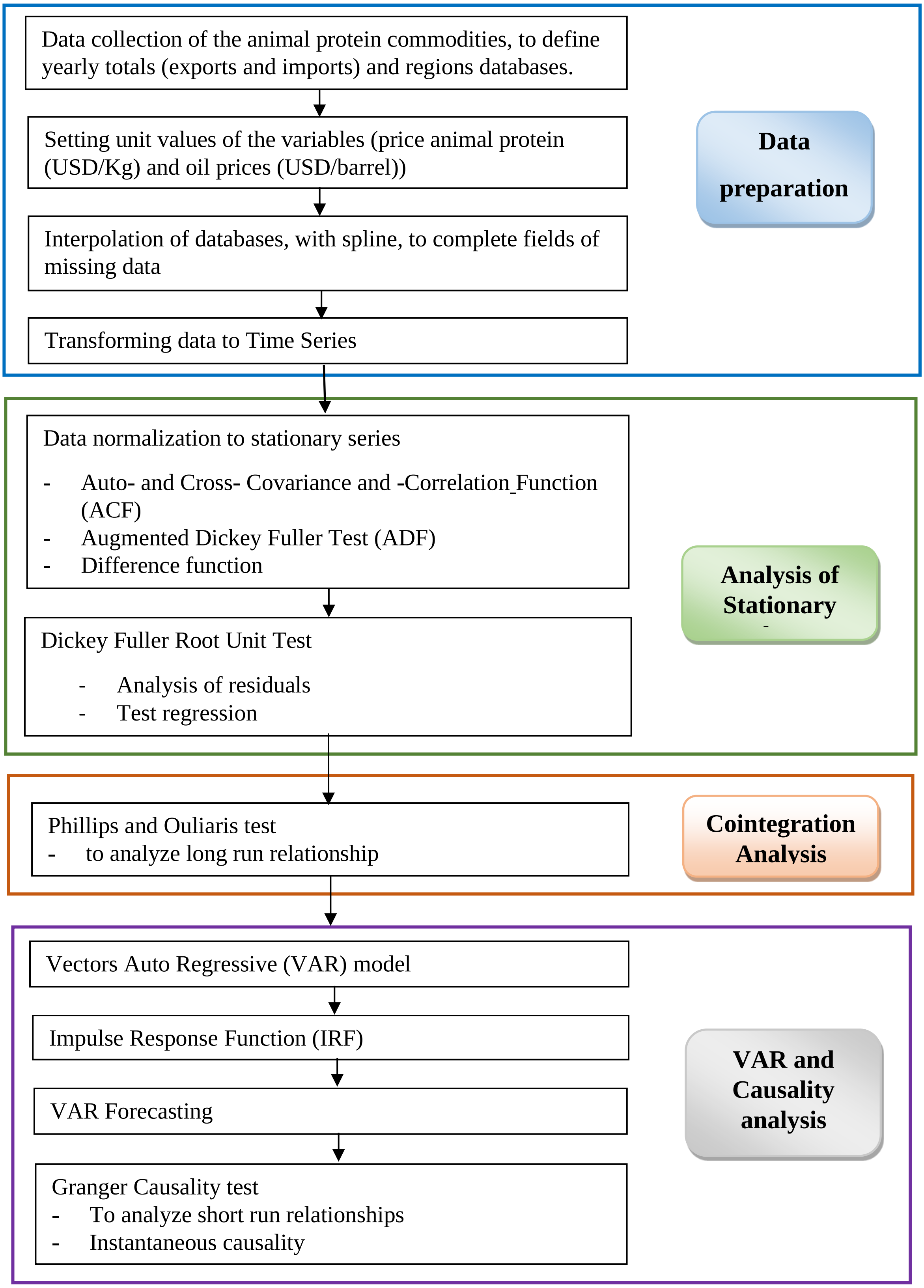


Figure 7. Process of statistical analysis for cointegration and causal analysis in animal protein prices.

Source: Elaborated by author

4.4.1. Data Preparation

a) Collecting the commodities' data (fresh, filled, and frozen products) for each animal protein, to define the yearly totals of production and trade value, for exports and imports, per country.

b) Organizing the region's database for each animal protein commodity.

c) Calculating and setting the unit values of the variables, the price animal protein (USD/Kg) and oil prices (USD/barrel).

d) Interpolation: (Spline) This function predicts values that fall between 2 existing data points; it is considered for data that come from the same region.

   This tool was used to complete lack of countries' data in some years.

e) Transforming the data to Time Series:

   Time series data is a collection of observations obtained through repeated measurements over time.

4.4.2. Analysis of Stationary data

a) Normalization:

   Scales each input variable separately to the range 0-1. This is also known as Min-Max scaling to normalize data on a similar scale.

b) Auto- and Cross- Covariance and -Correlation Function (ACF):

   Autocorrelation analysis facilitates detecting patterns and checking for randomness.

   Autocorrelation is the correlation between a time series with a lagged version of itself. The ACF starts at a lag of 0, which is the correlation of the time series with itself and therefore results in a correlation of 1. The lag is returned and plotted in units of time.

c) Augmented Dickey Fuller Test (ADF):

   It was done to review that all data is stationary, if the data was not stationary it should be treated to became stationary, since this is necessary to assess the cointegration between the variables.

   For this test is set the null hypothesis= series has a unit root, or it is not stationary

   If p-value is smaller than the significant value (0.05) the null hypothesis can be rejected and accept the alternative hypothesis= Data is stationary

d) Difference function:

   Indicates how many times need to be differentiated a variable to be stationary.

e) Dickey Fuller Root Unit Test:

   This test permits checking if the residuals data is stationary.

If p-value is > 0.05, the residuals are no stationary. If the variables are stationary means they are cointegrated.

- Analysis of residuals:

To check the co-integration of variables, through the generation of residuals (errors) of models. Once the model is generated, it should test if residuals are stationaries. If residuals are stationary the variables are co-integrated. If cointegration test is positive, means that variables have relationship of equilibrium in the long term.

- Test regression:

The cointegration test checks if the errors are stationary. If test-statistic is lower than critical values, at 10%, falls in the region of non-rejection Ho = No stationary; falls in the region of accepted Ho, which means that there is a unit root.

- Test with tendency – Test regression trend.
  Add tendency variable to the model, looking for residuals be stationaries.
- Test with constant – Test regression drift.
- Test with constant and tendency – Test regression None.

The hypotheses considered in this test were: The residuals are non-stationary (Ho) and the residuals are stationary (H_1).

4.4.3. Cointegration Analysis

Phillips and Ouliaris test:

It is used to determine if there is a long-run relationship between the variables. If p-value < 0.05 the null hypothesis can be rejected, meaning the variables are cointegrates.

The hypotheses considered in this test were:

- Null Hypothesis (H_0): There is not cointegration between the 2 variables.
- Alternative Hypothesis (H_6): There is cointegration between the 2 variables.

4.4.4. VAR model and causality analysis

a) Vectors Auto Regressive (VAR) model:

It is an Econometric model multivariate, System of regressions or equations.

There are not endogenous or exogenous variables (it's not needed to identify dependent and independent variables). Used for forecasting.

Consideration to build VAR models:

- Optimal Lag length**:** To identify # of observation that should be excluded (more lags, loss observations, dimensionality problem) (using few Lags, serious autocorrelation problem with the errors). To define # Lag use information criteria.
- Estimate equations - model: Coefficients of regression models
- Check model is stable: through Roots of the characteristic polynomial (stability condition).

  If all the values in this section are < 1, there is stability, meaning that there is a correct number of lags, and the order of the VAR model (p=) Is correct.

b) Impulse Response Function (IRF)

It traces the dynamic path of variables in the system to shocks to other variables in the system. This is done by:

- Estimating the VAR model.
- Implementing a one-unit increase in the error of one of the variables in the model, while holding the other errors equal to zero.
- Predicting the impacts h-period ahead of the error shock.
- Plotting the forecasted impacts, along with the one-standard-deviation confidence intervals.

IRF chart presents how to change one variable when there is a change in the other variable. If the response is close to 0, the response is insignificant. As far is the line from 0 is the significant of the response to the shock.

The dot lines are the confidence interval.

c) VAR Forecasting:

Forecasts are generated for VAR models using an iterative forecasting algorithm:

- Estimating the VAR model using OLS for each equation.
- Computing the one-period-ahead forecast for all variables.
- Computing the two-period-ahead forecasts, using the one-period-ahead forecast.
- Iterating until the h-step ahead forecasts are computed.

d) Granger Causality

It is a statistical method used to determine if one time series is useful in forecasting another. It is concerned to short run relationships between variables. The test is based on regression analysis and is commonly used in econometrics and finance. The test examines whether a model that uses current and past values of an X variable, and current and past values of Y variable can predict future values of Y, has smaller forecast error than a model than only uses current and past values of Y to predict Y.

Granger causality indicates if there is a correlation between the past values of one variable and the present value of another. Meaning that the causal variable could be used to predict future movements in the other variable (forecast another variable). It tests the null hypothesis (Ho) that the past values of one time series do not provide any information about the future values of another time series beyond what is already provided by the past values of the latter series.

The null hypothesis can be rejected and infer that time series X Granger causes time series Y if the p-value is less than a particular significance level [p-value <0.05], then it is concluded that the first series Granger-causes the second series. For this research the hypotheses were set as:

- Null Hypothesis (H_0): Oil prices do not granger cause price of respective animal protein.
- Alternative Hypothesis (H_7): Oil prices granger cause prices of respective animal protein.

e) Instantaneous Causality:

X instantaneously Granger causes Y if a model that uses current, past and future values of X, and current and past values of Y, to predict Y has smaller forecast error than a model than only uses current and past values of X and current and past values of Y (Kirchgässner et al., 2013). In other words, Instantaneous granger causality answers the question: does knowing the future of X help better predict the future of Y?

- H_0: There is No instantaneous causality between variables.
- H_8: There is instantaneous causality between variables.

5. RESULTS AND DISCUSSION

5.1. Role of the freshwater aquaculture sector, as an animal protein source, in the food availability and food access of the LAC region

Fish is recognized as a highly traded commodity both globally and locally, since it is considered as an efficient source of protein, especially for impoverished populations; due in particular to its accessibility and availability (Kawarazuka & Béné, 2010), these two components of food security are analyzed in this research.

In this chapter are identified the characteristics and contributions of the LAC fish products and freshwater aquaculture activity to the region's food availability and access. The availability of these resources is assessed through production indicators, highlighting their role as sources of animal protein in the region. This analysis also includes a comparison with other significant sources of animal protein in LAC, such as bovine, poultry, swine, and goat products. Regarding food access component, trade value indicators, specifically the balance between exports and imports of fish and four other types of animal protein, were taken into account.

5.1.1. Food availability approach

International agricultural trade has influenced the food systems of the countries through efficiently moving of agricultural commodities from surplus to deficit regions. Trade mechanisms continue to be pivotal in ensuring that consumers have access to adequate, safe, and nutritious food, while generated incomes for farmers, workers and traders in agriculture and food industry (OECD/FAO, 2023). Regarding the dimension of availability, was point out how higher levels of trade openness yield to a better food availability through increased efficiency in domestic food production and higher quantities of food inflows for importing countries (Marson et al., 2023).

The analysis of the role of fish commodities at the regional level employs indicators on production and fish trade, including exports and imports. This approach identifies the net trade of animal proteins in Latin America and the Caribbean (LAC) and highlights the significance of the fish sector. Figure 8 illustrates the animal protein products that contributed to the LAC trade balance from 2000 to 2021, showcasing the net trade and the proportion of each of the five commodities.

The observed surplus balance indicates that the region exports large quantities, primarily of bovine and poultry products, with 3.9 million tons and 2.6 million tons respectively, while importing smaller amounts of animal protein commodities. Swine and goat products presented highest imports than exports, at the beginning of the period analyzed and in 2015. Nevertheless, it is important to recognized that food import may also have a positive effect on the stability of domestic food availability in case of negative production shocks (Marson et al., 2023).

It is highlighted that the swine's net trade has undergone considerable changes, reflecting that in LAC this commodity might be more affected by internal and external factors than other animal protein products. This suggests a complex interaction of market demands, production capacities, and possibly regulatory and environmental considerations impacting the trade dynamics of swine commodities in the region.

The net trade of fish commodities in LAC has presented fluctuation during the period analyzed; on one side the tendency of the net was mainly surplus, except for the low deficit presented in the 2015's balance, confirming the fish net export projection by World Bank, (2013), which indicated that LAC have been the largest fish exporter region, maintaining surplus balance in 2010-2030 period. And on the other side, the trade surplus on LAC fish in the recent years did not overcome the highest fish net surplus of 2005, with around 463.000 tons.

This situation let identified that during the period analyzed the net balance of fish products has maintained the third position among the animal protein products traded in LAC. Nevertheless, regarding the proportion of the fish surplus trade growth, fish production traded has not been at the same level of growth to the biggest animal protein traded in LAC (poultry and bovine); the trade of fish commodities passed from occupied the second position to the third position with an extensive difference in the share respective bovine and poultry.

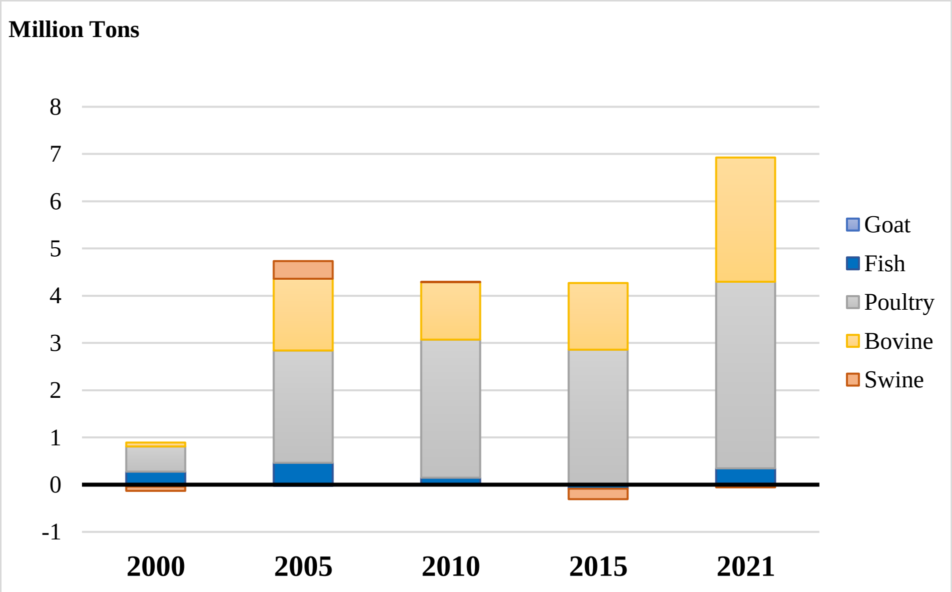


Figure 8. Trade balance of animal protein commodities in LAC region

Source: Elaborated by the author from statistical data of UN Comtrade (United Nations, 2024) and FAOSTAT (FAO, 2022a)

The region is among the largest fish producer, and apart from Asia and China, it occupies major position in terms of volume, with growth prospects of 33% in the next 10 years. Chile, with Brazil and Ecuador, accounted for 77% of the South America volume production. Together with Mexico and Peru, these countries contribute 87% of LAC's aquaculture production, according to data from FishStatJ (FAO, 2023).

In LAC, South America leads in volume terms, currently accounting for 90% of totals (FAO, 2016) and occupied the fourth position in world fish aquaculture producers (FAO, 2020), which was identified with the top five (5) of largest fish exporter countries of the region considered for this research, observed in Figure 9.

In the recent years, the export volume of fish commodities in LAC has been dominated by Chile, Argentina, Peru, Ecuador and Uruguay, whose production mainly rely on marine fish. In relation with other animal proteins production, Chile, Peru and Ecuador are the countries of the region where fish is the leader among the animal proteins traded, concentrating almost the total of exports of this sector in Peru and Ecuador, while Chilean fish exports gathered 47% of the total country's animal protein exports in 2021.

Fish exports from Argentina and Uruguay have excelled among the region , however the trade in these countries have been leading by bovine products, alike the tendency in LAC. It is highlighted the development of fish production in Chile, it has been overtaking largelly the other top countries.

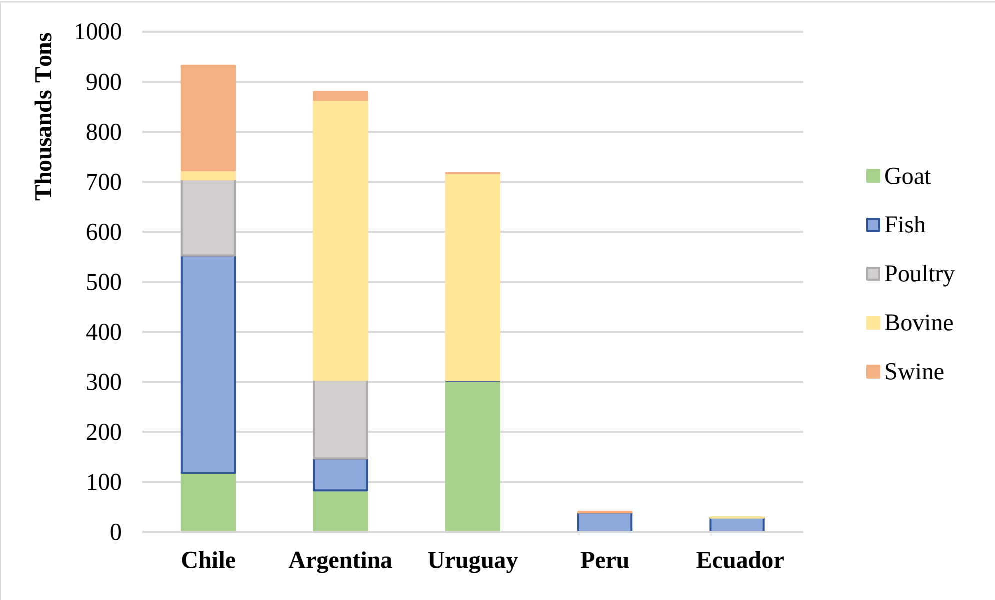


Figure 9. Animal protein exported in the largest fish exported countries of LAC, 2021

Source: Elaborated by the author from statistical data of UN Comtrade (United Nations, 2024) and FAOSTAT (FAO, 2022a)

Specifically on aquaculture development, Chile accounted for 43% of the volume of LAC aquaculture production between 2012 and 2014. Chile, together with Brazil and Ecuador, accounted for 77% of the South America volume production. Adding Mexico and Peru, these five countries contribute 87% of the LAC aquaculture, showing highly concentrated production in a few countries. OECD/FAO (2012) projected that aquaculture will continue as one of the fastest growing animal food-producing sectors, exceeding bovine, swine and poultry.

According to (FAO, 2020). Chile occupied eighth position in the ranking of major fish producers, with 1.0 million tons of finfish (excluding aquatic plant). Brazil comes thirteenth with 0.6 million tons of farmed species (excluding aquatic plant), and eighth in finfish production from island aquaculture (507.1 thousand tons). Regarding the exports of fishmeal, Peru and Chile have been identified as the leading exporters countries, with a 58% share of total fishmeal exports (OECD/FAO, 2012).

Aquaculture production is poised for continual expansion across all continents. According to projections from the FAO (2020), LAC region is anticipated to witness a substantial upswing of up to 33% by 2030. This expansion is evident in the participation of marine and freshwater aquaculture in fish production, as shown in Figure 10. Despite a reduction in the total fish production in the LAC region, aquaculture is steadily gaining more prominence in the industry.

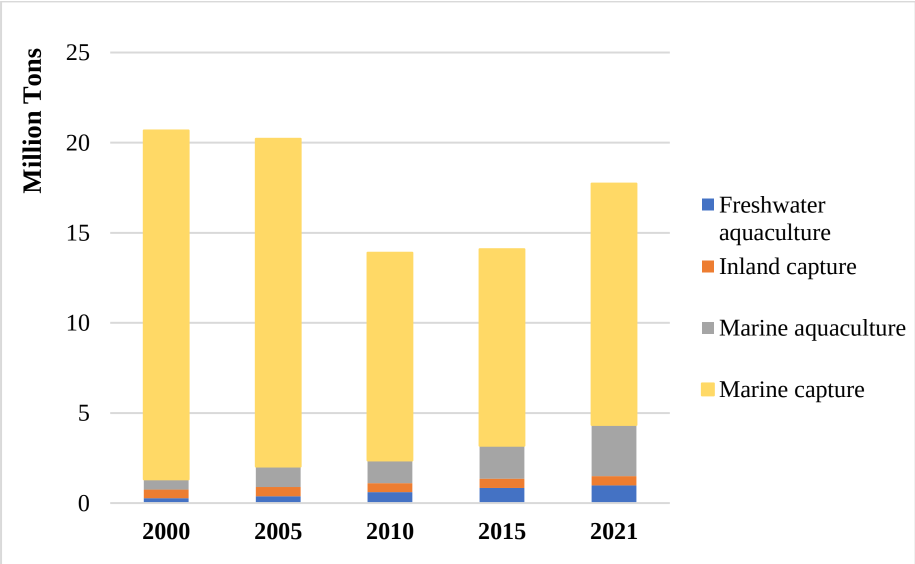


Figure 10. Source of fish production in LAC region 2000-2021

Source: Elaborated by the author from statistical data of FishStatJ database (FAO, 2023)

Agricultural commodities were traded more intensively in the early 2000s, reflecting the implementation of the WTO agreement on agriculture, and China accession to the rules of trading system (OECD/FAO, 2023). Capture fisheries and aquaculture play vital roles in bolstering the global animal-source protein supply. However, it is noteworthy that while the contribution of aquaculture to this supply is on the rise, capture fisheries are not experiencing similar growth, as highlighted by Boyd et al. (2022).

World Bank's prospective model predicts that total fish supply will likely be equally split between capture and aquaculture by 2030, 62% of food fish will be produced by aquaculture by 2030. In LAC aquaculture's share grew from 4.05% in 2000 to 21.6% in 2021.

The aquaculture sector has not simply increased the availability of fish, it has also prevented prices from rising as they would have if only wild fisheries were to meet the general increase in demand (Béné et al., 2016; World Bank, 2013). In the case of the LAC region, this scenario is not visible yet, since fish production is subject mainly on capture method (around 80% by 2021).

According to FAO (2021), in the first half of 2020, the COVID 19 pandemic hit all regions of the world, some worse than others, including many of the major fish producing/consuming countries and global fish feed suppliers. The same report points out that in some LAC countries, restrictions on population movement have been introduced slowly, so the real impact on food systems has generally not been felt.

Despite this, in Brazil, the market for fresh fillet or fresh fish has almost disappeared. Sales to local slaughterhouses decreased as a result of reduced demand from restaurants that are the main customers. However, there is now an emphasis on adapting the market with home delivery of clean and cooked fish. The Government of Peru has launched a specific fund that aims to reactivate the aquaculture sector, through innovation in areas such as market recovery, increased production efficiency, reduced production costs and production of inputs accessible to farmers. In Chile, some of the aquaculture-related measures include home deliveries of fresh and frozen fish. (Aquaculture's role in Latin America and Caribbean and updated data production)

Challenges aquaculture data collection, worker health and safety and decent work, mitigating impacts from and improving actions against covid-19, animal health, as well as low mechanization of the industry (Aquaculture's role in Latin America and Caribbean and updated data production)

The world trade of fish for human consumption has indeed been growing significantly it is expected to expand moderately over 25 % (OECD/FAO, 2012). In addition, it is important to note that the growth rate has been consistent.

5.1.2. Food access approach

Food prices has been recognized as one of the most important drivers in food and agriculture sector (FAO, 2022b); from 2010, fish market has evidenced higher fish production, demand, trade and prices (OECD/FAO, 2012). Commercialization of fish contributes to improved purchasing power and higher overall food consumption, besides to offer important livelihood opportunities in developing countries; these activities reinforce the economic and social empowerment of women (Kawarazuka & Béné, 2010). Higher prices in international markets can incentivize domestic producers to divert production from national markets to export (Marson et al., 2023).

The analysis of fish trade indicators and prices is crucial in understanding the complex impact of trade on food security. This impact can affect food access by causing changes in real income, while food trade directly influences food availability and utilization through imports and exports. It is important to note that the fishery sector is a significant part of international trade, with many countries trading a wide variety of fish species and products.

Due to most of databases and indicators available for fish commodities present totals of the production, without classified the source (capture or aquaculture), for this section of the research was analyzed the fish price and production of LAC as a whole, to identify its situation in relation to the other animal proteins.

At the begining of the period analyzed (2000) fish export prices had the second lowest LAC export value (1.94 USD/Kg) among the animal protein of this research, ending by 2021 (4.10 USD/Kg) as the third price among the five (5) analyzed. Peru and Ecuador are the countries with the highest fish export prices of the region.

While other countries, such as Argentina and Chile presented export prices around 2.80 USD/Kg in 2021, Peru registered 4.56 USD/Kg, and Ecuador 7.55 USD/Kg, because of the particularity of these two (2) countries, with the sort of fish commodities and prices, the fish export price average of the region is impacted.

In Figure 11 is presented the ranges of the fish prices traded in the prioritzed LAC countries, with data available by 2021. The maps reflect wider range in the fish prices exported, whereas fish import prices range is lightly short, from 1.27 USD/Kg in Peru to 6.51 USD/Kg in Argentina; exposing that fish commodities imported in the region tempt to be of lower trophic level, and therefore low price.

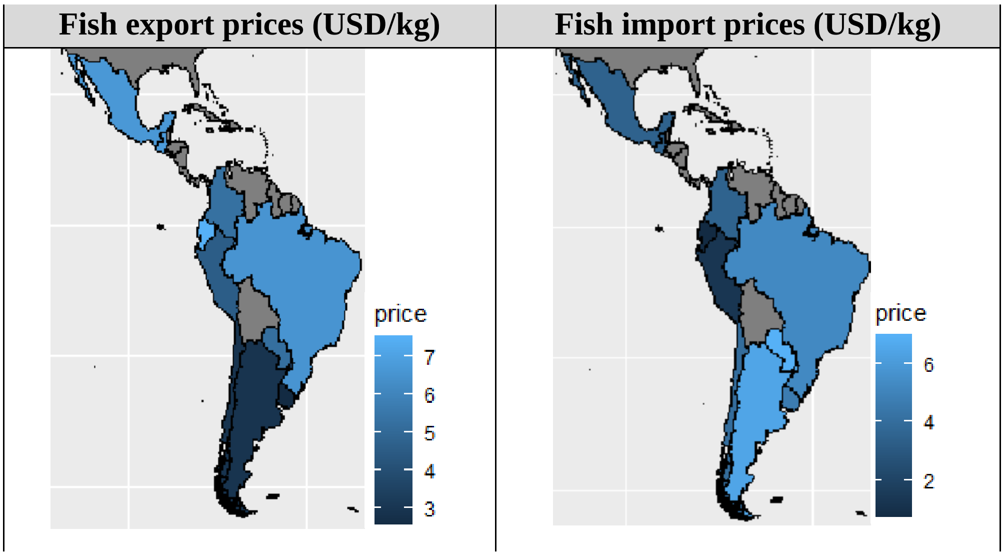


Figure 11. Export and import fish prices (USD/kg) in LAC countries by 2021

Source: elaborated by author, based on data from UN Comtrade and FishStatJ

The previous figure lets to identify the peculiarity where exporter countries as Mexico, Ecuador and Peru, which presented the highest fish export prices per kg traded, are the ones with low prices in the fish commodities imported. On the other side, Paraguay (7.03 USD/kg), Argentina (6.51 USD/kg) and Uruguay (4.71 USD/kg) presented high prices per kg of fish imported, while the fish exports done were on volume with lower value, 5.24 USD/kg, 2.92 USD/kg and 2.54 USD/kg, respectively. This presents the particularity in several countries of the region to focus fish exports and imports in opposite sort of fish commodities.

Regarding the animal protein export prices in LAC, these are presented in Figure 12, showing that during the period analyzed the export range was from 0.67 USD/Kg to 6.95 USD/Kg, being poultry the animal protein exported with the lowest price, except in 2003 (1.81 USD/Kg), and 2021 (3.16 USD/Kg), whereas Bovine, highlighting Brazil, Uruguay and Argentina, and Goat (Uruguay – Mexico – Chile – Argentina) were the exports with the highest price per Kg. Fish prices for exports and import were growing higher that swine and poultry, this last one had the lowest animal protein price in the exports and imports of the region.

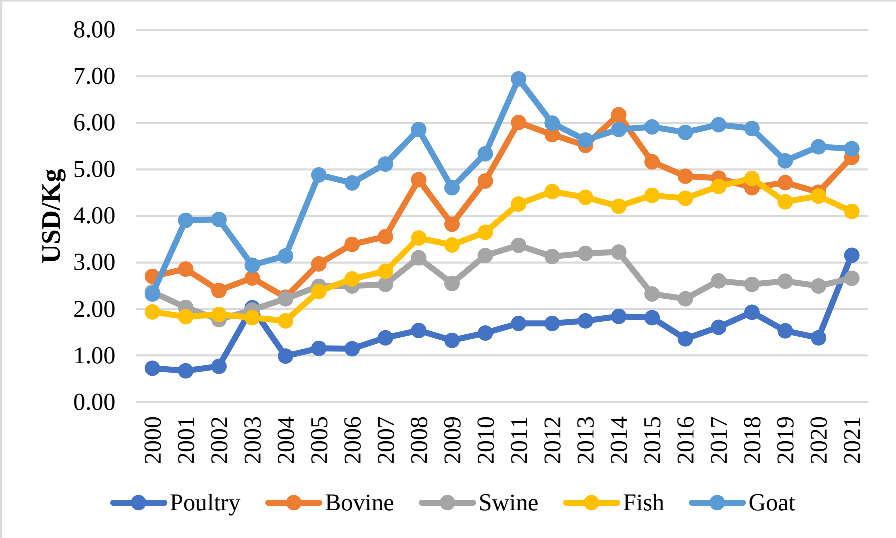


Figure 12. Export prices of animal proteins commodities (USD/Kg) in LAC region 2000-2021

Source: Elaborated by the author from statistical data of UN Comtrade and FAOSTAT

About imports prices, at the beginning of the century all the animal protein prices were grouped around two (2) USD/ Kg, and during the period analyzed the amounts per commodities scattered. Poultry import price was the unique that decreased; swine maintained the price between two (2) to three (3) USD/Kg; while fish, bovine and goat presented mainly a growing trend, as can be observed in the Figure 13. By 2021 goat was the most expensive animal protein imported in LAC (5.72 USD/Kg). Excepting of goat prices,the gap between export and import prices, per Kg, of each animal protein kept closed, meaning that the sort of commodities exported had similar characteristics to ones imported.

Respecting the differences between animal protein prices in LAC, the trade indicators analyzed let identifying that at the beginning of the period (2000 to 2021) there was not large differences between the animal protein prices; around 2004 began considerable variations, in export and import prices, and by 2020-2021 is appreciated wider differences among the commodities prices.

In the situation of the fish trade, despite of the reduction in the total LAC fish production between 2005-2015, the export price per kilogram traded maintained a growth trend, quite different to the association mentioned by Marson et al. (2023), that higher prices in international markets can incentivize domestic producers to divert production from national markets to export.

This might be presented by the sort of fish commodities exported by this time from LAC; the freshwater aquaculture productions is based on omnivores and herbivores, low trophic level species, with lower prices (Gyalog et al., 2022); however other fish source, as marine and capture, could contribute with carnivores fish species with high level and values, as the Ecuadorian's fish trade presented.

Once the expansion of aquaculture reach out more participation in the LAC fish production, this will cause that prices of farmed fish grow slowly than other animal foods source, even this growth reigned in increases of captured fish prices as Belton & Thilsted (2014) mentioned.

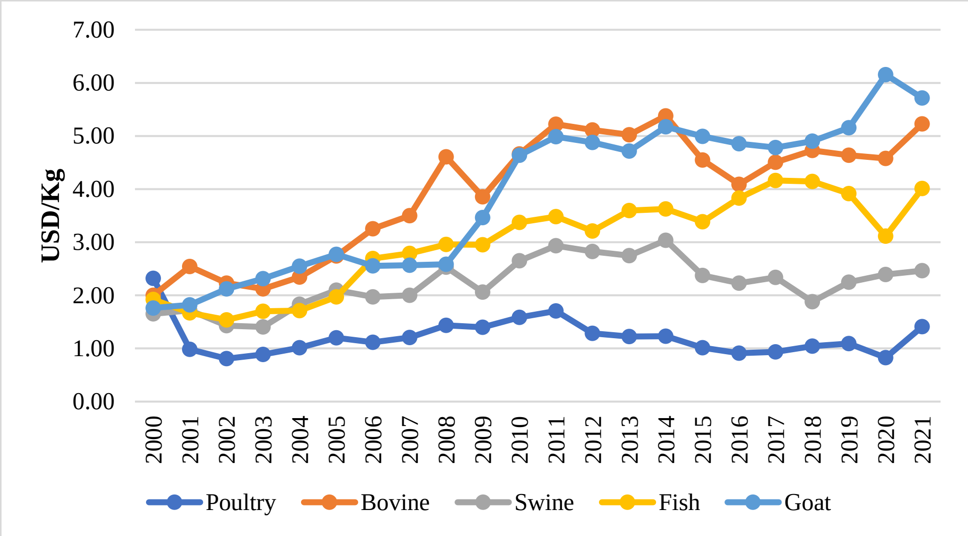


Figure 13. Import prices of animal proteins commodities (USD/Kg) in LAC region 2000-2021

Source: Elaborated by the author from statistical data of UN Comtrade and FAOSTAT

Poultry import price, as the cheapest animal protein, was observed that tended to maintain the price along the period analized, around 1USD/kg. On the other side, fish prices by 2000 was 1.92 USD/Kg, reaching the highest price at 2017 (4.16 USD/Kg); by 2021 this price was 4.01 USD/Kg.

Several factors interact with market dynamics, adding force to, or on the contrary counterweighing the price effect caused by the increased supply of fish following the expansion of aquaculture. The decrease in price that is expected, in theory from the development of aquaculture, with some potential positive impact on the food intake of the local population, has yet to be confirmed and seems to be complicated by the unclear and still poorly documented economic interactions that exist between aquaculture and wild fisheries at the local level (Kawarazuka & Béné, 2010).

5.2. Identifying the integration level of the freshwater aquaculture and food security in the public policies of the top 10 largest producer countries of LAC

Food security policies present an approach to establishing long-term goals, programs, and strategies (Aassouli et al., 2023), thus, the importance of integrated them in the analysis of an economic sector development, due to they have a significant role influencing changes in market structures (OECD/FAO, 2023). The review of the food security policies in the countries analyzed reflects that all of them establish goals, programs and strategies for long term, in the frame of these regulation; moreover, the policies are oriented to period between four to ten years.

From the three criteria analyzed, climate change is the one that has been most integrated in the food security policies of these LAC countries, included it as a programmatic focus (Guatemala), identified as critical issue that can restrict food production (Mexico and Costa Rica), needed to implement measures of climate changes adaptation, to guarantee access to adequate food at every time (Peru and Honduras).

Regarding aquaculture, only three countries (Brazil, Peru and Honduras) included it in their food security polices, nevertheless the integration is considerably low, as it is scarcely mentioned as part of fish sector and agri-food systems.

Fish and fisheries are the most common concepts described in the policies and programs, with moderated level of integration in the countries of the region. The policies encompass all forms of fish production, including aquaculture, and fisheries activities, indicating a holistic view of the sector. Among the strategies to boost productive systems and fish consumption is highlighted the Ecuador's case, it had high integration of fish sector as focus action, through programs like "eat fish -eat healthy", and incorporating fish in the food programs of vulnerable communities. Similarly, Brazil's strategy to promote fish consumption as healthy food reflects a proactive stance towards leveraging the nutritional benefits of fish to enhance food security.

Another approach identified was the fisheries communities, in several policies as for Paraguay and Peru these communities are associated to poverty, and prioritized to improve economic conditions, and food production. In the Peruvian policy is recognized the importance of increase food offer, due to less than 1/3 of national fish production is addressed to human consumption, and the other production is for industrial transformation.

In general, while climate change is a well-integrated aspect of food security policies in LAC countries, aquaculture remains underrepresented. The analysis highlights the importance of fish and fisheries in the region's food security strategies, with Ecuador and Peru providing notable examples of high integration of the fish sector into their policies, as can be observed in Table 11, with policies, and the integration level of the concepts considered.

Table 11. Integration in food security policy and strategies of LAC countries

	Type of Food security policy		Integration in the food security policies/Plan			Document analyzed
	National policy	Other	Climate change	Aquaculture only	Capture fisheries only	
Brazil		X	Moderate	Low	Low	National Plan of food security and nutrition 2016-2019 (CAISAN, 2018)
Colombia	X		Moderate	--	--	National Policy of food security and nutrition (Colombian government, 2008)
Mexico		X	Low	--	---	Institutional program of Mexican food security 2020-2024 (SADER & SEGALMEX, 2020)
Peru		X	High	Low	High	National strategy of Food and Nutrition security 2013-2021(Ministry of Agriculture and Irrigation & European Union, 2013)
Honduras	X	X	High	Low	Low	National Policy of Food and Nutritional security for long term, and National strategy (Honduras Government, 2018). National Strategy of Food and Nutrition security 2010-2022 (UTSAN, 2010)
Cuba		X	Low	--	Low	Plan of Food Sovereignty and nutritional education of Cuba (Ministry of Agriculture, 2020b)
Paraguay		X	Low	--	Moderate	National Plan of Food and Nutritional Sovereignty and Security 2009 (FAO & STP, 2009).
Ecuador		X	--	--	High	Intersectoral Plan of Food and Nutrition Ecuador 2018-2025 (Ministry of Health & FAO, 2018)
Costa Rica	X		High	--	--	National Policy of Food and Nutritional Security 2011-2021 (Ministry of Health, 2011)
Guatemala	X		Moderate	--	Low	National Policy of Food and Nutritional Security (SESAN, 2005)

Source: Elaborated by author

These integration results of the food security policies in LAC reflect that most of the countries of the region have not acknowledged the key role that sustainable aquaculture can provided, such as nutritious food, generating income, and supporting livelihoods, thereby addressing multiple dimensions of food security.

Besides, this low integration identified between the sector and food security policies might be caused by the scarce information documented on the direct and indirect impacts of fish on nutritional status that Kawarazuka & Béné (2010) highlighted; fish as essential fatty acids has been well documented, however, few information has been given on the role of fish as a source of micronutrients, this is a potential entry points for improving household nutritional security.

It was identified the need in the LAC countries to promote through the food security policies aquaculture expansion and sustainability, to become this sector an integral component of national food security strategy, as it has been recommended by experts Kawarazuka & Béné (2010), incorporating strategies to recognized fish production and consumption as nutritious food.

Fish and aquaculture policies were part of the other scope, these policies are instrumental in ensuring food security by expanding the production and commercialization of fish and aquaculture products, thereby guaranteeing the availability of quality and safe products.

The integration of food security within fish and aquaculture policies varies, with most countries exhibiting a moderate to high level of integration, as is detailed in Table 12. Notably, Costa Rica and Paraguay stand out for having specific programs and plans dedicated to aquaculture development, indicating a proactive approach to leveraging aquaculture as a means to enhance food security. Approach needed since it has been recognized and demonstrated that aquaculture development contributes to food and nutrition security (Belton et al., 2018).

Sustainability is a core focus within the Colombian and Brazilian fish policies, and programs to distribute fish products to children and elderly people, rural population to boost healthy consumption and food security. In the documents, the sector is recognized for its significant contributions to food security, social development, employment, social welfare, and dietary improvements in countries like Honduras. Other authors (Béné et al., 2016) found out, as well, the moderate to high recognition of the interactions and synergies between this sector, its commodities and the food security.

Regarding climate change, despite that aquatic systems, which sustain aquaculture, are already affected by climate change, and projections indicate that these will be accentuated in the future (Kreiss et al., 2020), this component presents low level of integration in the fish and aquaculture policies of most of the LAC countries, highlighting, it is described as a key condition for fish production in Brazilian's policy.

Considering the results from the policy integration, the hypothesis H_1 set is rejected, since the development of Freshwater fish Aquaculture in LAC has not been supported with the integration of fishing and aquaculture sector on the Food Security national policies. It was recognized that the gaps on policy makers identified by Béné et al. (2016) are still present in LAC, such as unawareness of the causal relationship between aquaculture and food security, fish data management, articulation of poverty, and information of fish contribution to the diets. Direct impact on nutritional contribution through fish consumption, and on incomes increased purchasing power through the sale of fish (Kawarazuka & Béné, 2010).

Table 12. Integration in Fish - Aquaculture policy and strategies of LAC countries

	Type of Fish-Aquaculture Policy		Integration in the Fish - Aquaculture Policies/Plan		Document analyzed
	National policy	Other	Climate change	Food security	
Brazil		X	Low	Low	National plan of aquaculture 2022-2032 (MAPA, 2022)
Colombia	X		Low	Moderate	Integral policy for the sustainable development of fish (FAO & Ministry of Agriculture and Rural Development, 2015)
		X	-	High	Strategy for the Fish and aquaculture policy 2018-2022 (Ministry of Agriculture and Rural Development, 2019)
Mexico		X	Low	High	National program of fish and aquaculture 2020-2024 (Ministry of Agriculture, 2020a)
Peru	X		High	High	National policy of aquaculture 2030 (Ministry of production, 2023)
Honduras	X		-	Low	General law of fish and aquaculture 2015 (OSPESCA & SICA, 2017)
		X	Moderate	Moderate	Strategic plan to improve freshwater aquaculture (ONUDI & Honduras Government, 2022)
Cuba		X	-	Moderate	Fishing Law No. 129/2019 (Ministry of Production, 2020)
Paraguay		X	Low	Moderate	National program of sustainable development of aquaculture (Ministry of Agriculture andLivestock, 2015)
Ecuador		X	Low	Low	Organic law for the aquaculture and fishing development (Ministry of Production, 2020)
Costa Rica		X	Low	-	Program of sustainable development of fish and aquaculture (INCOPESCA, 2022)
		X	-	Moderate	Strategic plan for aquaculture 2019-2023 (SEPSA & INCOPESCA, 2023)
Guatemala	X		-	-	Integration policy of fish and aquaculture 2005 (OSPESCA & Central America Integration Systems, 2005)

Source: Elaborated by author

Given the anticipated 30% increase in global demand for food fish by 2030, due to population growth, it is concerning that per capita fish consumption is expected to decline in regions such as Latin America, Europe, Central Asia, and Sub-Saharan Africa. Specifically, the per capita fish consumption in LAC is projected to decrease from 8.4 kg per person in 2010 to 7.5 kg per person by 2030 (World Bank, 2013). Considering this, it is crucial for fish and aquaculture policies to incorporate strategies aimed at boosting per capita fish consumption within the region. Despite LAC's status as a significant producer and net exporter of fish, this has not translated equivalently into nutritional benefits for the LAC population.

On the other hand, the global food and agricultural market's resilience has been significantly influenced by trade policies; international trade meets food demand of some economies with food shortages by supplying food produced elsewhere beyond self-consumption (Zhang & Zhou, 2022).

The global food and agricultural market has become more resilient, but countries remain vulnerable to the impact of trade shocks on food security (OECD/FAO, 2023), as sudden changes in global food prices, trade restrictions, or disruptions in the supply chain (Erokhin & Gao, 2020). Thus, the role of trade policies in shaping the geography of agricultural trade should be integrated and managed in the analysis and design of food security policies.

Reforming agricultural policies to address climate change mitigation objectives is a crucial step in combating the significant impact of agriculture on climate change. Agriculture is indeed a major driver of climate change, contributing to it through both direct on-farm emissions and indirect emissions from land use change. Direct on-farm emissions, such as methane and nitrous oxide, are released from agricultural activities like livestock farming and fertilizer use. Indirect emissions, on the other hand, result from changes in land use, such as deforestation for agricultural expansion, which releases stored carbon into the atmosphere.

5.3. Influential drivers of the growth of freshwater aquaculture in LAC that contributes to the reduction of poverty and food insecurity in the countries of the region

Studies have explored the relation between fish consumption and poverty (Garaway, 2005; Jahan et al., 2010), identifying in some cases that increased demand for fish might be linked to fisheries conflicts (Spijkers et al., 2021). Poor people in developing countries tend to depend essentially on carbohydrate-based diets for their nutritional intake, these are relatively low in protein and micronutrients. Then, fish can play a particularly important role in combating micronutrient deficiencies (Kawarazuka & Béné, 2010).

Considering the knowledge gaps in the fish sector, identified by Béné et al. (2016) and Bostock et al. (2016), this chapter developed the analysis to determine the factors/drives from fish and aquaculture activity that contribute the most to reduction of undernourishment and poverty in LAC.

5.3.1. Multiple regression analysis for Prevalence of undernourishment in LAC

Considering the five (5) independent variables, selected for the regression, was design the below formula for the linear model

$$\textit{PoU LAC}^{(1)} \sim \%\ \textit{FwAqP in LAC FP}^{(2)} + \%\ \textit{AqP in LAC FwP}^{(3)} + \%\ \textit{FwP in\_LAC FfP}^{(4)} + \%\ \textit{FwE in LAC TFfE}^{(5)} + \%\ \textit{FwI in LAC TFfI}^{(6)}$$

(1) Prevalence of Undernourishment in LAC
(2) Share of Freshwater fish Aquaculture Production in LAC Fish Production
(3) Share of Aquaculture Production in LAC Freshwater fish Production
(4) Share of Freshwater fish Production in LAC Fish Food Production
(5) Share of Freshwater fish Exports in Total LAC Fish Food Exports
(6) Share of Freshwater fish Imports in Total LAC Fish Food Imports

In the Table 13 can be observed the model summary and ANOVA test results; highlighting the F value data, which refers to the probability that the variation caused by the independent variables is real and not due to chance (Bevans, 2023); in this model three (3) variables presented considerable variations (% FwAqP in LAC FP, % AqP in LAC FwP, and % FwI in LAC TFfI), as higher F value as more likely that influence caused by the independent variable is real. In addition, all variations that are not explained by the independent variables are represented by the residual variance, 0.19 for this model.

The Pr (>F) is the p value of the F statistics, which shows how likely it is that the F value calculated occurs if the ANOVA's null hypothesis of no difference among group means were true. For this model, the same three independent variables with high variations, presented significant p value, meaning that % FwAqP in LAC FP, % AqP in LAC FwP, and % FwI in LAC TFfI have impact on the Prevalence of Undernourishment in LAC.

Table 13. Model summary and ANOVA

	Mean Sq	**F value**	**Pr (>F)**
% FwAqP in LAC FP	62.94	328.388	4.08e-^{11} ***
% AqP in LAC FwP	9.88	51.570	4.70e-^{06} ***
% FwP in_LAC FfP	0.00	0.026	0.874
% FwE in LAC TFfE	0.02	0.127	0.727
% FwI in LAC TFfI	1.26	6.570	0.022 *
Residuals	0.19		

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

Source: Elaborated by author, based of regression analysis output from R Studio with method from Mazerolle (2023).

According to the results presented in Table 14, the model has 0.9651 of coefficient of determination (R2), therefore 96.51% of the PoU LAC is explained by the independent variables. The standard error of regression was 0.4378; this low value indicates that the observations are closer to the fitted line.

The predictor variables with significant value to influence the PoU LAC are % *AqP in LAC FwP* (p value 0.027), and % FwI in LAC TFfI (p value 0.022).

Regarding % Aquaculture Production in LAC Freshwater fish Production, can be analyzed its negative relationship with PoU LAC, with the increase of the production of freshwater fish aquaculture in the region, from a share of 35.83% in 2000 (data per year in **Appendix 2**), to 65.60% of share in the total freshwater fish production of LAC by 2019, thus, contributing to the food availability.

Table 14. Results of multiple regression between Fish Driver Forces and Prevalence of Undernourishment in LAC

Residual				
Min	**1Q**	**Median**	**3Q**	**Max**
-0.652	-0.190	0.012	0.142	0.802
Coefficients				
	Estimate	**Std Error**	**T value**	**Pr(>|t|)**
(Intercept)	17.934	1.992	9.003	**3.37e-^{07}**
% FwAqP in LAC FP	-0.740	0.803	-0.922	0.372
% AqP in LAC FwP	-0.155	0.063	-2.468	**0.027**
% FwP in_LAC FfP	0.224	0.302	0.742	0.470
% FwE in LAC TFfE	-0.121	0.067	-1.807	0.092
% FwI in LAC TFfI	0.096	0.038	2.563	**0.022**
Residual standard error: 0.4378 on 14 degrees of freedom				
Multiple R-squared: 0.9651	Adjusted R-squared: 0.9526			
F-statistic: 77.34 on 5 and 14 DF	p-value: 1.08e-09			

Source: Elaborated by author, based of regression analysis output from R Studio,with method from Zeileis & Hothorn (2002).

The second predictor variable (% Freshwater fish Imports in Total LAC Fish Food Imports) reflected a positive relationship with PoU LAC; during the period analyzed freshwater fish food imports grew from 4.65% (2000) to occupied 31.94% of the total fish food imports of LAC in 2019, meaning that local production did not cover satisfactory this food demand, there was less availability of freshwater fish (food commodities) produced locally.

The equation of this model is defined as:

$$\textbf{PoU LAC} = \mathbf{17.93+(-0.155)*X_1 + 0.096*X_2} \qquad R^2 = 0.9651$$

$\mathbf{X_1}$= % Aquaculture Production in LAC Freshwater fish Production

$\mathbf{X_2}$= % Freshwater fish Imports in Total LAC Fish Food Imports

The model presents that if the aquaculture production increase its share in the total fish freswater production of LAC by one (1) unit, the PoU LAC will decrease on 0.155 units. Thus, the hypothesis H_2, which stated that share of aquaculture production in freshwater fish production of the region is the fish driver force that most impact the prevalence of undernourishment is accepted.

Whereas, if the share of freshwater fish imports grows one (1) unit in the total LAC fish food imports, PoU LAC will increase 0.096 units; with this is rejected the hypothesis H_3, that establish positive impact of fish freswater product balance trade with the PoU LAC, since export variable has negative relationship with the dependent variable.

5.3.2. Multiple regression analysis for Poverty Headcount Ratio in LAC

Considering the same five (5) independent variables, of the previous regression, was design the below formula for the linear model of Poverty Headcount Ratio (PHR LAC)

PHR LAC ~ % FwAqP in LAC FP + % AqP in LAC FwP +
% FwP in_LAC FfP + % FwE in LAC TFfE) + % FwI in LAC TFfI

The model summary and ANOVA of this regression generated three (3) large F values, related to probability of variation caused by the independent variables on the Poverty Headcount Ratio in LAC; as can be reviewed in Table 15, % FwAqP in LAC FP, % AqP in LAC FwP, and % FwI in LAC TFfI are the independent variables with the largest amounts, as well as in the model of Prevalence of Undernourishment. The residual value is 0.67.

Table 15. Model summary and ANOVA

	Mean Sq	F value	Pr (>F)
% FwAqP in LAC FP	176.20	264.263	**1.75e-^{10} *** **
% AqP in LAC FwP	22.87	34.305	**4.17e-^{05} *** **
% FwP in_LAC FfP	1.73	2.588	0.1300
% FwE in LAC TFfE	0.13	0.197	0.6639
% FwI in LAC TFfI	4.48	6.723	**0.0213 ***
Residuals	0.67		

Signif. codes: 0 ‘*’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1**

Source: Elaborated by author, based of regression analysis output from R Studio with method from Mazerolle (2023).

Regarding Pr (>F) p value of the F statistics, the results confirm that the three independent variables with the highest F value, present the significant p value as well, having influence on the Poverty Headcount Ratio of LAC region. At this point can be observed the relevance of the changes on the freshwater aquaculture production and the fish food imports on the tendencies of poverty and undernourishment in LAC.

The results of the PHR LAC regression are presented in Table 16, the model has 0.956 of coefficient of determination (R2), therefore 95.6% of the PoU LAC is explained by the independent variables. The standard error of regression was 0.816. The predictor variables with significant value on PHR LAC are the ones related with balance trade, % FwE in LAC TFfE (p value 0.036), and % FwI in LAC TFfI (p value 0.021).

The one with negative influence, on the dependent variable, is % Freshwater fish Exports in Total LAC Fish Food Exports; with this is rejected the hypothesis H_5, due to only fish imports had positive impact on PHR LAC. In addition, hypothesis H_4 is rejected as well, since the share of aquaculture production did not influence the reduction of poverty headcount ratio.

Table 16. Results of multiple regression between Fish Driver Forces and Poverty Headcount Ratio in LAC

Residual				
Min	**1Q**	**Median**	**3Q**	**Max**
-1.506	-0.448	0.022	0.488	1.270
Coefficients				
	Estimate	**Std Error**	**T value**	**Pr(>|t|)**
(Intercept)	25.492	3.715	6.862	7.79e-^{06}
% FwAqP in LAC FP	-0.794	1.497	-0.531	0.604
% AqP in LAC FwP	-0.205	0.117	-1.745	0.102
% FwP in_LAC FfP	0.099	0.564	0.176	0.103
% FwE in LAC TFfE	-0.289	0.125	-2.321	**0.036**
% FwI in LAC TFfI	0.182	0.070	2.593	**0.021**
Residual standard error: 0.816 on 14 degrees of freedom				
Multiple R-squared: 0.956		Adjusted R-squared: 0.941		
F-statistic: 61.62 on 5 and 14 DF		p-value: *4.926e-*^{09}		

Source: Elaborated by author, based of regression analysis output from R Studio,with method from Zeileis & Hothorn (2002).

Regarding fish exports, by 2019, 37.95% of the total fish food commodities, exported from LAC, corresponded to freshwater fish, by 2015 almost reach 40%. Considering that exports can impact either availability or economic access to food, this model reflects that freshwater fish food exports contribute to the reduction of LAC poverty ratio, might impact indirect aspects from the fishing sector, as employment and incomes.

Agriculture exports in the region are considered a driver of production growth, depending of open trade and the global market. This last one is increasingly volatile and fragile, with geopolitical fragmentation risk, improved internal market integration and functioning of small and medium enterprises, cooperatives and family farms could expand trade within the region, thus diversify market opportunities and improve the sector's resilience.

About freshwater fish imports in total LAC fish food imports, alike the previous regression with PoU, this variable presented positive relationship with PHR LAC. Increments of freshwater fish imports might generate less development of fish and aquaculture sector, affecting purchasing power and food access, as well.

The equation of this model is defined as:

$$\mathbf{PHR\ LAC = 25.492 + (-0.289)*X1 + 0.182*X2} \qquad R^2 = 0.956$$

$\mathbf{X_1}$= % Freshwater fish Exports in Total LAC Fish Food Exports

$\mathbf{X_2}$= % Freshwater fish Imports in Total LAC Fish Food Imports

The model presents that if the freshwater fish food exports increase its share in the total fish food exports of LAC by one (1) unit, the PHR LAC will decrease on 0.289 units. On the other side, if the share of Freshwater fish Imports grows one (1) unit in the Total LAC Fish Food Imports, PHR LAC will increase 0.182 units.

The results of these regressions confirm the strong influence of Fish Imports, World Bank (2013) projections identified increase of fish imports dependency in some regions, from 14% in 2000 to 34% in 2030.

The impact of freshwater fish exports on the reduction of PHR LAC, and the aquaculture production on the decrease of PoU LAC, as identified in the results of this chapter, are aligned with the benefits of aquaculture on household incomes observed in other studies (Kawarazuka & Béné, 2010).

For aquaculture, national and household studies tend to focus on export value chains and use diverse approaches (Kawarazuka & Béné, 2010). They suggest some degree of poverty alleviation and possibly other positive outcomes for adopters, but these outcomes also depend on the small-scale farming contexts and on whether adoption was emergent or due to development assistance interventions (Béné et al., 2016). On the other side, population and income growth have been identified as key drivers on agricultural commodities, in the case of fish products, during 2013-2022 these were determined mainly by population growth (OECD/FAO, 2023).

5.4. Emerging role of fish products as an animal protein source in LAC by 2030, and comparative analysis with developing regions

In previous forecast analysis of fishing sector (World Bank, 2013) have been incorporated indicators such as supply, demand, and trade of fish and fish products. While OECD/FAO (2012) recognized that the main drivers with inpact on fish prices prospects were demand, income, population growth, climate - environment, increase of inputs factors as feed and crude oil, increase of meat prices. These last two factors were considered in this research.

Initially, were identified the price tendencies of the fish commodities traded, considering that fish is the third accessible animal protein price in the region. Figure 14 presents the fish price trend of the largest exporter and importer countries in LAC, and the global crude oil prices tendency, as well.

It can be observed that in the period contemplated most of the fish exporter prices were concentrated around 2 - 4.5 USD/Kg, except for Ecuador, that could trade distinct sort of fish commodities. In addition, from 2015 the differences of the fish export prices of Ecuador and Peru became wider respect the other LAC countries. Highlighting that Peru is one of the largest fishmeal exporter globally, and according to OECD/FAO (2023) this commodities are projected to continue growing by 2030.

OECD and FAO projected that fish sector would experience high prices between 2012 to 2022, as it is confirmed with the results presented in Figure 14, with high production costs as well, due to growing prices of fishmeal and other feeds.

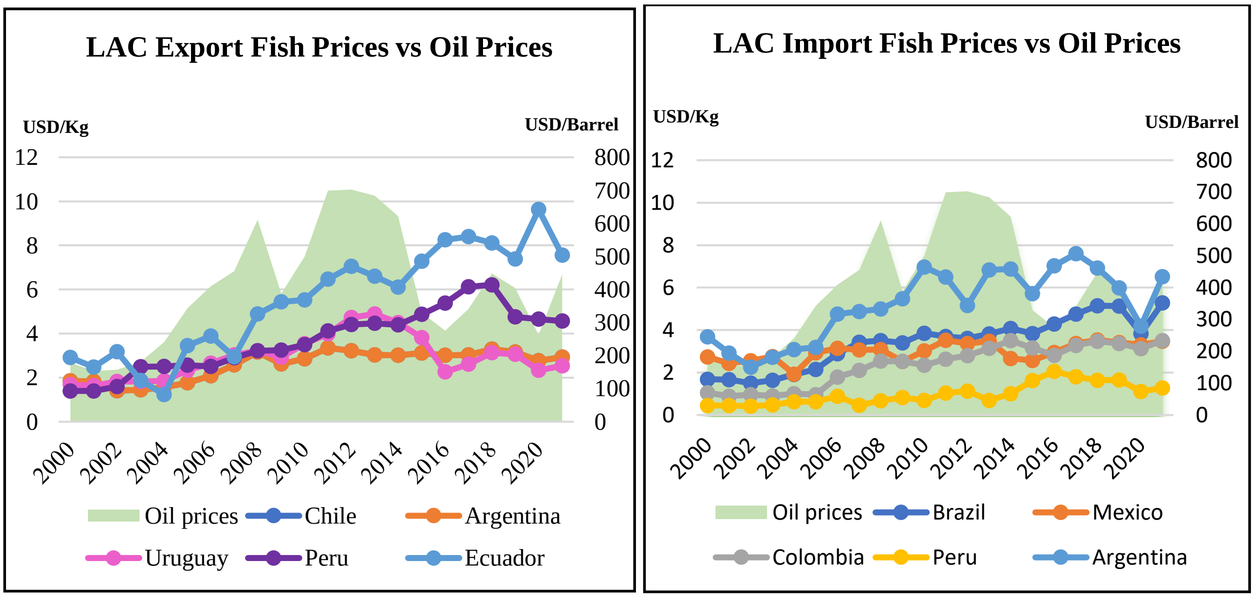


Figure 14. LAC export - import Fish prices (USD/Kg) vs Oil price (USD/Barrel)

Source: elaborated by author, based on data from UN Comtrade and FishStatJ

In relation to fish imports, the prices traded in the region were lower than fish export prices, this situation was favorable for a surplus balance trade on fish commodities in LAC. Among the countries analyzed, the prices were gathered in 0.40 and 6 USD/Kg, approximately, being Argentina the fish import country with the highest prices since 2004.

At this stage, it was not entirely clear the influence of oil prices variations on the LAC fish prices traded, due to the tendencies did not reflecting similar conducts. Therefore, it was performing an extended co-integration and causality analysis in this research, taking into account that previous studies have shown oil prices influence on food production index (Esmaeili & Shokoohi, 2011), meat prices index (Roman et al., 2020; Zmami & Ben-Salha, 2019), and agriculture raw materials (Tiwari et al., 2020).

Recognizing this, it was developed the analysis of oil prices influence on LAC fish prices traded in exports and imports, and its substitute animal protein commodities, since it has been demonstrated that fish prices are impacted by increased competition from other protein sources. Augmented production and falling prices of other protein sources will lead to a softening of demand and reduced prices of aquaculture and capture fisheries products (OECD/FAO, 2023). Thus, the analysis of this macroeconomic factor impact was extended to the animal protein prices of other developing regions, as well.

There are differential factors among the regions analyzed (LAC, MENA and EECA) such as demography, culture, development of the agriculture sector, volume of food trade, among others; however, it was found interesting similarities regarding the most popular animal protein traded. In the three developing regions, poultry has been the largest animal protein commodity, for exports segment and in most of the imports; reflected in the volume as total value traded, indicating its significant role in the food trade of these regions. The dominance of poultry in the animal protein trade underscores its importance in meeting the dietary needs and preferences of the populations in these regions.

Poultry, as the largest animal protein produced and traded, has remained as the fastest growing meat sector in the world, concentrating as well the per capita consumption increase (70%) (OECD/FAO, 2012). The growth in livestock production in developing and developed economies is being led by poultry; in fact, production in developing countries exceeds that of the developed world (Narrod et al., 2008). Poultry production is an integral part of smallholder agriculture in the developing world and has a multidimensional contribution to the livelihood of both rural and urban households (Akinola & Essien, 2011; Birhanu et al., 2023; Guèye, 2000).

The poultry industry possesses the technology, skills and capital to meet the expected demand targets (Kleyn & Ciacciariello, 2021); it adapted to increased demand for economical and safe products by becoming more efficient. From a consumer's perspective, poultry has many competitive advantages over other forms of animal protein, such as convenience, consistent product quality, the absence of religious strictures, a healthy image (white meat), low-cost production, a continuous stream of innovative products, and affordability (Alexandratos & Bruinsma, 2012).

OECD/FAO (2023) has identified a tendency of agriculture commodities traded between regions, the net exporting positions are kept by Americas, Eastern Europe and Central Asia, while the net importing ones are Asia, Middle East and Africa. This can be observed in the animal protein trade as well, as Figure 15 reflects with the three regions analyzed, where LAC has a strong export net and MENA region with trade deficit on these commodities.

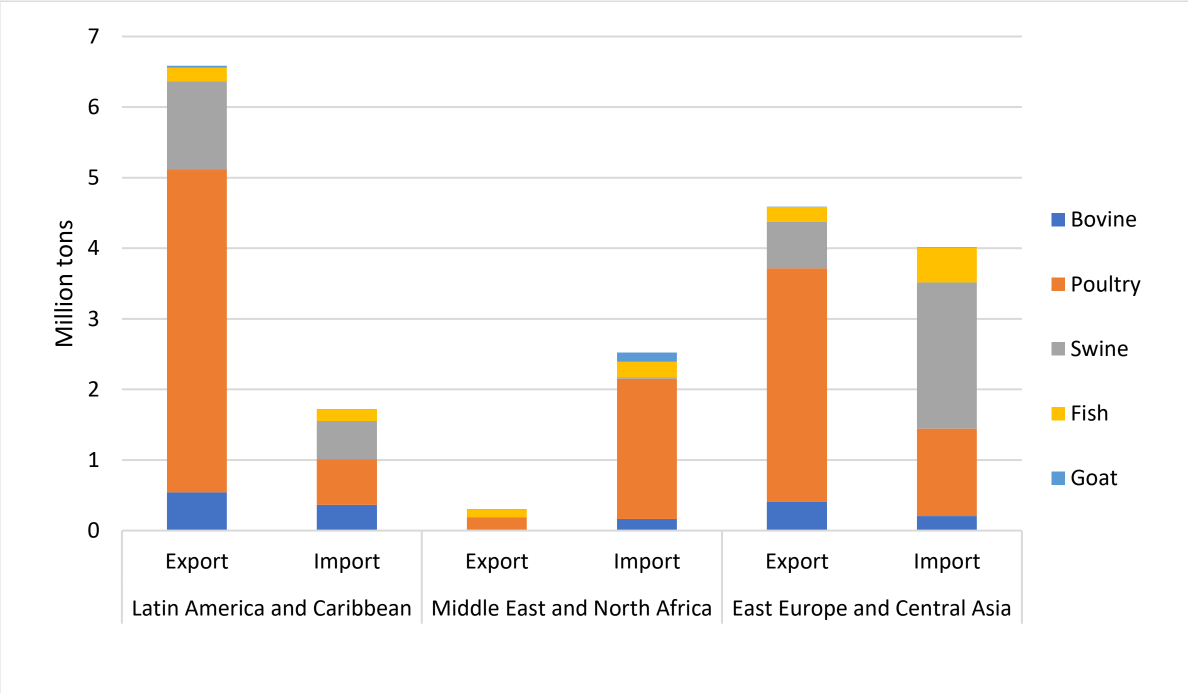


Figure 15. Distribution of animal protein traded in the developing regions, by 2021

Source: Elaborate by author with data from UN-Comtrade and FAO-STAT

It is evident that MENA and EECA presented a higher amount of animal protein imports than LAC. In the case of Near East and North Africa region, imports are projected to continue expanding over the next decade, while export are expected to decrease, increasing the net trade deficit of the region by a further 32% until 2032. This is attributed to the significant population growth in the region and the limited expansion of domestic production, which is constrained by natural resources (OECD/FAO, 2023).

Net import regions are facing a significant challenge in meeting their protein needs, and the projection to increase in net trade deficit highlights the need of a multi-faceted approach that considers both the quantity and quality of the imported protein, as well as the development of domestic production capabilities to ensure long-term food security in the region.

Specifically, fish's scenario is conspicuous, by 2032, global fish exports for human consumption are projected to reach 44 million tons, up from 42 million tons in 2020. Nevertheless, it is interesting to note that upper middle-income countries are the only income class expected to experience and increase in its share of global food fish exports, achieving 48% , while high income countries will account for 31% of total food fish export in 2032 (OECD/FAO, 2023). This shift in the distribution of fish exports highlights the changing dynamics of the global fish trade and the evolving role of different income classes in this industry.

OECD/FAO (2012) mentioned that the market situation for the meat sector is characterized by high nominal outputs prices for all meats, underpinned on the supply side by high input costs, for feed grain and energy related inputs, such as transport and cold chain storage; and these factors tend to favour greater domestic supply responses in developing countries. Meat prices are projected to decline in 2023, and continue to gradually fall in real terms over the next decade as demand weakens, supply chain stabilise, productivity growth and feed cost decrease.

In the consideration of the fish role in the LAC region, price is an important aspect to analyze; projections refers to slightly reduction but remaining high relative to historic levels (OECD/FAO, 2023). Besides, oil and energy prices as part of the analysis of agricultural sector, has been widely integrated, considered energy price forecasts for medium and long-term analysis s (OECD/FAO, 2012).

5.4.1. Analysis of Stationary data

As part of the data treatment for the statistical analysis of crude oil prices influence on animal protein prices traded during 2000 to 2021, Auto- and Cross- Covariance and -Correlation Function (ACF) and Augmented Dickey Fuller Test (ADF) were applied to all animal protein prices data of each country and the respective balance trade (exports -imports). Identifying the non-stationary condition of the time series data with ACF, and the p-value with the ADF Test. Through difference function was applied three (3) differences to all variables (crude oil prices, animal protein prices) to become the data stationary, thus running ADF again to each time series data was confirmed that all values are with ADF p-value below 0.05.

The ACF plots support the confirmation that whole data is stationary and enable to analyze. **Appendix 4** presents the ACF plots for the LAC, EECA and for MENA countries analyzed in each animal protein product. Moreover, **Appendix 5** has the ADF results per animal protein prices, on which can be observed that the data (fish, bovine, poultry, swine, and goat) considered for the three regions rejected the null hypothesis (H0), meaning that the residual data to use in the statistical analysis is stationary, and can be considered for cointegration analysis.

5.4.2. Co – integration analysis

Based on the Phillips and Ouliaris test was determined the long-run relationship between global crude oil prices and animal protein prices (export – exports) for the most traded countries of these animal protein commodities in each developing region.

In LAC, the null hypothesis was rejected in most of the countries (H0: there is not cointegration between the oil prices and animal protein prices), and trade balance as Table 17 shows, meaning that there is cointegration, as long-run relationship, between the oil prices and export-import prices of the animal protein prices in the LAC countries analyzed. The only case of exception for the long run relationship was the import prices of poultry in Chile, whose significant value reflects that there is not cointegration between these prices and the crude oil prices.

The cointegration results in the LAC's animal protein prices traded are aligned with the long- run relationship that have been identified in previous studies between oil prices and agriculture commodities prices, such as eggs in the study of Zingbagba et al. (2020) in Sao Paulo, Brazil, international dairy prices by Zmami & Ben-Salha (2019), meat price index ((Roman et al., 2020) and food price index (Melichar & Atems, 2019).

In **Appendix 6** are the tables with the detailed results of the cointegration assessment for EECA and MENA; in this last region, the results of the countries with the largest trading on the animal proteins, rejecting the null hypothesis, reflect that the import and export prices traded for these commodities presented long term influence of the global crude oil prices.

About EECA, the null hypothesis of the cointegration test was rejected in 49 of the test performed for the traded prices of the animal protein; specifically, the import price of goat to Romania was the only result that accept the null hypothesis, that set no cointegration between variables. From the 150 tests applied for all regions, there were two particulars cases that did no presented cointegration between the variables (import prices of poultry in Chile and goat in Romania).

Can be observed that the long run relationship of crude oil prices with animal protein prices during the period analyzed was not exclusively of one direction of the trade, but applied for both, imports or exports prices, and the influence of oil prices was found in the fish prices traded and all animal proteins considered in this research for the three developing regions.

Considering the long term impact of the oil prices on the fish, and in general animal protein prices, is supported the statement of Bostock et al. (2016) about price as the dominant factor and because of the significant variability over time is highlighted the need for relatively long term financial planning and assessments of the food prices.

Table 17. Phillips and Ouliaris Unit Root Test results for LAC countries

Phillips and Ouliaris Unit Root Test				
H0 = There is not cointegration between 2 variables				
H6 = There is cointegration between 2 variables				
Variable	**Category**	**Country**	**Test result**	**Result**
Fish	Exports	Chile	0.025	**Reject H0**
		Argentina	0.025	**Reject H0**
		Uruguay	0.010	**Reject H0**
		Peru	0.012	**Reject H0**
		Ecuador	0.010	**Reject H0**
	Imports	Brazil	0.010	**Reject H0**
		Mexico	0.010	**Reject H0**
		Colombia	0.010	**Reject H0**
		Peru	0.013	**Reject H0**
		Argentina	0.019	**Reject H0**
Bovine	Exports	Brazil	0.016	**Reject H0**
		Argentina	0.028	**Reject H0**
		Mexico	0.010	**Reject H0**
		Uruguay	0.017	**Reject H0**
		Paraguay	0.010	**Reject H0**
	Imports	Chile	0.010	**Reject H0**
		Mexico	0.010	**Reject H0**
		El Salvador	0.010	**Reject H0**
		Brazil	0.010	**Reject H0**
		Uruguay	0.010	**Reject H0**
Poultry	Exports	Brazil	0.016	**Reject H0**
		Argentina	0.010	**Reject H0**
		Chile	0.010	**Reject H0**
		Dominican Rep.	0.022	**Reject H0**
		Uruguay	0.010	**Reject H0**
	Imports	Mexico	0.011	**Reject H0**
		Chile	0.058	**Accept H0**
		Guatemala	0.010	**Reject H0**
		Peru	0.010	**Reject H0**
		Colombia	0.018	**Reject H0**
Swine	Exports	Brazil	0.020	**Reject H0**
		Mexico	0.022	**Reject H0**
		Chile	0.026	**Reject H0**
		Argentina	0.010	**Reject H0**
		Paraguay	0.045	**Reject H0**
	Imports	Mexico	0.019	**Reject H0**
		Chile	0.012	**Reject H0**
		Colombia	0.022	**Reject H0**
		Argentina	0.010	**Reject H0**
		Uruguay	0.013	**Reject H0**
Goat	Exports	Uruguay	0.034	**Reject H0**
		Chile	0.017	**Reject H0**
		Argentina	0.010	**Reject H0**
		Mexico	0.019	**Reject H0**
		Colombia	0.015	**Reject H0**
	Imports	Brazil	0.035	**Reject H0**
		Mexico	0.010	**Reject H0**
		Trinidad & Tobago	0.010	**Reject H0**
		Jamaica	0.010	**Reject H0**
		Bahamas	0.010	**Reject H0**

Source: Elaborated by author, based on cointegration test output from R Studio, with method from Pfaff, (2008a).

5.4.3. VAR model and causality analysis

The last component of the statistical analysis, to identify trend forecasting and short run relationships, involved the Vector Auto Regressive model (VAR), Impulse Response Function (IRF), forecasting and granger causality test, whose results are presented in this section. It was identified that the optimal lags, to develop the VAR model, were four (4), thus, the coefficient and equation were estimated for each of the animal protein, countries and regions.

5.4.3.1.Impulse Response Function (IRF)

With IRF is plotting the forecasted impacts, along with the one-standard-deviation confidence intervals; these were obtained from oil prices (95% bootstrap CI, 100 run) to predict the impacts ahead of the error shock. The results of Table 18 present the IRS plots for each of the tests, reflecting the confidence interval (red line), with the area of probable impulse response of the respective animal protein prices for the upcoming 10 years.

The responses of LAC animal protein prices to shocks or changes in crude oil prices were, in most of the cases, close to zero, interpreted as significantly low, since as far as the impulse is from zero as significant is the response to the shock.

For LAC export prices, there were cases of exception with high impulse response, in Argentinian prices of bovine (-4 to 2), poultry (-8 to 6) and goat (-8 to 6), Dominican Republic with poultry prices (-60 to 60), Chile with goat prices (-10 to 10), and Ecuador, which had the highest fish export prices of the region, presented high impulse response on this as well (fish export, -4 to 2).

While import prices impulse responses did not present large difference, but relatively similar ranges; there were three (3) high responses on Brazilian prices for bovine (-2 to 3), Uruguayan prices for swine (4 to 4), and Mexican prices for goat (-500 to 500).

The IRF results for the other two regions can be observed in **Appendix 7**; highlighting that in EECA export prices the case of Poland that was part of the largest export countries of the region in four animal proteins, except by goat. The highest impulse response was for fish export prices, between -2 to 2. Russia presented the highest impulse response on swine (-2 to 1) and goat export prices (-5 to 5). While Hungary has similar impulse responses (-1.5 to 5) in the export prices of bovine, poultry, and swine. The impulse response on EECA import prices were, mainly, significantly low, by few countries' exception, such as Poland with fish prices (-5 to 5), and Slovakia in poultry prices (-4 to 4).

In MENA, which includes several oil exporting countries, and whose economies are intrinsically tied to energy markets, the results reflect impulse responses more heterogeneous, being swine's exporter countries the ones that present most of the high IRF; in UAE (-3 to 3), Oman (-6 to 6) Egypt (-4 to 4), and Morocco (-10 to 10). While fish export prices presented a considerable impulse response in Tunisia (-5 to 5) and Mauritania (-4 to 4); bovine prices with Egypt (-6 to 4); poultry with a large range in UAE prices exports (-200 to 100); and goat with Bahrain (-5 to 5) and Oman (-3 to 3).

The response is less significant in the animal protein import prices of MENA; Swine with Oman (-4 to 4) and Egypt (-10 to 10) presenting high IRF; in fish import prices highlighted Oman (-4 to 4); and bovine with Egypt (-4 to 2).

Considering the results of impulse responses, can be analyzed from three (3) approaches:

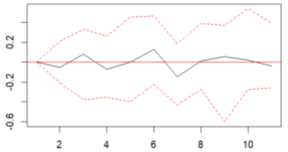
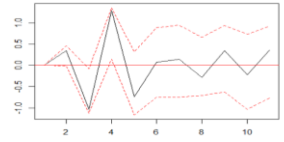
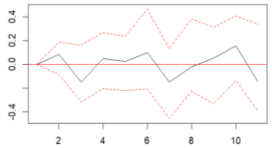
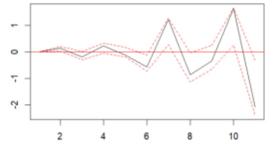
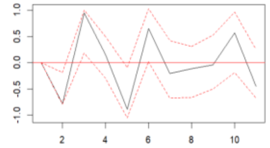
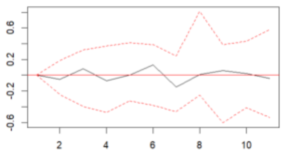
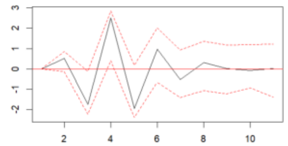
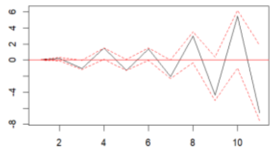
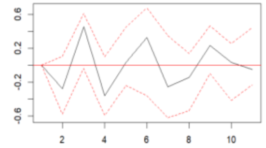
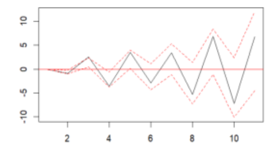
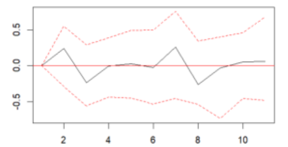
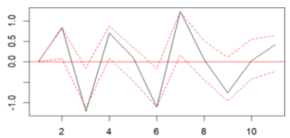
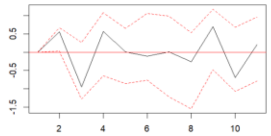
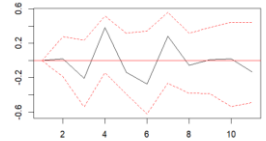
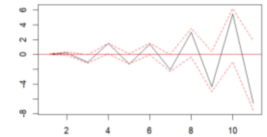
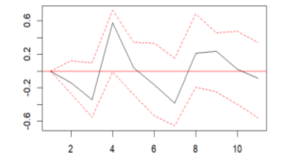
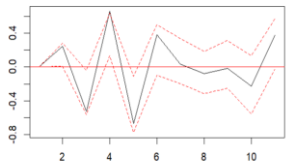
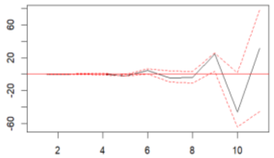
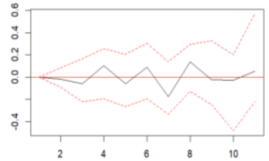
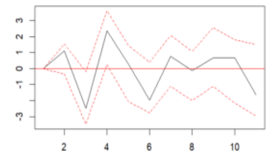
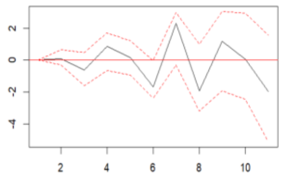
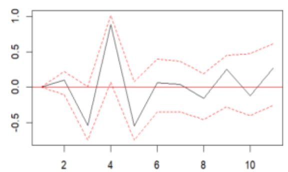
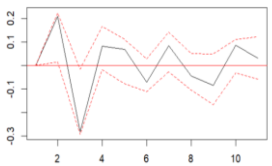
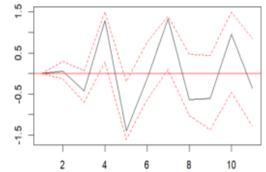
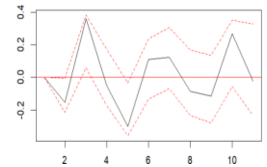
- From the perspective of animal protein commodity: there is not a pattern of high response focuses on a specific animal protein commodity; it was found that cases of exception were mainly linked with region's features.
- Trade flow: it was identified that export prices of countries in MENA and LAC presented more impulse responses and larger ranges than in import prices. In the case of EECA, there were less high responses than the other regions, thus there is not a considerable difference in the IRF of prices traded.
- Regional and countries features: this was identified as a relevant factor of the impulse responses of oil prices variation on animal protein prices, since the results of each region presented their particularities.

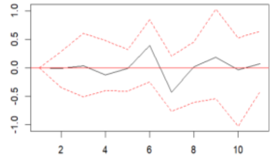
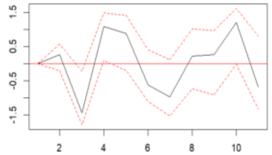
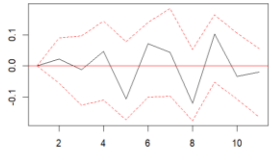
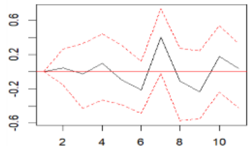
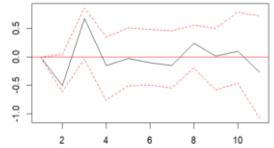
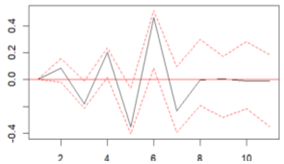
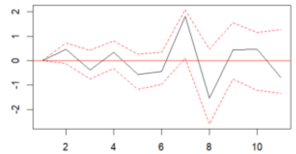
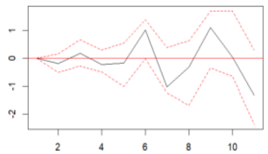
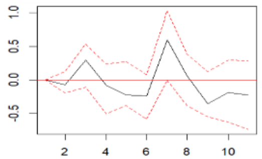
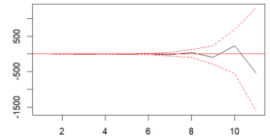
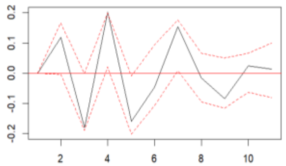
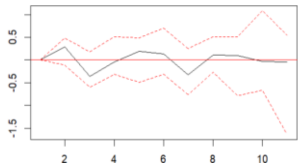
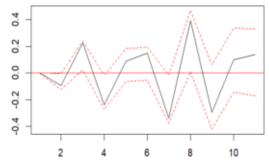
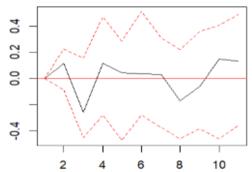
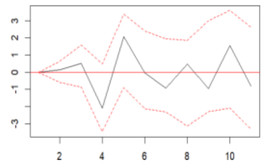
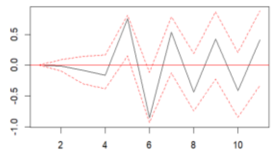
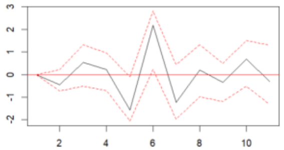
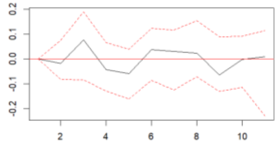
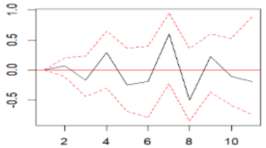
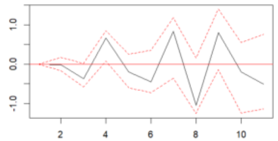
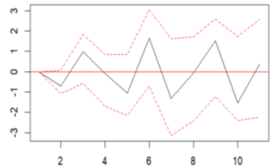
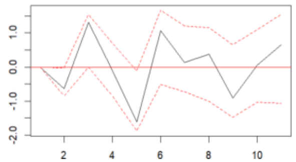
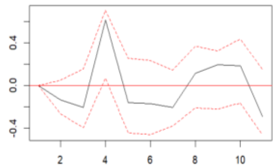
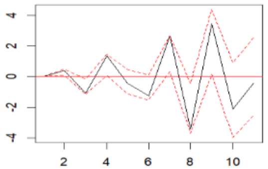
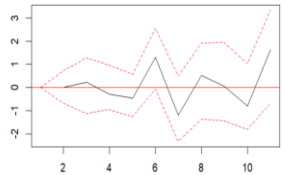
  For MENA region, swine export prices were the most influenced with oil prices shocks, three (3) of the largest countries presented wide ranges in the IRF, and the two (2) exception cases in swine imports had some of the highest ranges, as well.

  On its side, in LAC, Argentina was the country with more high responses in export prices (bovine, poultry and goat), this country presented some of the highest export prices of the region, for bovine and goat, then would be interesting to analyze in further studies if countries with high prices traded are more vulnerable to variation of oil prices.

According to OECD/FAO (2023), among the major challenges in food security have been recognized distribution of incomes, high prices, rising of property, disruptions such as the pandemic and macroeconomic instability in countries.

Table 18. Impulse Response Function (IRF) in LAC countries

	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORT	**Chile** 	**Brazil** 	**Brazil** 	**Brazil** 	**Uruguay** 
	Argentina 	**Argentina** 	**Argentina** 	**Mexico** 	**Chile** 
	Uruguay 	**Mexico** 	**Chile** 	**Chile** 	**Argentina** 
	Peru 	**Uruguay** 	**Dominican Rep.** 	**Argentina** 	**Mexico** 
	Ecuador 	**Paraguay** 	**Uruguay** 	**Paraguay** 	**Colombia** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORT	**Brazil** 	**Chile** 	**Mexico** 	**Mexico** 	**Brazil** 
	Mexico 	**Mexico** 	**Chile** 	**Chile** 	**Mexico** 
	Colombia 	**El Salvador** 	**Guatemala** 	**Colombia** 	**Trinidad &Tobago** 
	Peru 	**Brazil** 	**Peru** 	**Argentina** 	**Jamaica** 
	Argentina 	**Uruguay** 	**Colombia** 	**Uruguay** 	**Bahamas** 

Source: Elaborated by author, based on IRF outputs from R Studio, with methods from Pfaff (2008b)

5.4.3.2. VAR Forecasting

OECD/FAO (2023) highlighted that meat production in developing countries is expected to grow more than double the pace of that in developed countries, to meet strong demand from rising incomes and population, supported by flock expansion, improvement per-animal performance, through animal breeding, feed intensity, management, and technology. Poultry meat, the fastest growing segment of animal protein production (14%), is projected to account for 48% of the increase in total meat production over the coming decade. The OECD/FAO (2023) report mentioned that higher meat prices relative to the costs of feedstuffs were projected to improve livestock sector return and increase incentives.

The global price trends in nominal terms for animal proteins (fish, poultry, swine and bovine) presented by OECD/FAO (2012), reflect that in 2000-2021 period, fish prices had been the 3rd lowest price per tons, behind of Poultry and Swine, similar to the LAC trend identified in this research, and presented in Figure 12. In the World Bank (2013) projection, by 2030 the prices of all fish products continue on a slightly increasing trajectory, which is consistent with was observed in other global food commodity markets.

The projection highlighted fishmeal as fuel of the future growth of Asian aquaculture, which will largely be imported from Latin America. Fishmeal will likely continue to produce a surplus of feed for both fish and livestock production. Fish trade, over half of the food fish imports will continue to be concentrated in high income countries, according to projection of OECD/FAO (2023), with about 33% of total fish production exported in 2032.

The LAC results obtained from the VAR Forecasting are presented in Table 19, with plots for each test performed, to identify animal protein price projections for the next 10 years. Data is analyzed with the same three approaches of the previous section (animal protein, trade flow and region's feature). Can be observed that fish export prices are projected to rise at the end of the decade (2030), except by Ecuador, on which is projected price reductions. Fish import prices would present different tendencies, Colombia, Peru and Mexico are project to have variation on fish import prices between -3 and 3, finalizing the decade with up price tendencies. Whereas Brazil and Argentina would present large variations of -10 to 10. Thus, LAC fish prices for exports and imports are projected to have similar fluctuation ranges, except for the countries mentioned with particular tendencies. Both, fish export and import prices in the region are expected to rise.

Bovine export prices of the region are projected to fluctuate in the upcoming years, finalizing the period with increasing prices tendencies. While bovine imports prices are estimated to have slightly higher variation than export prices; nevertheless, ending the period with reduction in the import prices, by exception of Uruguay. This country had high prices fluctuations projected in fish export and bovine export prices. Swine export prices are expected to decline in the largest exporter countries of LAC, Brazil (10 to -20), Mexico (2 to 0), Chile (0.5 to -1) Paraguay (5 to 0), except for Argentina. Whereas imports prices are expected to rise. On its side, the outlook of goat export and prices reflected diverse tendencies among LAC countries, and some of the highest price variation in the coming years.

Poultry is the animal protein that projected less export prices variation in LAC; while poultry import prices estimations have a small increase at the end of the period, by except of Colombia.

Thus, it was identified that in LAC animal protein prices forecast presented this condition, according to the three (3) approaches:

- Focus on Animal protein commodity: the large fluctuations of prices are not exclusive of a commodity; this was identified in countries from different trade flow and product.
- Trade flow: It was identified common tendencies between the countries, depending on the commodity and its trade flow. Export prices tendencies in most of the largest exporter countries of LAC, specifically for poultry and swine, present decreasing projections.
  The outlook for import prices reflects an increasing trend in fish, poultry, and swine, while is estimated for bovine a decreasing tendency.
  Fish is the only commodity whose export and import prices would have the same tendency direction (to increase).
- Regional and countries features: It was not identified outlook prices patterns that lay down on LAC countries' features.

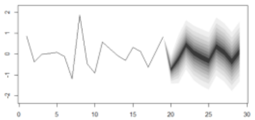
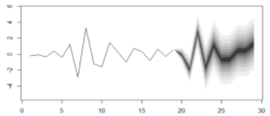
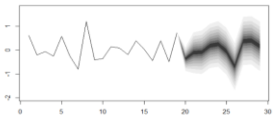
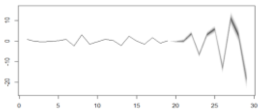
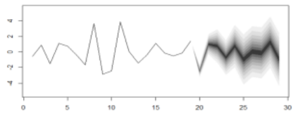
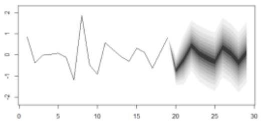
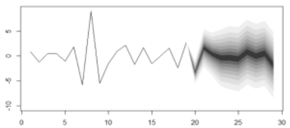
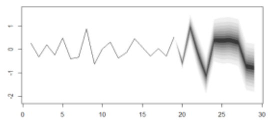
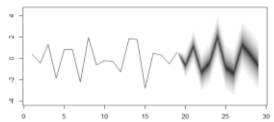
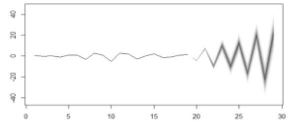
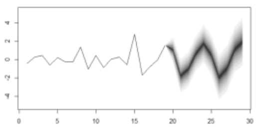
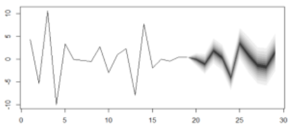
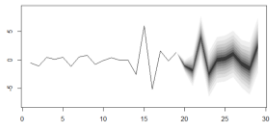
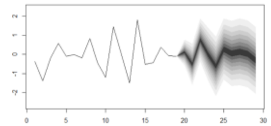
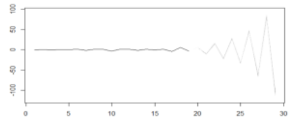
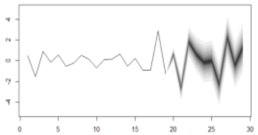
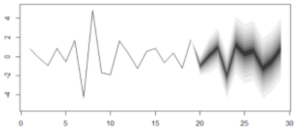
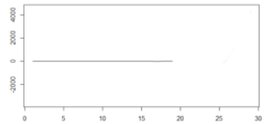
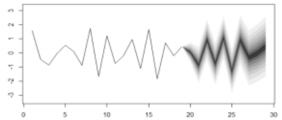
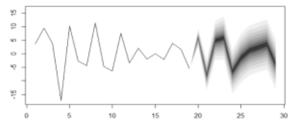
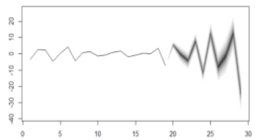
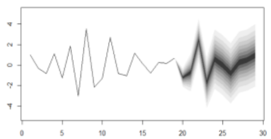
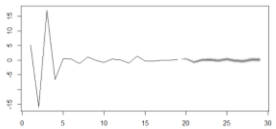
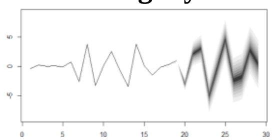
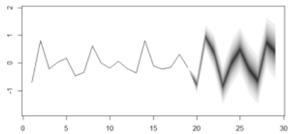
The VAR Forecasting results of EECA and MENA regions are included in **Appendix 8**. Regarding MENA prices, the tendencies are more diverse, cannot be determined patterns in the price changes of group of countries from a commodity or a trade flow, since there are different directions on the projections of prices trends. Thus, the regional and country features is highlighted as the outstanding approach for the forecasting of animal protein prices in MENA. Swine prices traded in the region are estimated to have largest variations; and cases as Saudi Arabia and Oman reflect prices fluctuations with common tendencies among the commodities traded by same country.

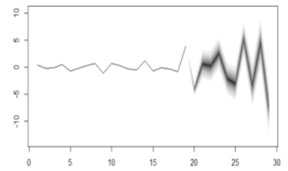
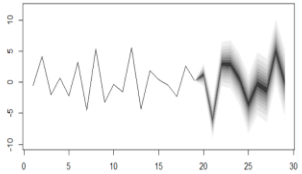
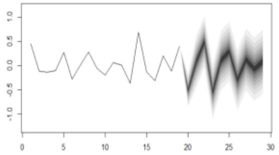
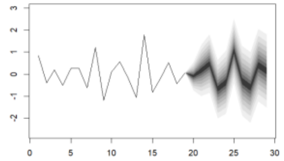
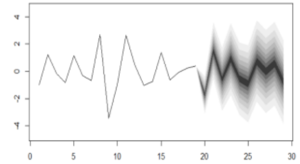
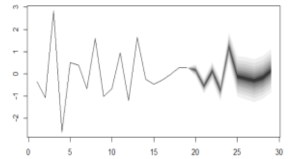
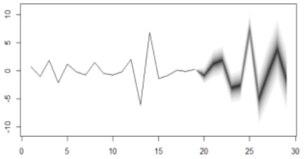
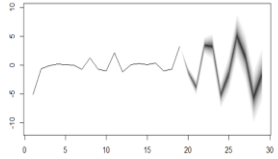
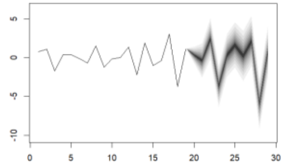
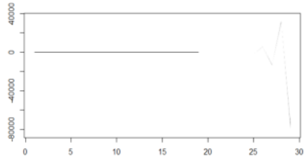
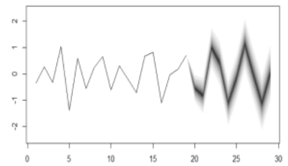
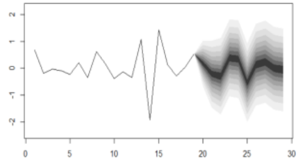
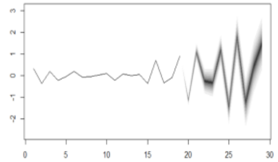
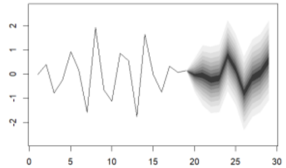
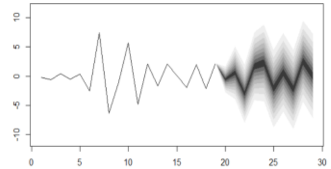
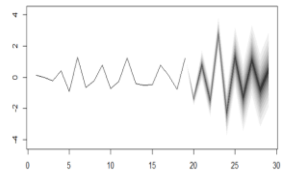
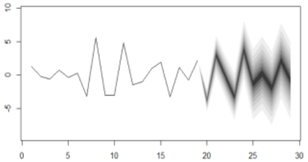
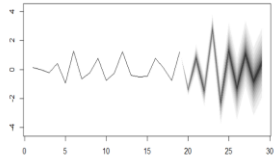
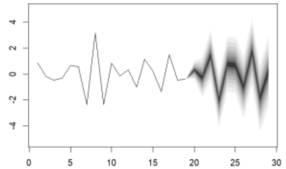
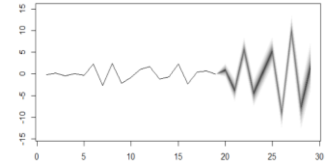
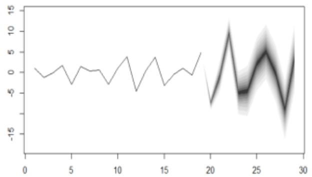
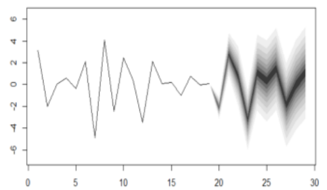
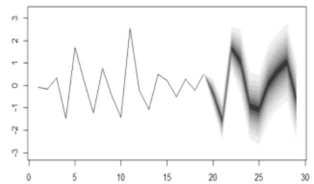
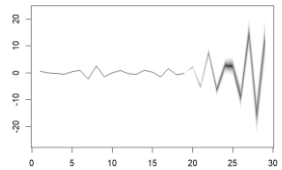
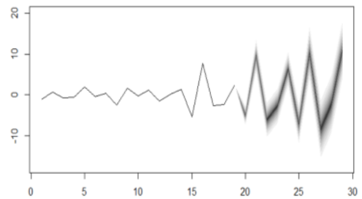
For EECA, was identified more common prices tendencies between the countries, with general projections of decreasing export prices for fish and swine, increase import price of fish and reduction on import prices for poultry. Whereas, for bovine, goat, poultry export, and swine import are estimated diverse tendencies among the countries. There are external factors as the political situation between Ukraine and Russia that have been affected the tendencies of prices in the region, and this will alter the projection identified in the VAR forecasting of this research.

In addition, factors such as climate change and socio-political scenarios, will significantly impact future price trends for fish, fuel, electricity, and fish feed ingredients (Kreiss et al., 2020). According to OECD/FAO (2023) in MENA less than 5% of total land is considered arable and water resources are constrained; the region is amongst the most vulnerable to climate change, due to its arid nature and limited water resources.

Bovine production is expected to expand by 9% and contribute to 16% of the total increase in global meat production, with higher carcass weights as feed costs decline, and animal genetics improve. Sheep meat production will contribute only 6% to the overall growth in meat production, and is expected to expand by 15% over the coming decade; increasing lambing rates in Sub-Saharan Africa. Production in the European Union is projected to increase slightly due to income support and favorable produce prices. Sheep and goat meat production in Sub-Saharan Africa will grow by almost 30%, despite pressure on pasture land due to desertification. While Trade growth in poultry is expected to drop sharply due to the slowdown of the convergence in diets and the reduction in Chinese imports from Europe and LAC regions (OECD/FAO, 2023).

Table 19. VAR Forecasting for LAC countries

	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORT	**Chile** 	**Brazil** 	**Brazil** 	**Brazil** 	**Uruguay** 
	Argentina 	**Argentina** 	**Argentina** 	**Mexico** 	**Chile** 
	Uruguay 	**Mexico** 	**Chile** 	**Chile** 	**Argentina** 
	Peru 	**Uruguay** 	**Dominican Rep.** 	**Argentina** 	**Mexico** 
	Ecuador 	**Paraguay** 	**Uruguay** 	**Paraguay** 	**Colombia** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORT	**Brazil** 	**Chile** 	**Mexico** 	**Mexico** 	**Brazil** 
	Mexico 	**Mexico** 	**Chile** 	**Chile** 	**Mexico** 
	Colombia 	**El Salvador** 	**Guatemala** 	**Colombia** 	**Trinidad & Tobago** 
	Peru 	**Brazil** 	**Peru** 	**Argentina** 	**Jamaica** 
	Argentina 	**Uruguay** 	**Colombia** 	**Uruguay** 	**Bahamas** 

Source: Elaborated by author, based on VAR forecasting output from R Studio, with methods from Pfaff (2008b)

5.4.3.3.Granger Causality test

The LAC results of the last component of the co-integration and causality analysis are presented in Table 20, reflecting that in the period analyzed (2000 to 2021) crude oil price influence in short run was presented in reduced animal protein prices of LAC countries, those that reject the null hypothesis (H0 = Oil price does not cause animal protein prices); meaning that the consideration of past and current prices of crude oil can predict future prices of those animal protein traded in the countries; highlighting that Mexico and Uruguay were the ones with more short term correlation between oil prices and commodities' prices traded.

Poultry prices were the unique animal protein that did not present short-term influence of oil prices in none of the largest LAC exporter and importer countries. Followed by swine, whose results show that there was not causality in none of swine importer countries, and by except of Brazil, all the swine exporter countries did not have short term impact of oil prices. The results confirmed that in LAC fish export prices there was not short-term influence from oil prices; and for fish import prices traded, particularly by Mexico and Peru, where the only countries that reject the null hypothesis, thus these prices reflected oil prices short term influence. The prices of poultry and fish exports are the only ones that did not present correlation, short run, with the oil prices in any of the LAC countries.

For goat prices, there was not short-term causality in the prices from largest goat importer, however in the export prices of Uruguay and Argentina there were granger causality with oil prices. In bovine export prices, only Mexico rejected H0, thus is the only bovine exporter country impacted by oil prices; and for bovine import prices, were Uruguay and Mexico, as well, whose reflected oil price short term causality. It was observed that there was not a marked influence (in short run) of oil prices specifically on imports or exports animal protein prices of the LAC countries analyzed. There were four LAC importer countries with results confirming correlation on the price traded; and the four exporter countries that present the granger causality, as well. The short run impact of oil prices on the animal protein prices in LAC countries is not defined by the balance trade side, non animal protein sort, but it might be for the particular conditions of each country.

From EECA countries' approach, was recognized that few cases (7) of countries with Granger causality of oil prices on their animal protein prices traded, were mainly in export trade, and concentrated in Russia (Bovine imports, swine export, goat export), Croatia (fish import), Belarus (bovine export), Ukraine (bovine export), Poland (swine export). While in MENA region, at least one country presented short run relationship of oil prices and each of the animal protein commodities; eleven (11) granger causalities identified in the region; Egypt, Jordan and Oman are the countries with most of the causalities.

Table 20. Results of Granger Causality test in LAC countries

Granger causality test							
H0 = Variable Oil Price does not cause price of animal protein.						**H0: No instantaneous causality between variables**	
H7 = Variable Oil Price cause price of animal protein.						**H8: Instantaneous causality between variables**	
Variable	**Category**	**Country**	**Granger P-value**	**Result**		**P-value**	**Result**
Fish	Exports	Chile	0.983	Accept H0		0.019	Reject H0
		Argentina	0.983	Accept H0		0.019	Reject H0
		Uruguay	0.943	Accept H0		0.011	Reject H0
		Peru	0.092	Accept H0		0.166	Accept H0
		Ecuador	0.665	Accept H0		0.199	Accept H0
	Imports	Brazil	0.937	Accept H0		0.023	Reject H0
		Mexico	0.003	Reject H0		0.603	Accept H0
		Colombia	0.096	Accept H0		0.051	Accept H0
		Peru	0.012	Reject H0		0.180	Accept H0
		Argentina	0.322	Accept H0		0.034	Reject H0
Bovine	Exports	Brazil	0.443	Accept H0		0.016	Reject H0
		Argentina	0.217	Accept H0		0.010	Reject H0
		Mexico	0.003	Reject H0		0.047	Reject H0
		Uruguay	0.223	Accept H0		0.009	Reject H0
		Paraguay	0.408	Accept H0		0.014	Reject H0
	Imports	Chile	0.266	Accept H0		0.030	Reject H0
		Mexico	0.029	Reject H0		0.018	Reject H0
		El Salvador	0.785	Accept H0		0.909	Accept H0
		Brazil	0.336	Accept H0		0.019	Reject H0
		Uruguay	0.046	Reject H0		0.434	Accept H0
Poultry	Exports	Brazil	0.936	Accept H0		0.010	Reject H0
		Argentina	0.124	Accept H0		0.016	Reject H0
		Chile	0.423	Accept H0		0.444	Accept H0
		Dominican Rep.	0.095	Accept H0		0.496	Accept H0
		Uruguay	0.126	Accept H0		0.013	Reject H0
	Imports	Mexico	0.923	Accept H0		0.010	Reject H0
		Chile	0.148	Accept H0		0.465	Accept H0
		Guatemala	0.371	Accept H0		0.807	Accept H0
		Peru	0.728	Accept H0		0.019	Reject H0
		Colombia	0.080	Accept H0		0.315	Accept H0
Swine	Exports	Brazil	0.006	Reject H0		0.011	Reject H0
		Mexico	0.493	Accept H0		0.023	Reject H0
		Chile	0.889	Accept H0		0.031	Reject H0
		Argentina	0.761	Accept H0		0.008	Reject H0
		Paraguay	0.132	Accept H0		0.031	Reject H0
	Imports	Mexico	0.884	Accept H0		0.015	Reject H0
		Chile	0.556	Accept H0		0.083	Accept H0
		Colombia	0.923	Accept H0		0.017	Reject H0
		Argentina	0.745	Accept H0		0.013	Reject H0
		Uruguay	0.402	Accept H0		0.044	Reject H0
Goat	Exports	Uruguay	0.003	Reject H0		0.318	Accept H0
		Chile	0.107	Accept H0		0.130	Accept H0
		Argentina	0.003	Reject H0		0.017	Reject H0
		Mexico	0.182	Accept H0		0.090	Accept H0
		Colombia	0.143	Accept H0		0.145	Accept H0
	Imports	Brazil	0.417	Accept H0		0.128	Accept H0
		Mexico	0.613	Accept H0		0.857	Accept H0
		Trinidad & Tob.	0.653	Accept H0		0.321	Accept H0
		Jamaica	0.351	Accept H0		0.039	Reject H0
		Bahamas	0.803	Accept H0		0.032	Reject H0

Source: Elaborated by author, based on granger causality output from R Studio, and method from Zeileis & Hothorn (2002)

Regarding the instantaneous granger cause, it was identified that the consideration of future oil prices influence or allow to predict better the future prices of animal protein in LAC countries. This causality was found in countries of the five-animal protein analyzed, those that reject the null hypothesis (H0) for instantaneous causality. Bovine export and swine (export and imports) are the ones with more countries that presented this causality.

Specifically for the fish commodities prices in the LAC countries, it was observed that in Chile, Argentina, and Uruguay there are instantaneous granger cause on fish export prices; whereas this cause is reflected in the fish import prices of Brazil and Argentina.

In the Granger causality results of MENA and EECA, presented in **Appendix 9**, was observed that instantaneous granger cause has signicant results in the animal protein prices for both regions as well. In EECA, this impact was identified, largely, on swine export and import prices (Poland, Hungary and Czechia), and goat export prices (Bulgaria, North Macedonia and Slovakia).

The fish export prices were the only segment in EECA on which all countries did not present this causality; whereas fish import prices present instantaneous causality in Russia and Belarus. Poultry was another animal protein in the region, whose import and export prices, in most of the cases, did not have instantaneous causality.

East Europe and Central Asia, includes a diverse range of countries, with various stages of developments, marked differences on agricultural resources, demographics and public policies. Facing risks associated to the political conflict of Russia and Ukraine, generating as consequences high food inflation, disturbs on agri-food chains, and the climatic fluctuation. One of the main challenges of Eastern Europe the restore of productive capacity, focusing on sustainability, as aim of the European agriculture policy, efforts to reduce energy dependency(OECD/FAO, 2023).

On the other side, the instantaneous granger cause in MENA was established for the prices of fish exports (Oman, Tunisia, Saudi Arabia), fish imports (Kuwait, Lebanon, Oman), bovine imports (Jordan, UAE, Kuwait), and goat imports prices (Saudi Arabia, Qatar).

Taking into account the results presented in both regions, can be confirmed that in these exists the same feature that in LAC, concerning that short run and future influence of oil prices on the animal protein prices traded in these developing regions is defined mainly for particular conditions of each country, instead of balance trade flow, or animal protein commodity.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

All the LAC countries analyzed have developed policies and programs, with long term approach, to guarantee food and nutritional security to the population, and boost the fish and aquaculture activity. Nevertheless, in the integration analysis was identified that there has been a low integration of aquaculture in the food /security policies of the region. Fisheries concept is widely used in the documents, tackling it as poverty population in fisheries areas, few of them highlight contributions of fish and aquaculture to the food availability. Thus, the hypothesis (H_1) set is rejected, since the development of Freshwater fish Aquaculture in LAC has not been supported with the integration of fishing and aquaculture sector on the food security national policies.

Only Costa Rica and Paraguay had specific program and plans for aquaculture development; while, fishing sector presented moderate integration in other LAC countries, since production of fish and other aquatic commodities are associated mainly to this field, and not segregated by production methods. Ecuador and Peru provided notable examples of high integration of the fish sector into their policies.

There are gaps still present in LAC on the knowledge of the contribution of this sector to improve purchase of power, be source of healthy and nutritious food, and unawareness of the causal relationship between aquaculture and food security. Ecuador is one of the countries with high integration of fishing, establishing it as strategies of health food to vulnerable communities, through the fish consumption. Aquaculture production has been growing in LAC, which is not reflected in rise on per capita fish consumption of the region, although its role in the trade of fishmeal is significant, achieving 40% of the global fishmeal exports.

Considering the three criteria contemplated in the integration analysis, climate change is the one that have been most integrated in the food security policies of the LAC countries, as part of programmatic focus (Guatemala), critical issue that can restrict food production (Mexico and Costa Rica), prioritized to implement measures of climate changes adaptation, and to guarantee access to adequate food at every time (Peru and Honduras).

From the food availability approach results, it was recognized that LAC is a net exporter region of animal protein commodities, led by poultry and bovine products. During the period analyzed (2000 – 2021) fish production traded did not grow at the same level as the biggest animal protein traded in LAC. Fish commodities trade passed from occupied the second position in the region to the third one with an extensive difference in the shares, respective bovine, and poultry.

The region is among the largest fish producers, which is not reflected in rise on per capita fish consumption of the region. The participation of freshwater fish aquaculture in the fish production of LAC, has been growing in the last decades, however its contribution is still considered low (5.51% by 2021). The importance of this sector remains on the food options from freshwater fish commodities, on this, aquaculture is the dominant method of fish food production in LAC (65.60% by 2021).

Aquaculture production have been growing in LAC, and according to FAO's projections (2020), LAC aquaculture is anticipated to provide 33% of total fish production by 2030; it was identified that the share in 2000 was 4.05%, finalizing 2021 with 21.6%. However, the aquaculture benefits highlighted by several reports and studies on fish prices (Béné et al., 2016; Kawarazuka & Béné, 2010; World Bank, 2013), such as prevent rising prices, positive impact on the purchasing power of consumers and possibly on their nutritional intake, are not currently visible in LAC, because the region's production still falls mainly on capture method; by 2021 the share of capture production in LAC was around 80%. Once the expansion of aquaculture reach out more participation in the LAC fish production, this will cause that prices of farmed fish grow slower than other animal foods source, even this growth reigned in increases of capture fish price as Belton & Thilsted (2014) mentioned.

About the access perspective analyzed, it was identified that in LAC the animal protein trade has presented a growing surplus balance in most of the animal's commodities, by exception of swine, and fish in 2015. The trade indicators analyzed in the food access approach reflect that at the beginning of the period (2000 to 2021) there was not large differences between the animal protein prices traded in LAC; around 2004 began considerable variations, and by 2020-2021 is appreciated wide differences among the commodities prices.

The fish export and import prices in LAC were the second (2^{nd}) cheapest animal protein (USD/Kg) traded at the beginning of the period analyzed (2000), and from 2007 has been maintained the third (3^{rd}) position as accessible animal protein exported and imported in the region, leading by poultry, and followed by swine.

In the driver forces from the fish aquaculture production, it was identified that the most influential one, in the prevalence of undernourishment and poverty headcount ratio in LAC, was freshwater fish imports share in total lac fish food imports, presenting positive impact on these poverty indicators. During the period analyzed this import'share grew from 4.65% (2000) to 31.94% (2019);

this highlight attention considering that other studies as Nugroho et al. (2022) found that the imports dependency ratio became an important element in the countries of LAC, which have been more reliant on external food sources.

There were two (2) other driver forces with influence, but negative relationship, on one side % freshwater fish exports in total LAC fish food exports had negative impact on poverty headcount ratio of LAC, might be reflected by income and employment generated, and considering that exports reduce exposure to macroeconomic instability and improving resilience to exogenous shocks. By 2015 freshwater fish export reached 40% of total LAC fish food exports.

On the other side % Aquaculture Production in LAC Freshwater fish Production was the only driver force with negative influence on the Prevalence of Undernourishment in LAC, reflected by the rise of aquaculture share in LAC freshwater production from 35.83% in 2000 to 65.60%, by 2019. Considering this, the hypothesis H_2 of the multiple regression has been accepted, whereas H_3, H_4 and H_5 have been rejected, as table 21 summarizes.

From the last specific objective developed, was identified long run influence of oil prices in the fish prices traded and all animal proteins considered in this research, confirming the hypothesis H_6. The long run relationship was not exclusively of one direction of the trade, but applied for both, imports and exports prices, and these results were reflected on the animal protein prices traded by the other developing regions analyzed (MENA and EECA) as well; despite of the difference on production, balance trade, and that LAC is the largest net exporter of agriculture and fisheries commodities, amongst all the regions.

Regarding the impulse response, it was recognized that regional and countries features is the most relevant factor to determine the impulse response of crude oil prices variations on the animal protein prices traded, further than the particular animal protein and the trade direction or flow (import or export).

It is highlighted that export prices of countries in MENA and LAC presented more variation and larger ranges than in import prices. In the case of EECA, there were less high impulse responses than the other regions.

The granger causality results of LAC fish export prices confirmed that there was not short-term influence from oil prices, therefore, rejecting the hypothesis H_7. For fish import prices traded, particularly Mexico and Peru were the only countries that reject the null hypothesis (H0 = Oil price does not cause animal protein prices), thus these prices reflected oil prices short term influence.

The prices of poultry and fish exports are the only ones that do not present correlation, short run, with the oil prices in any of the LAC countries. The short run impact of oil prices on animal protein prices in LAC countries is not defined by the balance trade side, non the sort of animal protein commodity, but it might be for the particular conditions of each country.

Nevertheless, with the instantaneous causality was determined that, in the long term, past, current, and future oil prices allow to predict better future prices of animal protein. This causality was found in LAC countries of the five animal protein analyzed, being bovine export and swine (export and imports), the ones with more countries that presented instantaneous causality; thus, hypothesis H_8 is accepted. This causality has significant results in the animal protein prices for EECA and MENA regions as well. In EECA, this impact was identified, largely, on swine export and import prices (Poland, Hungary and Czechia), goat export prices (Bulgaria, North Macedonia and Slovakia). In MENA, at least one country presented relationship of oil prices and each of the animal protein commodities.

Specifically for the fish commodities prices in the LAC countries, it was observed that in Chile, Argentina, and Uruguay there are instantaneous granger cause on fish export prices; whereas this cause is reflected in the fish import prices of Brazil and Argentina

From the VAR forecasting results, cannot be generalized the tendencies of future prices per animal protein, since the large fluctuations of prices are not exclusive to a commodity. It was observed that the outlook of export prices in most of the largest exporter countries of LAC, especially for poultry and swine, present decreasing projections at the end of the decade (2030); and the import prices projections reflect an increasing trend in fish, poultry, and swine, while is estimated for bovine a decreasing tendency. Poultry is the animal protein commodity that projects less export prices variation in LAC; while poultry import prices are projected to have a small increase at the end of the period, by except of Colombia.

Fish is the only commodity in LAC, whose export and import prices would have the same growth tendency, except by Ecuador, on which is projected export price reductions. Whereas fish export prices in EECA and MENA are estimated to decrease, and fish import prices to increase.

In relation to MENA forecast tendencies, regional and country features is highlighted as the outstanding approach for the forecasting of animal protein prices, as in LAC. Swine prices traded in the region are estimated to have largest variations. For EECA, was identified more common prices tendencies between the countries, with general projections of decreasing export prices for fish and swine, increase import price of fish and reduction on import prices for poultry. Whereas, for bovine, goat, poultry export, and swine import are estimated diverse tendencies among the countries.

Table 21. Research hypotheses results.

No	Hypotheses	Result
H1	The development of Freshwater fish Aquaculture in LAC has been supported with the integration of fishing and aquaculture sector on the Food Security national policies.	**Rejected**
H2	Share of aquaculture production in LAC freshwater fish production is the fish driver force that most impacts the reduction of undernourishment.	**Accepted**
H3	Share of freshwater fish production in the food balance trade of LAC influence positively on the prevalence of undernourishment.	**Rejected**
H4	Share of aquaculture production in LAC freshwater fish production is the fish driver force that most impacts the reduction of poverty headcount ratio.	**Rejected**
H5	Share of freshwater fish production in the food balance trade of LAC influence positively on the poverty headcount ratio.	**Rejected**
H6	Oil prices have long-run influence on animal protein prices	**Accepted**
H7	Oil prices have short -term influence on animal protein prices.	**Rejected**
H8	There is instantaneous causality of oil prices on the animal protein prices.	**Accepted**

Source: Elaborated by author

6.2. Recommendations

Fish and aquaculture policies are instruments ensuring food security by expanding the production and commercialization of fish and aquaculture products, thereby guaranteeing the availability of quality and safe products. Due to the low integration in the policies analyzed, considering the result of this research, the internship experience of the author in Hungarian fishing and aquaculture research centers (Research Centre for Aquaculture and Fisheries, MATE university and Institute of Animal Science, Biotechnology and Nature Conservation, Debrecen university), it was identified six (6) main factors needed to incorporate to the Fish and aquaculture policies, and Food security policies of LAC countries:

- Fish food production management:

LAC as the largest fishmeal producing region in the world, (40 % of world's fishmeal supply), and world production of fishmeal expected to expand over the next decade with the proportion of fishmeal obtained from fish residues (OECD/FAO, 2023), locate LAC fishmeal production to be even higher by 2023(World Bank, 2013). Therefore, fish and aquaculture policies should establish programs for the management of fish food production, with strategies to share this increasing of fish production with the rise of fish availability for human consumption in LAC countries, and as an alternative of healthy and nutritious food.

Aquaculture expansion and sustainability of small-scale fisheries should become an integral component of national food security strategy developing countries (Kawarazuka & Béné, 2010). On the other side, should be considered the strong demand for fishmeal, given expansion of the global aquaculture. Fishmeal prices have been projected to rise by 90 % (World Bank, 2013); with higher fishmeal traded, species substitution in production is expected, and animal protein source as well.

- Competitiveness of the fish products:

LAC is a net exporter region in agriculture commodities, and is among the largest fish producers, however, the animal protein commodities that led the trade are poultry and bovine. Seeing the result of this research, LAC fish and aquaculture sector should improve its factor of production and price, to generate a trade growth at the same level of these commodities.

Freshwater fish aquaculture has been growing in the last decades; however, its contribution is still considered low (5.51% by 2021). It is necessary to expedite the transition from capture to aquaculture production basis, thus will be reflected the benefits on cost production and low fish prices traded.

According to the price tendencies identified, poultry is the animal protein commodity that projects less export prices variation in LAC, while its import prices are estimated to have a small increase by 2030, whereas fish export and import prices would present a growth tendency. Therefore, strategies on production and cost efficiency in the fish and freshwater aquaculture sector are needed to be more competitive to poultry and swine commodities.

In relation to projection of the World Bank, (2013) global tilapia production is expected to almost double from 4.3 million tons to 7.3 million tons between 2010 and 2030, being this the main freshwater fish commodity produced in LAC, it is an aspect to consider in the policies, for strategies on diversification of fish production.

- Integration of trade policies:

This research focused on the analysis of fish and aquaculture contribution to food security through the trade factors, and the results reflect the extensive importance of food trade on the availability and access to agriculture commodities in the regions.

Price transmissions are affected by trade policies, where restrictive policies can effectively dampen the transmission of price volatility to domestic markets. Thus, further than the integration of fish and aquaculture policies on the food security policies, and vice versa, should be considered the integration of the national and if applicable, regional trade policies and agreements, since objectives, program and restrictions established by these ones are impacting the food access, availability, and stability.

Agriculture exports of the region should consider and manage that the global market is increasingly volatile and fragile, with geopolitical fragmentation risk, improved internal market integration and functioning of small and medium enterprises, cooperatives and family farms could expand trade within the region, thus diversify market opportunities and improve the sector's resilience (OECD/FAO, 2023).

- Per capita fish consumption:

Aquaculture production has been growing in LAC, which is not reflected in rise on per capita fish consumption of the region. The demand of food fish commodities in the last decade was determined mainly by population growth than per capita food demand growth (OECD/FAO, 2023).

The decline in the per capita fish consumption in the region is one of the priority aspects that fish and aquaculture policies in LAC should tackle, since was identified in the policies analyzed that countries did not integrate programs and strategies to boost per capita fish consumption, as source of nutrient food; but these were focused on production and improve of fisheries communities' socio-economic conditions.

- Sustainable development of aquaculture:

The results of the integration analysis reflect that climate change is one of the most relevant criteria in the food security policies of most of the LAC countries, prioritizing to implement measures for climate changes adaptation, to guarantee access to adequate food at every time, as Peru and Honduras; this approach should be extended to all national policies.

Climate change has been identified to impact with high significance the productivity of capture fisheries, where aquaculture has become the main fish production strategy, adapting process and methods to the current environmental risks. Then, assessment and design actions to tackle climatic risk as "El Niño", which presents dry weather conditions each four years, should be included in the long-term planning. Aquaculture will likely dominate global fish supply. Thus, ensuring successful and sustainable development of global aquaculture is an imperative agenda for the global economy (World Bank, 2013).

- Fish food imports dependency:

Freshwater fish imports share in total fish food import of the region was the most influential driver force in the LAC poverty indicators analyzed. This negative impact should be prioritized to be tackled, since the share of this LAC fish imports grew from 4.65% (2000) to 31.94% (2019).

On the other hand, LAC has maintained a net export in the fish trade, being the largest fish exporter region in the world, and projected to continue leading by 2030. However, it is needed programs to reduce the fish food import dependency, and do not became a net importer of fish, considering the upcoming growth on fish demand from Asia to feed fish and livestock production, which has been supplied by LAC.

Regarding further studies in this field, it is recommended to extend the analysis of:

- Fishing and aquaculture sector contribution to the food security, considering the four components of it (availability, access, stability, and utilization) since this research focuses specifically on the availability and access component.
- Role of women in food systems, as entrepreneurs, workers and consumers evidence gaps in food systems and food policies, as Burns et al. (2014) and Kawarazuka & Béné (2010) have identified, encouraging future research to bring a gender perspective to the aquaculture sector.
- Environmental impacts of agricultural production, GHG emissions.
- As the data records allow it, is suggested to include in the analysis of food security indicators on climate change, sustainability, and in general the Sustainable Development Goals (SDG) indicators. Another segment for future research might include post-Covid impacts, by extending the period to study.
- The analysis of the external factors on fish and animal protein prices can be widely explored, since this research focused on oil prices, further studies might cover other indicators that influence the supply chain, raw materials, or inputs along the production process.
- Considering the results of the impulse response to oil prices, further studies can be developed to identify if countries with high animal protein prices traded are more vulnerable to variation of global oil prices.

6.3. Limitation of the research

- **Data of indicators on fish and aquaculture**: With the data and indicator, available at this moment for fish and aquaculture sector, is not possible to focus studies of the aquaculture sector in specific segments, should still need to be studied considering the whole component.

  Indicators on fish food trade have data until 2019, besides few indicators were found specifically for aquaculture data. There are databases with fish production, some report the source (marine / freshwater), but most of the cases are not the same that report method of production.

  In the development of the 3rd specific objective was needed different datasets to collect the indicators; databases that are not mutually consistent, requesting bunch of time to identify the sources of discrepancy and reconciling them.
- **Food security analysis**: Indicators on food security and nutrition, health diet, and SDG have data only from 2017, this is a limitation to perform statistical analysis.
- **Limitation of methods:** Since the analysis of aquaculture at regional level, and on social-economic perspectives has not been extended study, there are limited records of methodologies and assessment on this scope. Similar situation on the analysis between animal protein commodities; previous research focused on general meat indicators, with other food commodities, such as cereal. Therefore, the methodologies defined for this research were referred to several research fields (economic and poverty analysis, fish and aquaculture studies, and food security framework).
- **Geographic factor**: the availability of data depends as well of the countries reports, for analysis focus on regions and/or countries, this is an influential factor since for data that is not centralized by international organizations, require extra effort to consolidate the information, to identified similar statistics records, and indicators.

7. NEW SCIENTIFIC RESULTS

- This research involved the integration of large international literature, databases and institutional reports on social-economic aspects and fish sector management. With this work there is a contribution to reduce the existing knowledge gap in issues identified, with the application of methodologies and statistical analysis.

  The results accomplished in this research provided a new frame of knowledge on the fish sector gaps identified by Béné et al. (2016) and Bostock et al. (2016), providing insights into:

  - Socio-economic policies analysis, regarding the impact of commercial fish and aquaculture activities in developing countries.
  - Knowledge gap of causal relationships between aquaculture development and food security, economic growth.
  - Freshwater aquaculture production systems regarding market demand and competitiveness.
  - Evidence of how fish production and trade translate into developmental benefits and reduce poverty.

- The policies integration results enable to clearly identify that the recent development of freshwater fish Aquaculture in LAC has not been supported with the integration of fishing and aquaculture sector on the food security national policies. Due to there are significant gaps still present in LAC on the knowledge of the contribution of fish and aquaculture sector; whereas the integration of food security within fish and aquaculture policies varies, with most countries exhibiting a moderate to high level of integration.

- The new scientific results on fish production revealed that during the period analyzed fish production traded did not grow at the same level as the biggest animal protein traded in LAC. Regarding access, it was demonstrated that aquaculture sector growth in LAC has not contributed yet, to prevent fish prices from rising. Fish commodities prices were overshadowed, in terms of competitiveness and access, with substitute animal protein traded in the region.

- The results show that the main driver force from the freshwater aquaculture activity in LAC was imports share of freshwater fish. It influenced positively the prevalence of undernourishment and poverty headcount ratio of LAC, while aquaculture production and exports share freshwater fish were the driver forces that contributed to the reduction of these poverty indicators in the region.

- This study confirms the long run influence of oil prices on the fish prices and all animal proteins prices traded that were analyzed; this relationship was not exclusive of the trade direction. This long run impact was evidenced in the prices traded by the other developing regions analyzed (MENA and EECA) as well.
- The results proved that the short run impact of oil prices on the animal protein prices in LAC countries, and the other regions, was presented in scarce cases. Therefore, short run influence and the impulse response of crude oil prices variation on the animal protein prices, in the developing regions, is not determined by the sort of animal protein or the trade direction, but it is determine by the countries and regions features or particularities.
- The finding of instantaneous causality between crude oil prices and the animal protein prices reveals that the inclusion of past, current, and future oil prices allow to predict better future prices of animal protein of these regions. This research developed the first analysis of oil price influences on animal protein prices, covering several commodities, providing details of cointegration with export and import prices, and allowing the contrast of results among developing regions. There was no published research on the impact of fish commodities, and specifically on animal protein products.

8. SUMMARY

The aim of this research is to provide wide details of the aquaculture and freshwater fish aquaculture contribution to the food availability and food access in LAC, analyzing it from economics aspects as international trade, fish price, and the role of fish as animal protein source in the region. This social and economic analysis considered the identification of the integration level of this economic sector in the food security policy of the region’s countries, and its contribution to food production and affordability.

The research was developed through three specific objectives and the consideration of eight hypotheses; tackling policy integration analysis, driver forces from aquaculture production, and influence of crude oil prices, as external factor, on the animal protein prices traded (fish, bovine, poultry, swine, and goat) in LAC, and two developing regions, MENA and EECA.

The methods considered in this research involved content analysis for the identification of policies integration; structure of regional statistics considering production and trade indicators of the sector. Besides cross-sectional time-series data for multiple regression analysis; and for the last chapter was developed cointegration, Vector Auto Regressive (VAR), and causality analysis.

Among the results are highlighted that there has been a low integration of aquaculture in the food security policies of the region; climate change is one of the criteria that have been most integrated in the food security policies of the LAC countries.

It was demonstrated that freshwater fish aquaculture has been growing in the last decades, however its contribution is still considered low (5.51% by 2021). The importance of this sector remains on the food options from freshwater fish commodities, and this aquaculture activity is the dominant method of fish food production in LAC (65.60% by 2021). Moreover, the results confirmed long run influence of oil prices in the fish prices traded and all animal proteins considered in this research. This relationship was not exclusively of one direction of the trade, but applied for both, imports and exports prices. The results were reflected on the animal protein prices traded by the other developing regions analyzed (MENA and EECA) as well.

The short run impact of crude oil prices on the animal protein prices in LAC countries, and the other regions, was presented in scarce cases, identified that it might be defined by the particular conditions of each country. The impulse response of crude oil prices variation on the animal protein prices, in the three develping regions, is not determined by the sort of animal protein or the trade direction, but it is determine by the countries and regions features or particularities, as well.

The finding of instantaneous causality reveals that the inclusion of past, current, and future crude oil prices allow to predict better future prices of animal protein of these regions. Being bovine export and swine (export and imports) the ones on which was found more cases for LAC; swine export, import and goat export prices in EECA; while in MENA fish exports, imports, bovine imports, and goat imports.

Considering the new finding in the results and the contribution to the gap knowledge on the fish sector was recommended the integration of six factors to the fish and aquaculture policies, and food security policies of LAC countries:

- Fish food production management
- Competitiveness of the fish products
- Integration of trade policies
- Per capita fish consumption
- Sustainable development of aquaculture
- Fish food imports dependency.

Regarding further studies in this field, it is recommended to extend the analysis the four components of food security (availability, access, stability, and utilization) since this research focuses specifically on the availability and access; analysis women's role in food systems; assess environmental impacts of agricultural production, analysis of the external factors on fish and animal protein prices.

9. APPENDICES

9.1. Appendix 1: References

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9.2. Appendix 2: Indicators considered as driver forces for Multiple regression analysis.

Year	**LAC freshwater fish aquaculture production** (Tons - live weight)	**Total LAC Fish production** (Tons - live weight)	**Share of freshwater fish aquaculture production in LAC Fish production**	**Total LAC freshwater fish production** (Tons - live weight)	**Share Aq in Freshwater fish production**	**Total LAC Fish production** (Tons - live weight)	**Total LAC freshwater fish food production** (Tons - live weight)	**Share of freshwater fish in LAC Fish Food production**	**Total LAC Fish Food export** (Tons - live weight)	**Freshwater fish food Exports** (Tons - live weight)	**Share of freshwater fish in LAC fish food export**	**Total LAC Fish Food Import** (Tons - live weight)	**Freshwater fish food import** (Tons - live weight)	**Share of freshwater fish in LAC fish Food imports**	**Prevalence of undernourishment – LAC (%)**	**Poverty headcount ratio (%)**
2000	270938	20682274.6	1.31	756200	35.83	19209594	1088887	5.26	2181271.39	331500.01	15.20	918833.50	42708.17	4.65	10.7	13.5
2001	290571	18051324.5	1.61	766161	37.93	16548544	1259477	6.98	2554008.67	510377.62	19.98	956800.15	50657.28	5.29	10.79	13.2
2002	327111	19220500.7	1.70	812672	40.25	17674875	1282569	6.67	2424257.74	510410.77	21.05	866898.05	31590.3	3.64	10.53	12.4
2003	336160	15853944	2.12	842619	39.89	14189887	1317357	8.31	2471110.86	493534.61	19.97	888788.46	37622.66	4.23	10.31	12.1
2004	358077.5	20846143.5	1.72	910774.5	39.32	19016382	1462889	7.02	2692384.42	630563.34	23.42	1043446.52	47727.63	4.57	9.81	11
2005	374753.16	20213527.86	1.85	899541.16	41.66	18161083	1487395	7.36	2791933.13	676226.4	24.22	1147003.70	50171.37	4.37	9.34	10.4
2006	397633.01	18163281.81	2.19	944937	42.08	15651171.49	1564624.49	8.61	2819587.76	669202.38	23.73	1219159.49	59171.05	4.85	8.81	8.5
2007	416721.11	17981188.07	2.32	935736.11	44.53	15579551.1	1519660.1	8.45	2771627.6	663354.87	23.93	1465550.25	69450.69	4.74	8.29	8.1
2008	460739.03	18274784.37	2.52	975370.03	47.24	15700225.19	1587117.19	8.68	2620240.21	722405.2	27.57	1544441.44	78644.89	5.09	7.95	7.5
2009	549323.13	17571739.63	3.13	1058224.13	51.91	15429336.97	1620072.67	9.22	2587933.16	597162.93	23.07	1650208.07	84404.3	5.11	7.29	7.1
2010	601264.45	13886977.23	4.33	1112790.45	54.03	11484157.95	1527947.35	11.00	2184317.72	486492.49	22.27	1835253.32	91777.15	5.00	6.70	6.4
2011	650585.59	18537303.59	3.51	1144849.59	56.83	15975123.1	1752197.4	9.45	2521697.61	630764.48	25.01	2103107.97	102769.38	4.89	6.02	6
2012	723388.46	14659965.81	4.93	1215686.1	59.50	12183006.7	1971842.4	13.45	2511261.82	817808.94	32.57	2045586.82	356884.24	17.45	5.77	5.1
2013	733569.78	14875801.31	4.93	1225036.39	59.88	12379347.34	1957126.44	13.16	2550895.6	896751.94	35.15	2224824.12	568541.77	25.55	5.51	4.5
2014	898195.67	13541645.45	6.63	1395324.67	64.37	10523650.35	2292305.16	16.93	2675806.58	950217.32	35.51	2305465.40	685005.36	29.71	5.33	4.3
2015	829408.44	14093387.3	5.89	1351839.75	61.35	11339335.69	2178819.63	15.46	2465460.21	981150.82	39.80	2138539.04	664141.63	31.06	5.54	4.2
2016	849692.91	12863729.39	6.61	1399705.19	60.71	10244148.16	2119186.45	16.47	2433063.93	884901.69	36.37	2139543.80	689571.98	32.23	5.78	4.4
2017	899851.16	14100770.77	6.38	1435681.58	62.68	11287100.98	2277374.65	16.15	2579856.52	907163.94	35.16	2250989.07	721707.9	32.06	6.09	4.4
2018	932287.4	17562367.53	5.31	1506546.6	61.88	14468638.74	2377208.03	13.54	2670503.86	1028057.92	38.50	2215702.41	700708.96	31.62	5.99	4.3
2019	959465.75	15311414.74	6.27	1474249.64	65.08	11975526.31	2455109.56	16.03	2778897.52	1054464.52	37.95	2144860.36	684971.2	31.94	6.04	4.3

Source: Elaborated by author, based on data from FishStatJ (FAO, 2023) and World Bank database (World Bank, 2022b).

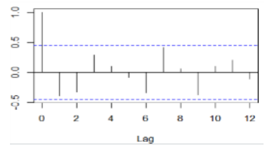
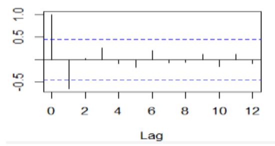
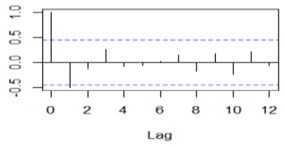
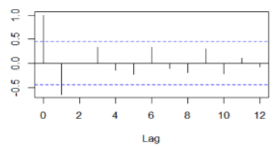
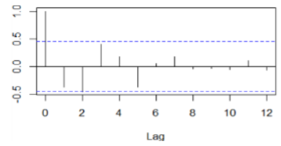
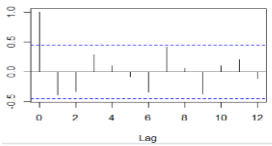
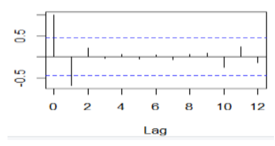
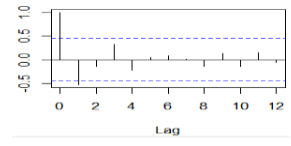
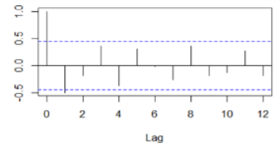
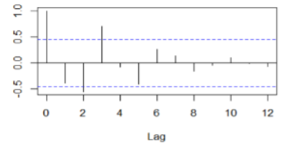
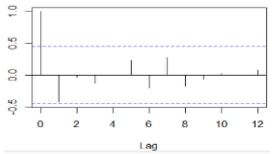
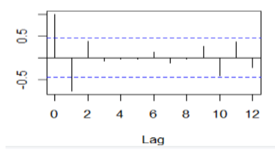
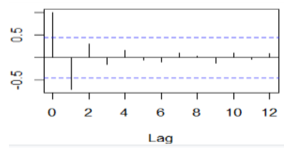
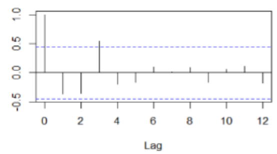
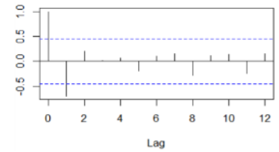
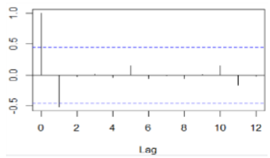
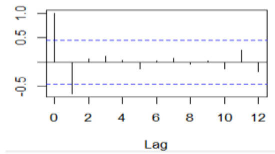
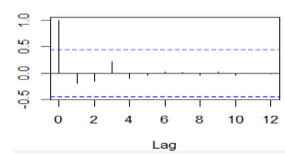
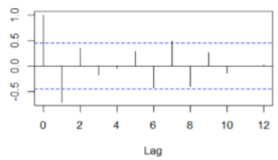
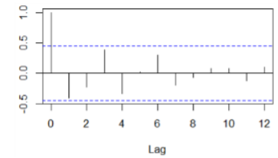
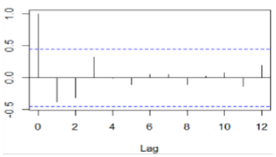
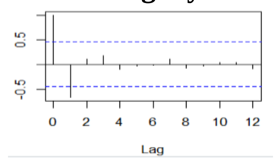
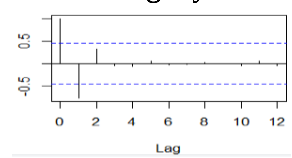
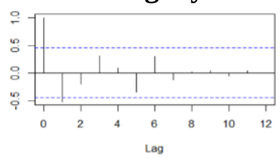
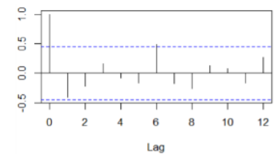
9.3. Appendix 3: List of countries per developing region, considered in the analysis of this research paper.

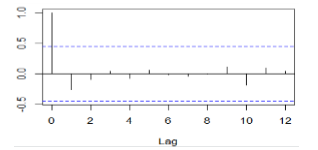
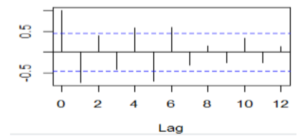
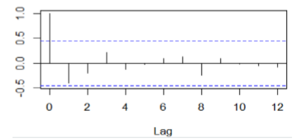
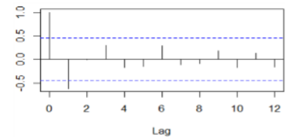
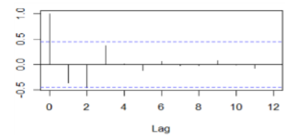
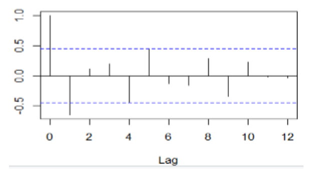
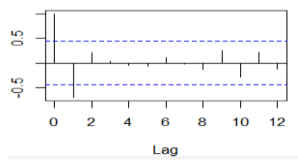
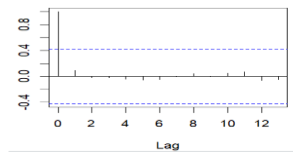
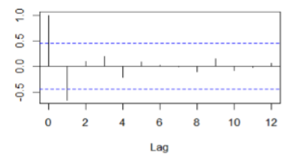
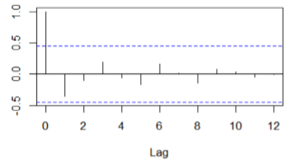
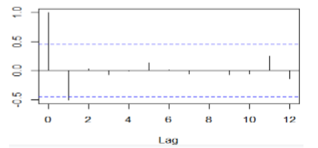
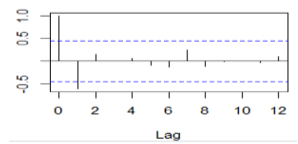
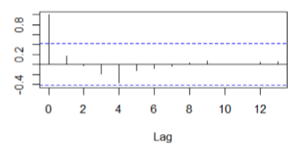
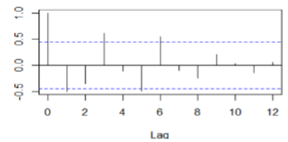
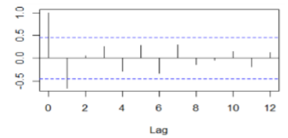
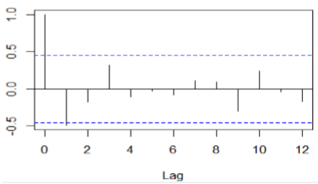
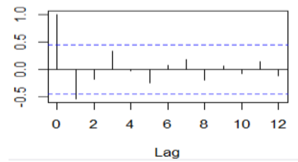
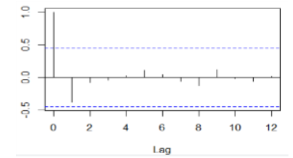
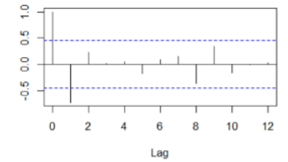
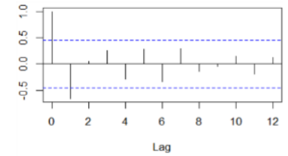
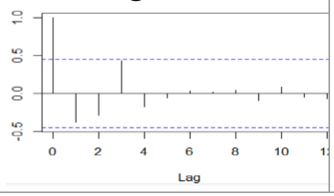
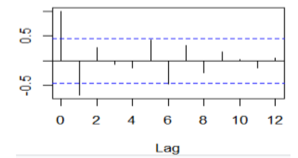
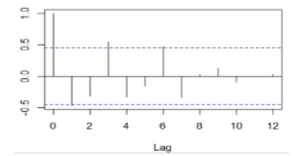
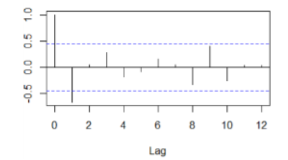
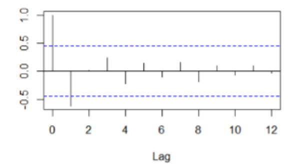
Latin America and Caribbean		
Antigua and Barbuda Argentina Aruba Bahamas Barbados Belize Bolivia Brazil Chile	Colombia Costa Rica Dominican Rep. Ecuador El Salvador Guatemala Guyana Honduras Jamaica	Mexico Nicaragua Panama Paraguay Peru Suriname Trinidad and Tobago Uruguay
Note: Cuba and Venezuela were excluded for lack of data registered during period analyzed.		
Middle East and North Africa		
Algeria Bahrain Djibouti Egypt Iran Jordan	Kuwait Lebanon Mauritania Morocco Oman Qatar	Saudi Arabia Palestine Sudan Tunisia United Arab Emirates Yemen
Note: Syria (2003-2010), Libya, and Iraq were excluded for insufficient data reported during period analyzed. Iran: Data 2000-2018 Sudan: Data 2012-2018		
Eastern Europe and Central Asia		
Albania Armenia Azerbaijan Belarus Bosnia Herzegovina Bulgaria Croatia Cyprus Czechia Estonia	Georgia Hungary Kazakhstan Kyrgyzstan Latvia Lithuania Montenegro North Macedonia Poland Rep. of Moldova	Romania Russia Federation Serbia Slovakia Slovenia Tajikistan Turkey Ukraine
Note: Turkmenistan and Uzbekistan were excluded because of lack of data reported during period analyzed.		

Source: Elaborated by author

9.4. Appendix 4: Auto- and Cross- Covariance and -Correlation Function (ACF) plots – Stationary series in LAC, EECA and MENA

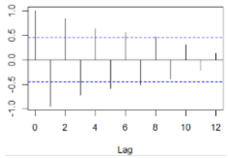
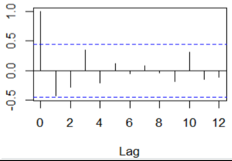
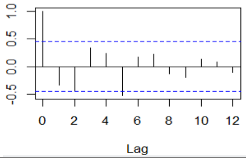
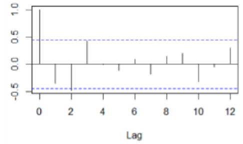
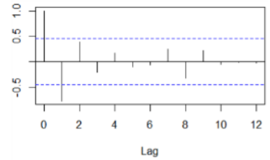
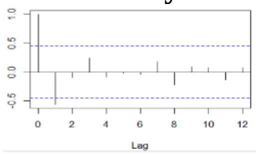
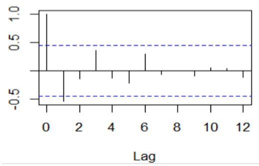
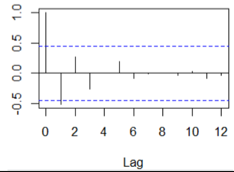
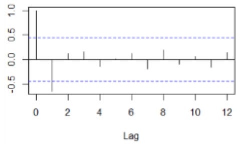
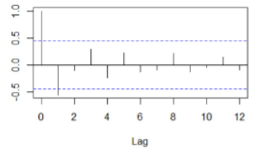
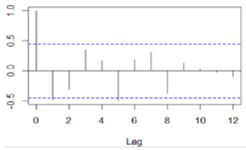
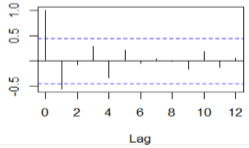
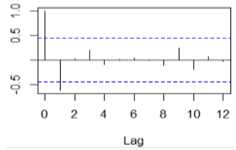
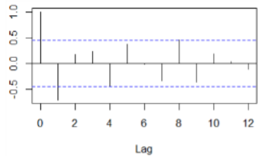
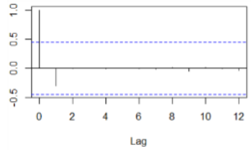
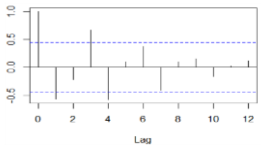
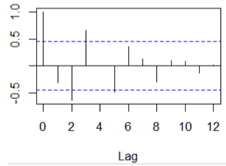
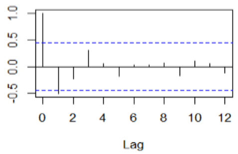
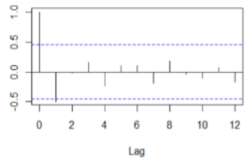
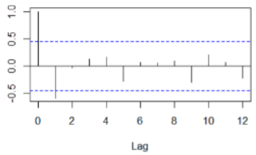
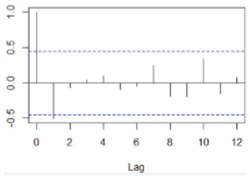
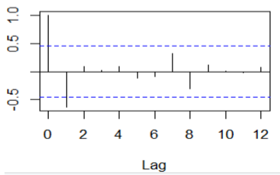
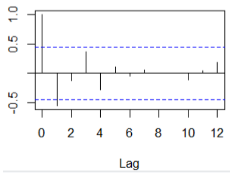
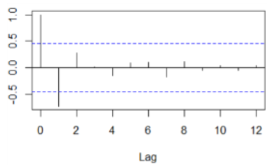
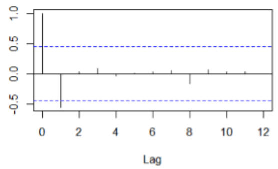
ACF plots – Stationary series for LAC countries

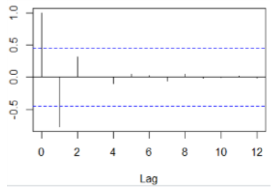
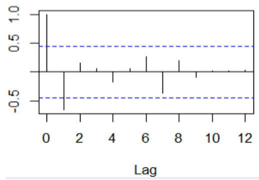
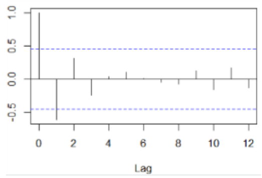
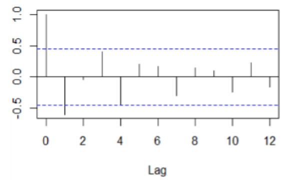
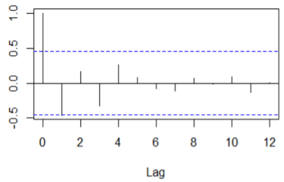
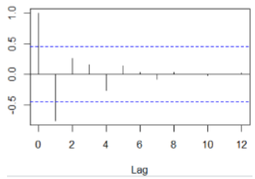
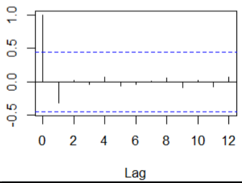
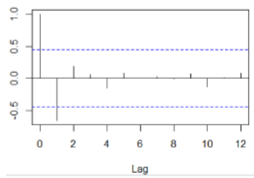
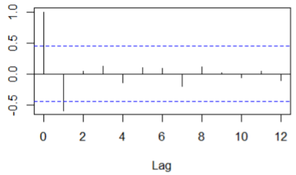
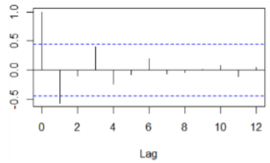
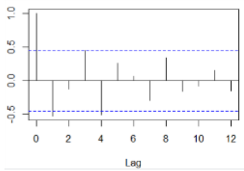
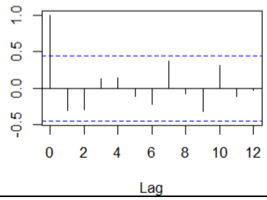
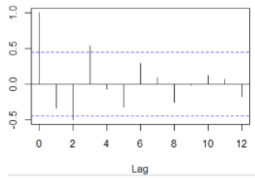
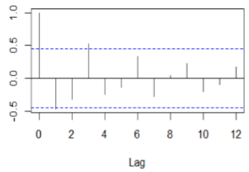
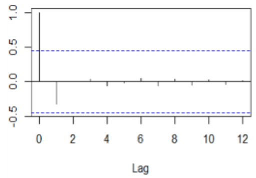
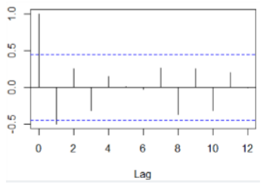
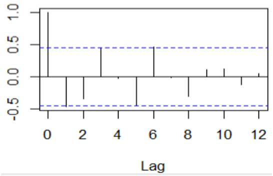
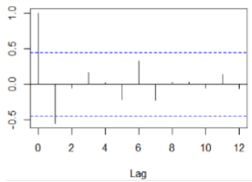
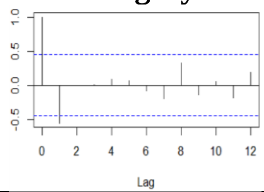
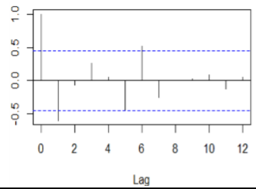
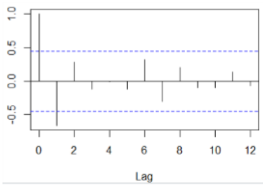
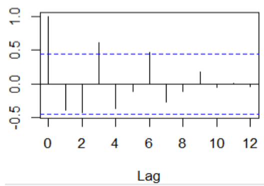
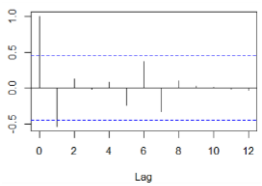
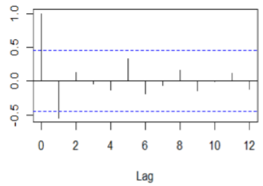
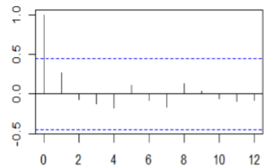
	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORTS	**Chile** 	**Brazil** 	**Brazil** 	**Brazil** 	**Uruguay** 
	Argentina 	**Argentina** 	**Argentina** 	**Mexico** 	**Chile** 
	Uruguay 	**Mexico** 	**Chile** 	**Chile** 	**Argentina** 
	Peru 	**Uruguay** 	**Dominican Republic** 	**Argentina** 	**Mexico** 
	Ecuador 	**Paraguay** 	**Uruguay** 	**Paraguay** 	**Colombia** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORTS	**Brazil** 	**Chile** 	**Mexico** 	**Mexico** 	**Brazil** 
	Mexico 	**Mexico** 	**Chile** 	**Chile** 	**Mexico** 
	Colombia 	**El Salvador** 	**Guatemala** 	**Colombia** 	**Trinidad y Tobago** 
	Peru 	**Brazil** 	**Peru** 	**Argentina** 	**Jamaica** 
	Argentina 	**Uruguay** 	**Colombia** 	**Uruguay** 	**Bahamas** 

Source: Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

ACF plots – Stationary series for EECA countries

	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORTS	**Poland** 	**Poland** 	**Poland** 	**Poland** 	**Russia** 
	Turkey 	**Belarus** 	**Turkey** 	**Hungary** 	**Romania** 
	Russia 	**Lithuania** 	**Hungary** 	**Russia** 	**Bulgaria** 
	Croatia 	**Ukraine** 	**Ukraine** 	**Czechia** 	**North Macedonia** 
	Lithuania 	**Hungary** 	**Russia** 	**Slovakia** 	**Slovakia** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORTS	**Poland** 	**Russia** 	**Russia** 	**Poland** 	**Russia** 
	Russia 	**Bulgaria** 	**Kazakhstan** 	**Czechia** 	**Croatia** 
	Lithuania 	**Czechia** 	**Czechia** 	**Romania** 	**Bulgaria** 
	Ukraine 	**Bosnia** 	**Romania** 	**Hungary** 	**Poland** 
	Belarus 	**Croatia** 	**Slovakia** 	**Russia** 	**Romania** 

Source: Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

ACF plots – Stationary series for MENA countries

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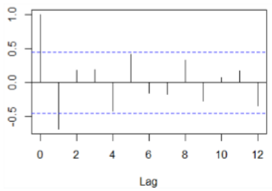
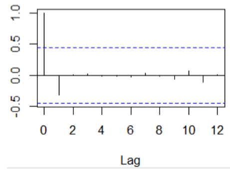
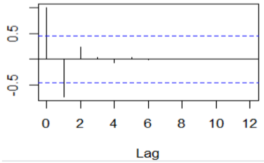
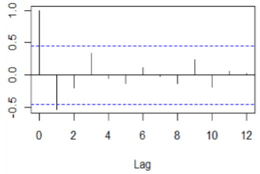
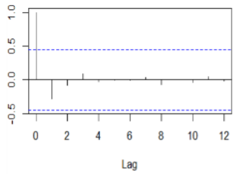
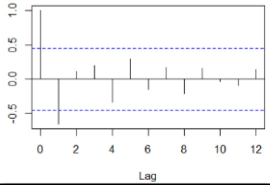
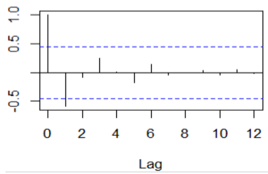
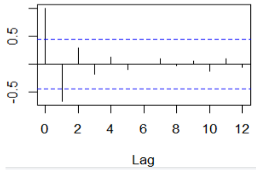
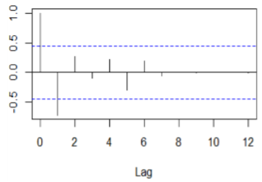
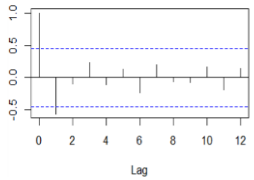
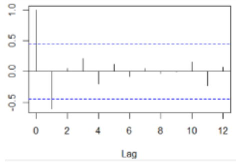
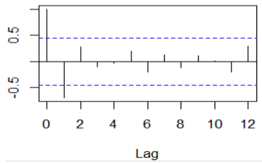
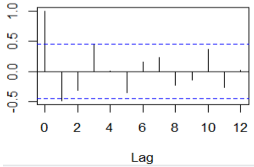
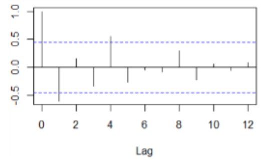
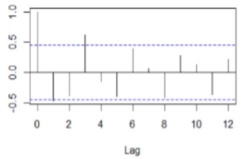
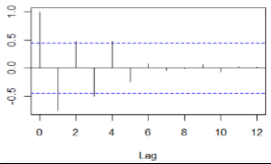
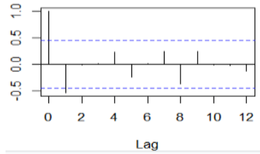
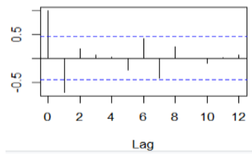
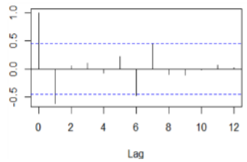
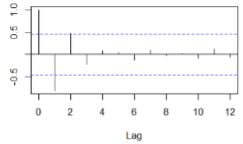
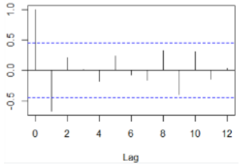
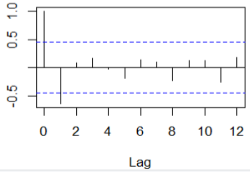
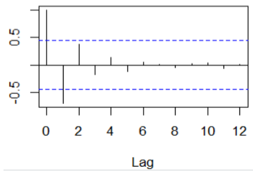
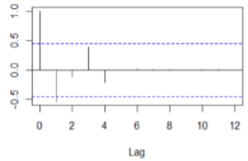
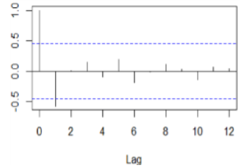
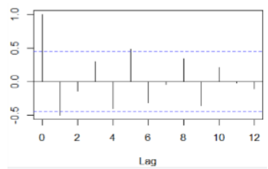
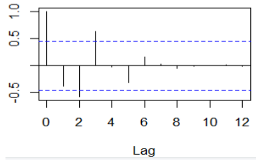
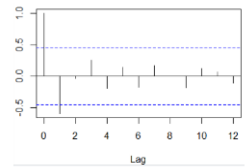
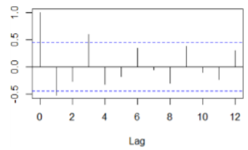
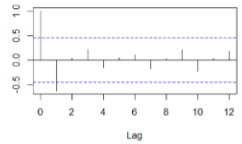
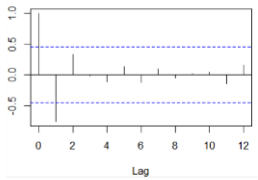
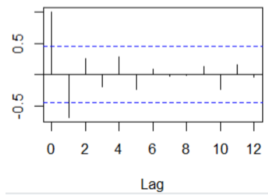
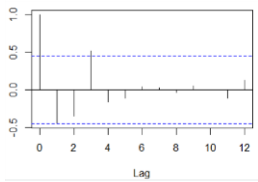
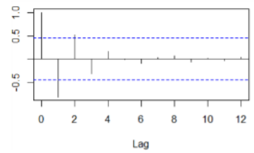
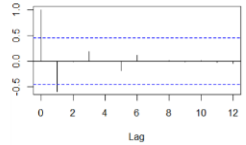
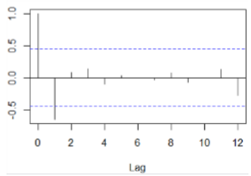
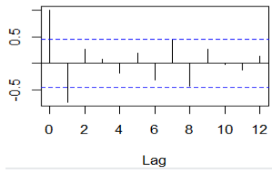
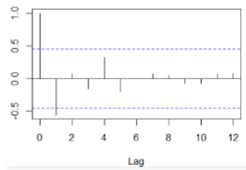
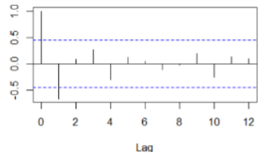
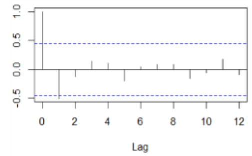
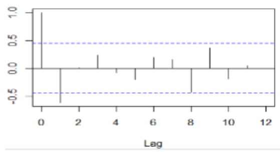
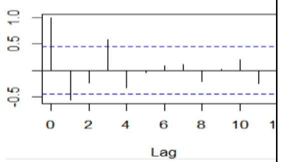
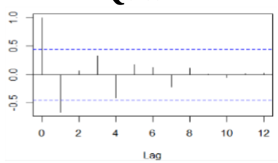
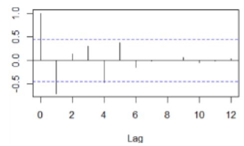
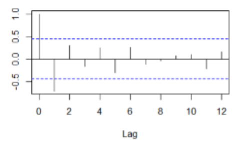
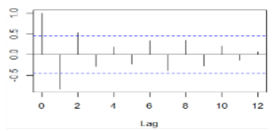
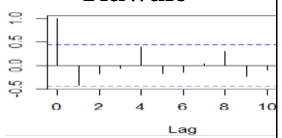
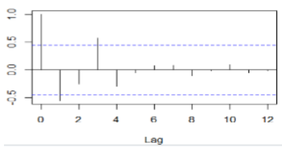
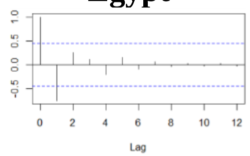
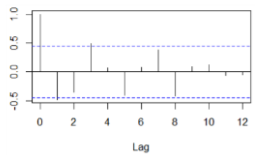
EXPORTS	**Morocco** 	**UAE** 	**UAE** 	**UAE** 	**UAE** 
	Oman 	**Egypt** 	**Saudi Arabia** 	**Oman** 	**Saudi Arabia** 
	Tunisia 	**Saudi Arabia** 	**Tunisia** 	**Egypt** 	**Jordan** 
	Mauritania 	**Jordan** 	**Oman** 	**Bahrain** 	**Bahrain** 
	Saudi Arabia 	**Kuwait** 	**Jordan** 	**Morocco** 	**Oman** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
	Saudi Arabia 	**Egypt** 	**Saudi Arabia** 	**UAE** 	**UAE** 
	UAE 	**Jordan** 	**UAE** 	**Oman** 	**Saudi Arabia** 
IMPORTS	**Kuwait** 	**Saudi Arabia** 	**Kuwait** 	**Bahrain** 	**Qatar** 
	Lebanon 	**UAE** 	**Qatar** 	**Lebanon** 	**Jordan** 
	Oman 	**Kuwait** 	**Oman** 	**Egypt** 	**Oman** 

Source: Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

9.5. Appendix 5: Augmented Dickey Fuller Test (ADF) results in LAC, EECA and MENA

Augmented Dickey Fuller Test (ADF) for LAC countries, in Fish exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Fish	**Exports**	Chile	0.011	With Tendency	-5.938	-4.38	-3.60	-3.24	1.40E-05	**Reject H0**
				With constant	-6.073	-3.75	-3.00	-2.63	2.06E-06	**Reject H0**
				Merge type	-5.938	-2.66	-1.95	-1.6	8.53E-07	**Reject H0**
		Argentina	0.010	With Tendency	-5.781	-4.38	-3.60	-3.24	1.68E-04	**Reject H0**
				With constant	-5.938	-3.75	-3.00	-2.63	3.25E-05	**Reject H0**
				Merge type	-6.073	-2.66	-1.95	-1.6	1.76E-05	**Reject H0**
		Uruguay	0.087	With Tendency	-4.926	-4.38	-3.60	-3.24	2.57E-05	**Reject H0**
				With constant	-4.988	-3.75	-3.00	-2.63	4.77E-06	**Reject H0**
				Merge type	-5.161	-2.66	-1.95	-1.6	2.00E-06	**Reject H0**
		Peru	0.030	With Tendency	-4.662	-4.38	-3.60	-3.24	4.82E-05	**Reject H0**
				With constant	-4.837	-3.75	-3.00	-2.63	7.46E-06	**Reject H0**
				Merge type	-5.057	-2.66	-1.95	-1.6	3.25E-06	**Reject H0**
		Ecuador	0.010	With Tendency	-7.86	-4.38	-3.60	-3.24	4.94E-06	**Reject H0**
				With constant	-8.143	-3.75	-3.00	-2.63	6.82E-07	**Reject H0**
				Merge type	-7.853	-2.66	-1.95	-1.6	5.57E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Fish imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Fish	**Imports**	Brazil	0.532	With Tendency	-6.196	-4.38	-3.60	-3.24	5.18E-05	**Reject H0**
				With constant	-5.884	-3.75	-3.00	-2.63	2.59E-05	**Reject H0**
				Merge type	-5.619	-2.66	-1.95	-1.6	2.67E-05	**Reject H0**
		Mexico	0.023	With Tendency	-6.820	-4.38	-3.60	-3.24	5.52E-07	**Reject H0**
				With constant	-7.016	-3.75	-3.00	-2.63	7.05E-08	**Reject H0**
				Merge type	-7.086	-2.66	-1.95	-1.6	2.92E-08	**Reject H0**
		Colombia	0.052	With Tendency	-5.178	-4.38	-3.60	-3.24	1.44E-05	**Reject H0**
				With constant	-5.329	-3.75	-3.00	-2.63	2.18E-06	**Reject H0**
				Merge type	-5.516	-2.66	-1.95	-1.6	8.59E-07	**Reject H0**
		Peru	0.038	With Tendency	-6.586	-4.38	-3.60	-3.24	1.68E-05	**Reject H0**
				With constant	-6.818	-3.75	-3.00	-2.63	2.50E-06	**Reject H0**
				Merge type	-6.974	-2.66	-1.95	-1.6	1.12E-06	**Reject H0**
		Argentina	0.141	With Tendency	-7.718	-4.38	-3.60	-3.24	7.89E-06	**Reject H0**
				With constant	-7.961	-3.75	-3.00	-2.63	1.13E-06	**Reject H0**
				Merge type	-8.136	-2.66	-1.95	-1.6	4.91E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Bovine exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Bovine	Exports	Brazil	0.026	With Tendency	-3.9603	-4.38	-3.6	-3.24	0.0005	**Reject H0**
				With constant	-4.2457	-3.75	-3.00	-2.63	9.74E-05	**Reject H0**
				Merge type	-4.3201	-2.66	-1.95	-1.6	5.998E-05	**Reject H0**
		Argentina	0.010	With Tendency	-3.8767	-4.38	-3.60	-3.24	0.001321	**Reject H0**
				With constant	-4.0752	-3.75	-3.00	-2.63	0.0003216	**Reject H0**
				Merge type	-4.2079	-2.66	-1.95	-1.6	0.0001911	**Reject H0**
		Mexico	0.010	With Tendency	-6.0829	-4.38	-3.60	-3.24	7.00E-08	**Reject H0**
				With constant	-6.176	-3.75	-3.00	-2.63	8.11E-09	**Reject H0**
				Merge type	-6.3921	-2.66	-1.95	-1.6	2.14E-09	**Reject H0**
		Uruguay	0.014	With Tendency	-3.7244	-4.38	-3.60	-3.24	0.000374	**Reject H0**
				With constant	-3.8877	-3.75	-3.00	-2.63	7.58E-05	**Reject H0**
				Merge type	-4.0707	-2.66	-1.95	-1.6	3.83E-05	**Reject H0**
		Paraguay	0.136	With Tendency	-4.3209	-4.38	-3.60	-3.24	7.57E-05	**Reject H0**
				With constant	-4.5231	-3.75	-3.00	-2.63	1.22E-05	**Reject H0**
				Merge type	-4.7163	-2.66	-1.95	-1.6	5.41E-06	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Bovine imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Bovine	Imports	Chile	0.010	With Tendency	-4.490	-4.38	-3.60	-3.24	2.77E-06	**Reject H0**
				With constant	-4.654	-3.75	-3.00	-2.63	3.52E-07	**Reject H0**
				Merge type	-4.878	-2.66	-1.95	-1.6	1.13E-07	**Reject H0**
		Mexico	0.031	With Tendency	-6.113	-4.38	-3.60	-3.24	3.10E-07	**Reject H0**
				With constant	-6.343	-3.75	-3.00	-2.63	3.48E-08	**Reject H0**
				Merge type	-6.461	-2.66	-1.95	-1.6	1.25E-08	**Reject H0**
		El Salvador	0.028	With Tendency	-5.374	-4.38	-3.60	-3.24	8.51E-06	**Reject H0**
				With constant	-5.472	-3.75	-3.00	-2.63	1.49E-06	**Reject H0**
				Merge type	-5.469	-2.66	-1.95	-1.6	8.10E-07	**Reject H0**
		Brazil	0.010	With Tendency	-5.081	-4.38	-3.60	-3.24	1.35E-05	**Reject H0**
				With constant	-5.258	-3.75	-3.00	-2.63	1.98E-06	**Reject H0**
				Merge type	-5.472	-2.66	-1.95	-1.6	7.71E-07	**Reject H0**
		Uruguay	0.049	With Tendency	-5.039	-4.38	-3.60	-3.24	1.57E-05	**Reject H0**
				With constant	-5.249	-3.75	-3.00	-2.63	2.21E-06	**Reject H0**
				Merge type	-5.429	-2.66	-1.95	-1.6	8.99E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Poultry exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Poultry	Exports	Brazil	0.010	With Tendency	-5.304	-4.38	-3.60	-3.24	3.71E-05	**Reject H0**
				With constant	-5.500	-3.75	-3.00	-2.63	5.70E-06	**Reject H0**
				Merge type	-5.622	-2.66	-1.95	-1.6	2.89E-06	**Reject H0**
		Argentina	0.019	With Tendency	-5.577	-4.38	-3.60	-3.24	3.80E-06	**Reject H0**
				With constant	-5.684	-3.75	-3.00	-2.63	6.28E-07	**Reject H0**
				Merge type	-5.888	-2.66	-1.95	-1.6	2.24E-07	**Reject H0**
		Chile	0.010	With Tendency	-6.031	-4.38	-3.60	-3.24	5.49E-07	**Reject H0**
				With constant	-6.195	-3.75	-3.00	-2.63	6.37E-08	**Reject H0**
				Merge type	-6.429	-2.66	-1.95	-1.6	1.94E-08	**Reject H0**
		Dominican Republic	0.882	With Tendency	-7.199	-4.38	-3.60	-3.24	1.46E-06	**Reject H0**
				With constant	-7.489	-3.75	-3.00	-2.63	2.75E-07	**Reject H0**
				Merge type	-5.407	-2.66	-1.95	-1.6	5.84E-06	**Reject H0**
		Uruguay	0.010	With Tendency	-14.41	-4.38	-3.60	-3.24	2.84E-12	**Reject H0**
				With constant	-13.59	-3.75	-3.00	-2.63	6.44E-13	**Reject H0**
				Merge type	-13.58	-2.66	-1.95	-1.6	1.51E-13	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Poultry imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Poultry	Imports	Mexico	0.010	With Tendency	-7.262	-4.38	-3.60	-3.24	1.06E-06	**Reject H0**
				With constant	-7.263	-3.75	-3.00	-2.63	1.82E-07	**Reject H0**
				Merge type	-6.962	-2.66	-1.95	-1.6	1.48E-07	**Reject H0**
		Chile	0.010	With Tendency	-5.720	-4.38	-3.60	-3.24	0.000113	**Reject H0**
				With constant	-5.961	-3.75	-3.00	-2.63	2.01E-05	**Reject H0**
				Merge type	-4.927	-2.66	-1.95	-1.6	0.00011	**Reject H0**
		Guatemala	0.074	With Tendency	-7.482	-4.38	-3.60	-3.24	4.71E-06	**Reject H0**
				With constant	-6.959	-3.75	-3.00	-2.63	2.22E-06	**Reject H0**
				Merge type	-6.620	-2.66	-1.95	-1.6	2.26E-06	**Reject H0**
		Peru	0.022	With Tendency	-5.376	-4.38	-3.60	-3.24	7.70E-06	**Reject H0**
				With constant	-5.538	-3.75	-3.00	-2.63	1.29E-06	**Reject H0**
				Merge type	-5.599	-2.66	-1.95	-1.6	6.24E-07	**Reject H0**
		Colombia	0.055	With Tendency	-3.953	-4.38	-3.60	-3.24	0.000475	**Reject H0**
				With constant	-4.127	-3.75	-3.00	-2.63	9.29E-05	**Reject H0**
				Merge type	-4.262	-2.66	-1.95	-1.6	4.90E-05	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Swine exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Swine	Exports	Brazil	0.138	With Tendency	-5.931	-4.38	-3.60	-3.24	4.18E-05	**Reject H0**
				With constant	-6.284	-3.75	-3.00	-2.63	6.43E-06	**Reject H0**
				Merge type	-6.305	-2.66	-1.95	-1.6	4.25E-06	**Reject H0**
		Mexico	0.010	With Tendency	-6.941	-4.38	-3.60	-3.24	2.17E-05	**Reject H0**
				With constant	-7.138	-3.75	-3.00	-2.63	3.58E-06	**Reject H0**
				Merge type	-7.367	-2.66	-1.95	-1.6	1.52E-06	**Reject H0**
		Chile	0.014	With Tendency	-5.965	-4.38	-3.60	-3.24	5.03E-05	**Reject H0**
				With constant	-6.443	-3.75	-3.00	-2.63	8.50E-06	**Reject H0**
				Merge type	-6.274	-2.66	-1.95	-1.6	7.27E-06	**Reject H0**
		Argentina	0.039	With Tendency	-8.208	-4.38	-3.60	-3.24	1.60E-08	**Reject H0**
				With constant	-8.378	-3.75	-3.00	-2.63	1.55E-09	**Reject H0**
				Merge type	-8.079	-2.66	-1.95	-1.6	8.92E-10	**Reject H0**
		Paraguay	0.150	With Tendency	-5.581	-4.38	-3.60	-3.24	5.26E-04	**Reject H0**
				With constant	-5.68	-3.75	-3.00	-2.63	1.45E-04	**Reject H0**
				Merge type	-5.824	-2.66	-1.95	-1.6	8.56E-05	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Swine imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Swine	Imports	Mexico	0.010	With Tendency	-5.557	-4.38	-3.60	-3.24	8.49E-05	**Reject H0**
				With constant	-5.796	-3.75	-3.00	-2.63	1.59E-05	**Reject H0**
				Merge type	-6.014	-2.66	-1.95	-1.6	7.51E-06	**Reject H0**
		Chile	0.038	With Tendency	-6.554	-4.38	-3.60	-3.24	1.68E-06	**Reject H0**
				With constant	-6.820	-3.75	-3.00	-2.63	1.93E-07	**Reject H0**
				Merge type	-7.150	-2.66	-1.95	-1.6	6.53E-08	**Reject H0**
		Colombia	0.271	With Tendency	-7.415	-4.38	-3.60	-3.24	1.87E-05	**Reject H0**
				With constant	-7.758	-3.75	-3.00	-2.63	2.66E-06	**Reject H0**
				Merge type	-7.817	-2.66	-1.95	-1.6	1.50E-06	**Reject H0**
		Argentina	0.022	With Tendency	-5.193	-4.38	-3.60	-3.24	2.24E-05	**Reject H0**
				With constant	-5.496	-3.75	-3.00	-2.63	3.26E-06	**Reject H0**
				Merge type	-5.610	-2.66	-1.95	-1.6	1.70E-06	**Reject H0**
		Uruguay	0.023	With Tendency	-5.499	-4.38	-3.60	-3.24	3.28E-05	**Reject H0**
				With constant	-5.831	-3.75	-3.00	-2.63	4.89E-06	**Reject H0**
				Merge type	-5.889	-2.66	-1.95	-1.6	2.97E-06	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Goat exports sector

Variable	Category	Country	DF test p=value	Test Type	τ<τlower τ	1%	τ>τupper 5%	10%	p-value	Result
					Dickey-Fuller unit root test: H0 = The residuals are non-stationary - HA = The residuals are stationary					
Goat	Exports	Uruguay	0.010	With Tendency	-4.809	-4.38	-3.60	-3.24	0.000818	**Reject H0**
				With constant	-4.979	-3.75	-3.00	-2.63	0.000171	**Reject H0**
				Merge type	-5.162	-2.66	-1.95	-1.6	9.09E-05	**Reject H0**
		Chile	0.010	With Tendency	-7.900	-4.38	-3.60	-3.24	3.93E-06	**Reject H0**
				With constant	-8.138	-3.75	-3.00	-2.63	5.32E-07	**Reject H0**
				Merge type	-8.424	-2.66	-1.95	-1.6	1.90E-07	**Reject H0**
		Argentina	0.010	With Tendency	-5.865	-4.38	-3.60	-3.24	1.56E-07	**Reject H0**
				With constant	-6.083	-3.75	-3.00	-2.63	1.49E-08	**Reject H0**
				Merge type	-5.965	-2.66	-1.95	-1.6	7.21E-09	**Reject H0**
		Mexico	0.010	With Tendency	-5.210	-4.38	-3.60	-3.24	0.000102	**Reject H0**
				With constant	-5.365	-3.75	-3.00	-2.63	1.83E-05	**Reject H0**
				Merge type	-5.615	-2.66	-1.95	-1.6	8.01E-06	**Reject H0**
		Colombia	0.218	With Tendency	-4.06	-4.38	-3.60	-3.24	0.000571	**Reject H0**
				With constant	-4.185	-3.75	-3.00	-2.63	0.000118	**Reject H0**
				Merge type	-4.374	-2.66	-1.95	-1.6	5.23E-05	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for LAC countries, in Goat imports sector

Variable	Category	Country	DF test p=value	Test Type	τ<τlower τ	1%	τ>τupper 5%	10%	p-value	Result
					Dickey-Fuller unit root test: H0 = The residuals are non-stationary - HA = The residuals are stationary					
Goat	Imports	Brazil	0.034	With Tendency	-4.943	-4.38	-3.60	-3.24	0.000833	**Reject H0**
				With constant	-5.118	-3.75	-3.00	-2.63	0.000174	**Reject H0**
				Merge type	-5.308	-2.66	-1.95	-1.6	9.14E-05	**Reject H0**
		Mexico	0.010	With Tendency	-8.265	-4.38	-3.60	-3.24	1.55E-06	**Reject H0**
				With constant	-8.670	-3.75	-3.00	-2.63	1.85E-07	**Reject H0**
				Merge type	-7.372	-2.66	-1.95	-1.6	6.40E-07	**Reject H0**
		Trinidad & Tobago	0.027	With Tendency	-5.246	-4.38	-3.60	-3.24	1.04E-05	**Reject H0**
				With constant	-5.413	-3.75	-3.00	-2.63	1.53E-06	**Reject H0**
				Merge type	-5.549	-2.66	-1.95	-1.6	6.55E-07	**Reject H0**
		Jamaica	0.139	With Tendency	-4.605	-4.38	-3.60	-3.24	7.09E-05	**Reject H0**
				With constant	-4.789	-3.75	-3.00	-2.63	1.17E-05	**Reject H0**
				Merge type	-4.929	-2.66	-1.95	-1.6	5.46E-06	**Reject H0**
		Bahamas	0.042	With Tendency	-7.002	-4.38	-3.60	-3.24	1.47E-06	**Reject H0**
				With constant	-7.269	-3.75	-3.00	-2.63	1.67E-07	**Reject H0**
				Merge type	-7.509	-2.66	-1.95	-1.6	5.58E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Fish exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	$\tau<\tau lower$		$\tau>\tau upper$		p-value	Result
					τ	1%	5%	10%		
Fish	Exports	Poland	0.010	With Tendency	-3.231	-4.38	-3.60	-3.24	2.48E-08	**Reject H0**
				With constant	-3.297	-3.75	-3.00	-2.63	2.61E-09	**Reject H0**
				Merge type	-3.322	-2.66	-1.95	-1.6	7.90E-10	**Reject H0**
		Turkey	0.061	With Tendency	-4.251	-4.38	-3.60	-3.24	6.86E-04	**Reject H0**
				With constant	-4.594	-3.75	-3.00	-2.63	1.40E-04	**Reject H0**
				Merge type	-4.629	-2.66	-1.95	-1.6	9.40E-05	**Reject H0**
		Russia	0.018	With Tendency	-7.545	-4.38	-3.60	-3.24	6.64E-06	**Reject H0**
				With constant	-7.852	-3.75	-3.00	-2.63	8.69E-07	**Reject H0**
				Merge type	-8.096	-2.66	-1.95	-1.6	3.47E-07	**Reject H0**
		Croatia	0.248	With Tendency	-10.06	-4.38	-3.60	-3.24	9.91E-08	**Reject H0**
				With constant	-10.07	-3.75	-3.00	-2.63	1.41E-08	**Reject H0**
				Merge type	-10.39	-2.66	-1.95	-1.6	4.04E-09	**Reject H0**
		Lithuania	0.018	With Tendency	-4.784	-4.38	-3.60	-3.24	1.53E-04	**Reject H0**
				With constant	-4.976	-3.75	-3.00	-2.63	2.64E-05	**Reject H0**
				Merge type	-5.131	-2.66	-1.95	-1.6	1.27E-05	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Fish imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	$\tau<\tau lower$		$\tau>\tau upper$		p-value	Result
					τ	1%	5%	10%		
Fish	Imports	Poland	0.010	With Tendency	-6.845	-4.38	-3.60	-3.24	2.30E-07	**Reject H0**
				With constant	-7.102	-3.75	-3.00	-2.63	2.24E-08	**Reject H0**
				Merge type	-7.351	-2.66	-1.95	-1.6	6.37E-09	**Reject H0**
		Russia	0.010	With Tendency	-8.69	-4.38	-3.60	-3.24	2.44E-08	**Reject H0**
				With constant	-9.02	-3.75	-3.00	-2.63	1.98E-09	**Reject H0**
				Merge type	-9.33	-2.66	-1.95	-1.6	4.76E-10	**Reject H0**
		Lithuania	0.022	With Tendency	-6.259	-4.38	-3.60	-3.24	1.36E-05	**Reject H0**
				With constant	-6.49	-3.75	-3.00	-2.63	1.90E-06	**Reject H0**
				Merge type	-6.69	-2.66	-1.95	-1.6	7.66E-07	**Reject H0**
		Ukraine	0.037	With Tendency	-4.112	-4.38	-3.60	-3.24	5.50E-05	**Reject H0**
				With constant	-4.192	-3.75	-3.00	-2.63	1.10E-05	**Reject H0**
				Merge type	-4.308	-2.66	-1.95	-1.6	5.30E-06	**Reject H0**
		Belarus	0.010	With Tendency	-5.504	-4.38	-3.60	-3.24	7.05E-05	**Reject H0**
				With constant	-5.713	-3.75	-3.00	-2.63	1.13E-05	**Reject H0**
				Merge type	-5.929	-2.66	-1.95	-1.6	4.98E-06	**Reject H0**

Elaborated by author, based on stationary series output from R Studio , with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Bovine exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Bovine	Exports	Poland	0.010	With Tendency	-5.740	-4.38	-3.6	-3.24	6.75E-06	**Reject H0**
				With constant	-5.789	-3.75	-3.00	-2.63	1.17E-06	**Reject H0**
				Merge type	-5.987	-2.66	-1.95	-1.6	4.424E-07	**Reject H0**
		Belarus	0.028	With Tendency	-9.177	-4.38	-3.60	-3.24	2.59E-07	**Reject H0**
				With constant	-9.496	-3.75	-3.00	-2.63	2.62E-08	**Reject H0**
				Merge type	-9.888	-2.66	-1.95	-1.6	7.37E-09	**Reject H0**
		Lithuania	0.027	With Tendency	-5.931	-4.38	-3.60	-3.24	4.84E-06	**Reject H0**
				With constant	-6.135	-3.75	-3.00	-2.63	6.29E-07	**Reject H0**
				Merge type	-6.384	-2.66	-1.95	-1.6	2.21E-07	**Reject H0**
		Ukraine	0.010	With Tendency	-8.833	-4.38	-3.60	-3.24	4.10E-06	**Reject H0**
				With constant	-9.148	-3.75	-3.00	-2.63	5.30E-07	**Reject H0**
				Merge type	-9.521	-2.66	-1.95	-1.6	1.79E-07	**Reject H0**
		Hungary	0.017	With Tendency	-5.740	-4.38	-3.60	-3.24	2.23E-06	**Reject H0**
				With constant	-5.974	-3.75	-3.00	-2.63	2.64E-07	**Reject H0**
				Merge type	-6.182	-2.66	-1.95	-1.6	8.97E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Bovine imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Bovine	Imports	Russia	0.025	With Tendency	-7.518	-4.38	-3.60	-3.24	4.23E-07	**Reject H0**
				With constant	-7.795	-3.75	-3.00	-2.63	4.36E-08	**Reject H0**
				Merge type	-8.043	-2.66	-1.95	-1.6	1.35E-08	**Reject H0**
		Bulgaria	0.010	With Tendency	-4.698	-4.38	-3.60	-3.24	6.74E-06	**Reject H0**
				With constant	-4.703	-3.75	-3.00	-2.63	1.20E-06	**Reject H0**
				Merge type	-2.825	-2.66	-1.95	-1.6	1.89E-05	**Reject H0**
		Czechia	0.023	With Tendency	-6.908	-4.38	-3.60	-3.24	1.30E-05	**Reject H0**
				With constant	-7.223	-3.75	-3.00	-2.63	1.78E-06	**Reject H0**
				Merge type	-6.885	-2.66	-1.95	-1.6	1.85E-06	**Reject H0**
		Bosnia	0.010	With Tendency	-9.564	-4.38	-3.60	-3.24	3.76E-07	**Reject H0**
				With constant	-9.980	-3.75	-3.00	-2.63	3.83E-08	**Reject H0**
				Merge type	-10.279	-2.66	-1.95	-1.6	1.13E-08	**Reject H0**
		Croatia	0.042	With Tendency	-7.321	-4.38	-3.60	-3.24	7.87E-06	**Reject H0**
				With constant	-7.577	-3.75	-3.00	-2.63	1.09E-06	**Reject H0**
				Merge type	-7.760	-2.66	-1.95	-1.6	4.63E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Poultry exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Poultry	Exports	Poland	0.010	With Tendency	-5.655	-4.38	-3.60	-3.24	2.25E-05	**Reject H0**
				With constant	-5.886	-3.75	-3.00	-2.63	3.26E-06	**Reject H0**
				Merge type	-5.965	-2.66	-1.95	-1.6	1.68E-06	**Reject H0**
		Turkey	0.178	With Tendency	-4.007	-4.38	-3.60	-3.24	2.07E-06	**Reject H0**
				With constant	-4.141	-3.75	-3.00	-2.63	2.97E-07	**Reject H0**
				Merge type	-3.851	-2.66	-1.95	-1.6	2.21E-07	**Reject H0**
		Hungary	0.010	With Tendency	-5.924	-4.38	-3.60	-3.24	3.88E-06	**Reject H0**
				With constant	-6.129	-3.75	-3.00	-2.63	5.06E-07	**Reject H0**
				Merge type	-6.348	-2.66	-1.95	-1.6	1.81E-07	**Reject H0**
		Ukraine	0.010	With Tendency	-8.004	-4.38	-3.60	-3.24	1.31E-06	**Reject H0**
				With constant	-8.302	-3.75	-3.00	-2.63	1.56E-07	**Reject H0**
				Merge type	-8.473	-2.66	-1.95	-1.6	6.10E-08	**Reject H0**
		Russia	0.039	With Tendency	-7.368	-4.38	-3.60	-3.24	1.35E-06	**Reject H0**
				With constant	-7.632	-3.75	-3.00	-2.63	1.58E-07	**Reject H0**
				Merge type	-7.896	-2.66	-1.95	-1.6	5.33E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Poultry imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Poultry	Imports	Russia	0.214	With Tendency	-5.617	-4.38	-3.60	-3.24	7.08E-07	**Reject H0**
				With constant	-5.747	-3.75	-3.00	-2.63	8.67E-08	**Reject H0**
				Merge type	-5.921	-2.66	-1.95	-1.6	2.83E-08	**Reject H0**
		Kazakhstan	0.358	With Tendency	-4.128	-4.38	-3.60	-3.24	1.31E-06	**Reject H0**
				With constant	-4.299	-3.75	-3.00	-2.63	1.59E-07	**Reject H0**
				Merge type	-4.495	-2.66	-1.95	-1.6	5.69E-08	**Reject H0**
		Czechia	0.010	With Tendency	-6.812	-4.38	-3.60	-3.24	1.23E-06	**Reject H0**
				With constant	-7.133	-3.75	-3.00	-2.63	1.39E-07	**Reject H0**
				Merge type	-7.342	-2.66	-1.95	-1.6	4.73E-08	**Reject H0**
		Romania	0.010	With Tendency	-5.264	-4.38	-3.60	-3.24	2.78E-06	**Reject H0**
				With constant	-5.457	-3.75	-3.00	-2.63	3.37E-07	**Reject H0**
				Merge type	-5.627	-2.66	-1.95	-1.6	1.20E-07	**Reject H0**
		Slovakia	0.010	With Tendency	-6.648	-4.38	-3.60	-3.24	5.62E-07	**Reject H0**
				With constant	-6.876	-3.75	-3.00	-2.63	6.60E-08	**Reject H0**
				Merge type	-6.367	-2.66	-1.95	-1.6	6.88E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Swine exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Swine	Exports	Poland	0.010	With Tendency	-7.919	-4.38	-3.60	-3.24	5.66E-06	**Reject H0**
				With constant	-8.187	-3.75	-3.00	-2.63	7.54E-07	**Reject H0**
				Merge type	-8.533	-2.66	-1.95	-1.6	2.64E-07	**Reject H0**
		Hungary	0.010	With Tendency	-5.847	-4.38	-3.60	-3.24	6.25E-06	**Reject H0**
				With constant	-5.878	-3.75	-3.00	-2.63	1.14E-06	**Reject H0**
				Merge type	-6.168	-2.66	-1.95	-1.6	4.16E-07	**Reject H0**
		Russia	0.016	With Tendency	-8.763	-4.38	-3.60	-3.24	6.27E-08	**Reject H0**
				With constant	-9.044	-3.75	-3.00	-2.63	6.16E-09	**Reject H0**
				Merge type	-9.251	-2.66	-1.95	-1.6	1.86E-09	**Reject H0**
		Czechia	0.026	With Tendency	-6.046	-4.38	-3.60	-3.24	6.13E-05	**Reject H0**
				With constant	-6.161	-3.75	-3.00	-2.63	1.19E-05	**Reject H0**
				Merge type	-6.337	-2.66	-1.95	-1.6	6.29E-06	**Reject H0**
		Slovakia	0.097	With Tendency	-5.933	-4.38	-3.60	-3.24	1.91E-06	**Reject H0**
				With constant	-6.157	-3.75	-3.00	-2.63	2.22E-07	**Reject H0**
				Merge type	-6.384	-2.66	-1.95	-1.6	7.40E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Swine imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Swine	Imports	Poland	0.038	With Tendency	-6.542	-4.38	-3.60	-3.24	2.17E-05	**Reject H0**
				With constant	-6.609	-3.75	-3.00	-2.63	5.15E-06	**Reject H0**
				Merge type	-6.715	-2.66	-1.95	-1.6	2.84E-06	**Reject H0**
		Czechia	0.021	With Tendency	-6.072	-4.38	-3.60	-3.24	7.27E-06	**Reject H0**
				With constant	-6.302	-3.75	-3.00	-2.63	9.74E-07	**Reject H0**
				Merge type	-6.559	-2.66	-1.95	-1.6	3.69E-07	**Reject H0**
		Romania	0.010	With Tendency	-8.359	-4.38	-3.60	-3.24	1.03E-06	**Reject H0**
				With constant	-8.676	-3.75	-3.00	-2.63	1.13E-07	**Reject H0**
				Merge type	-9.063	-2.66	-1.95	-1.6	3.53E-08	**Reject H0**
		Hungary	0.010	With Tendency	-5.611	-4.38	-3.60	-3.24	3.92E-05	**Reject H0**
				With constant	-5.816	-3.75	-3.00	-2.63	6.07E-06	**Reject H0**
				Merge type	-6.051	-2.66	-1.95	-1.6	2.54E-06	**Reject H0**
		Russia	0.035	With Tendency	-6.430	-4.38	-3.60	-3.24	6.29E-07	**Reject H0**
				With constant	-6.667	-3.75	-3.00	-2.63	6.70E-08	**Reject H0**
				Merge type	-6.832	-2.66	-1.95	-1.6	2.28E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for EECA countries, in Goat exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Goat	Exports	Russia	0.010	With Tendency	-6.603	-4.38	-3.60	-3.24	1.41E-07	**Reject H0**
				With constant	-6.828	-3.75	-3.00	-2.63	1.39E-08	**Reject H0**
				Merge type	-7.033	-2.66	-1.95	-1.6	4.07E-09	**Reject H0**
		Romania	0.057	With Tendency	-6.95	-4.38	-3.60	-3.24	9.40E-07	**Reject H0**
				With constant	-7.674	-3.75	-3.00	-2.63	1.05E-07	**Reject H0**
				Merge type	-7.811	-2.66	-1.95	-1.6	4.02E-08	**Reject H0**
		Bulgaria	0.010	With Tendency	-6.738	-4.38	-3.60	-3.24	5.37E-10	**Reject H0**
				With constant	-7.091	-3.75	-3.00	-2.63	4.68E-11	**Reject H0**
				Merge type	-2.939	-2.66	-1.95	-1.6	2.33E-08	**Reject H0**
		North Macedonia	0.010	With Tendency	-3.912	-4.38	-3.60	-3.24	7.53E-05	**Reject H0**
				With constant	-4.066	-3.75	-3.00	-2.63	1.21E-05	**Reject H0**
				Merge type	-4.210	-2.66	-1.95	-1.6	5.39E-06	**Reject H0**
		Slovakia	0.010	With Tendency	-5.327	-4.38	-3.60	-3.24	4.61E-06	**Reject H0**
				With constant	-5.468	-3.75	-3.00	-2.63	6.40E-07	**Reject H0**
				Merge type	-5.627	-2.66	-1.95	-1.6	2.46E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for Test for EECA countries, in Goat imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Goat	Imports	Russia	0.047	With Tendency	-4.086	-4.38	-3.60	-3.24	2.97E-05	**Reject H0**
				With constant	-4.238	-3.75	-3.00	-2.63	5.27E-06	**Reject H0**
				Merge type	-4.38	-2.66	-1.95	-1.6	2.44E-06	**Reject H0**
		Croatia	0.205	With Tendency	-6.090	-4.38	-3.60	-3.24	8.43E-07	**Reject H0**
				With constant	-6.318	-3.75	-3.00	-2.63	9.37E-08	**Reject H0**
				Merge type	-6.581	-2.66	-1.95	-1.6	2.84E-08	**Reject H0**
		Bulgaria	0.335	With Tendency	-6.176	-4.38	-3.60	-3.24	5.53E-08	**Reject H0**
				With constant	-5.759	-3.75	-3.00	-2.63	1.43E-08	**Reject H0**
				Merge type	-2.728	-2.66	-1.95	-1.6	1.43E-06	**Reject H0**
		Poland	0.096	With Tendency	-8.906	-4.38	-3.60	-3.24	1.24E-07	**Reject H0**
				With constant	-9.251	-3.75	-3.00	-2.63	1.19E-08	**Reject H0**
				Merge type	-9.696	-2.66	-1.95	-1.6	2.98E-09	**Reject H0**
		Romania	0.010	With Tendency	-3.514	-4.38	-3.60	-3.24	1.11E-02	**Reject H0**
				With constant	-3.919	-3.75	-3.00	-2.63	3.12E-03	**Reject H0**
				Merge type	-3.827	-2.66	-1.95	-1.6	3.52E-03	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in fish exports sector

Variable	Category	Country	DF test p=value	Test Type	τ<τlower τ	1%	τ>τupper 5%	10%	p-value	Result
			Dickey-Fuller unit root test; H0 = The residuals are non-stationary - HA = The residuals are stationary							
Fish	Exports	Morocco	0.269	With Tendency	-6.077	-4.38	-3.60	-3.24	2.83E-07	**Reject H0**
				With constant	-6.392	-3.75	-3.00	-2.63	3.03E-08	**Reject H0**
				Merge type	-6.569	-2.66	-1.95	-1.6	9.25E-09	**Reject H0**
		Oman	0.010	With Tendency	-6.811	-4.38	-3.60	-3.24	5.13E-07	**Reject H0**
				With constant	-7.133	-3.75	-3.00	-2.63	5.34E-08	**Reject H0**
				Merge type	-7.398	-2.66	-1.95	-1.6	1.60E-08	**Reject H0**
		Tunisia	0.018	With Tendency	-5.857	-4.38	-3.60	-3.24	3.13E-06	**Reject H0**
				With constant	-6.165	-3.75	-3.00	-2.63	3.81E-07	**Reject H0**
				Merge type	-6.275	-2.66	-1.95	-1.6	1.63E-07	**Reject H0**
		Mauritania	0.010	With Tendency	-3.097	-4.38	-3.60	-3.24	3.55E-07	**Reject H0**
				With constant	-3.090	-3.75	-3.00	-2.63	4.99E-08	**Reject H0**
				Merge type	-3.117	-2.66	-1.95	-1.6	1.81E-08	**Reject H0**
		Saudi Arabia	0.104	With Tendency	-5.869	-4.38	-3.60	-3.24	7.17E-07	**Reject H0**
				With constant	-6.001	-3.75	-3.00	-2.63	8.92E-08	**Reject H0**
				Merge type	-6.173	-2.66	-1.95	-1.6	3.21E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in fish imports sector

Variable	Category	Country	DF test p=value	Test Type	τ<τlower τ	1%	τ>τupper 5%	10%	p-value	Result
			Dickey-Fuller unit root test; H0 = The residuals are non-stationary - HA = The residuals are stationary							
Fish	Imports	Saudi Arabia	0.169	With Tendency	-5.655	-4.38	-3.60	-3.24	2.27E-05	**Reject H0**
				With constant	-5.658	-3.75	-3.00	-2.63	4.79E-06	**Reject H0**
				Merge type	-5.861	-2.66	-1.95	-1.6	1.95E-06	**Reject H0**
		UAE	0.108	With Tendency	-8.247	-4.38	-3.60	-3.24	2.40E-09	**Reject H0**
				With constant	-8.187	-3.75	-3.00	-2.63	3.32E-10	**Reject H0**
				Merge type	-8.541	-2.66	-1.95	-1.6	6.60E-11	**Reject H0**
		Kuwait	0.010	With Tendency	-9.907	-4.38	-3.60	-3.24	2.94E-09	**Reject H0**
				With constant	-10.22	-3.75	-3.00	-2.63	3.99E-10	**Reject H0**
				Merge type	-10.37	-2.66	-1.95	-1.6	1.10E-10	**Reject H0**
		Lebanon	0.010	With Tendency	-6.281	-4.38	-3.60	-3.24	1.08E-06	**Reject H0**
				With constant	-6.436	-3.75	-3.00	-2.63	1.37E-07	**Reject H0**
				Merge type	-6.675	-2.66	-1.95	-1.6	4.44E-08	**Reject H0**
		Oman	0.026	With Tendency	-6.249	-4.38	-3.60	-3.24	6.94E-08	**Reject H0**
				With constant	-6.470	-3.75	-3.00	-2.63	6.25E-09	**Reject H0**
				Merge type	-6.667	-2.66	-1.95	-1.6	1.73E-09	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in bovine exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Bovine	**Exports**	UAE	0.010	With Tendency	-7.599	-4.38	-3.6	-3.24	3.27E-07	**Reject H0**
				With constant	-7.646	-3.75	-3.00	-2.63	4.68E-08	**Reject H0**
				Merge type	-3.391	-2.66	-1.95	-1.6	3.863E-05	**Reject H0**
		Egypt	0.010	With Tendency	-7.418	-4.38	-3.60	-3.24	5.61E-06	**Reject H0**
				With constant	-7.669	-3.75	-3.00	-2.63	7.77E-07	**Reject H0**
				Merge type	-7.858	-2.66	-1.95	-1.6	3.23E-07	**Reject H0**
		Saudi Arabia	0.015	With Tendency	-6.031	-4.38	-3.60	-3.24	7.48E-07	**Reject H0**
				With constant	-6.212	-3.75	-3.00	-2.63	9.46E-08	**Reject H0**
				Merge type	-6.393	-2.66	-1.95	-1.6	3.17E-08	**Reject H0**
		Jordan	0.010	With Tendency	-5.671	-4.38	-3.60	-3.24	1.80E-05	**Reject H0**
				With constant	-5.810	-3.75	-3.00	-2.63	3.05E-06	**Reject H0**
				Merge type	-6.037	-2.66	-1.95	-1.6	1.23E-06	**Reject H0**
		Kuwait	0.010	With Tendency	-7.380	-4.38	-3.60	-3.24	2.77E-07	**Reject H0**
				With constant	-7.493	-3.75	-3.00	-2.63	3.50E-08	**Reject H0**
				Merge type	-7.374	-2.66	-1.95	-1.6	1.76E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in bovine imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Bovine	**Imports**	Egypt	0.011	With Tendency	-10.765	-4.38	-3.60	-3.24	2.99E-07	**Reject H0**
				With constant	-11.169	-3.75	-3.00	-2.63	2.99E-08	**Reject H0**
				Merge type	-11.517	-2.66	-1.95	-1.6	9.13E-09	**Reject H0**
		Jordan	0.010	With Tendency	-5.736	-4.38	-3.60	-3.24	1.34E-05	**Reject H0**
				With constant	-5.879	-3.75	-3.00	-2.63	2.13E-06	**Reject H0**
				Merge type	-6.083	-2.66	-1.95	-1.6	8.43E-07	**Reject H0**
		Saudi Arabia	0.199	With Tendency	-6.545	-4.38	-3.60	-3.24	2.09E-07	**Reject H0**
				With constant	-6.776	-3.75	-3.00	-2.63	2.21E-08	**Reject H0**
				Merge type	-6.936	-2.66	-1.95	-1.6	7.79E-09	**Reject H0**
		UAE	0.010	With Tendency	-8.087	-4.38	-3.60	-3.24	6.53E-07	**Reject H0**
				With constant	-8.370	-3.75	-3.00	-2.63	7.15E-08	**Reject H0**
				Merge type	-8.581	-2.66	-1.95	-1.6	2.48E-08	**Reject H0**
		Kuwait	0.010	With Tendency	-5.840	-4.38	-3.60	-3.24	2.65E-05	**Reject H0**
				With constant	-6.030	-3.75	-3.00	-2.63	4.19E-06	**Reject H0**
				Merge type	-6.305	-2.66	-1.95	-1.6	1.46E-06	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in poultry exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Poultry	Exports	UAE	0.010	With Tendency	-6.331	-4.38	-3.60	-3.24	2.08E-07	**Reject H0**
				With constant	-6.568	-3.75	-3.00	-2.63	2.03E-08	**Reject H0**
				Merge type	-6.785	-2.66	-1.95	-1.6	5.85E-09	**Reject H0**
		Saudi Arabia	0.019	With Tendency	-4.883	-4.38	-3.60	-3.24	9.93E-07	**Reject H0**
				With constant	-5.064	-3.75	-3.00	-2.63	1.10E-07	**Reject H0**
				Merge type	-5.195	-2.66	-1.95	-1.6	3.79E-08	**Reject H0**
		Tunisia	0.010	With Tendency	-7.960	-4.38	-3.60	-3.24	1.90E-06	**Reject H0**
				With constant	-8.278	-3.75	-3.00	-2.63	2.19E-07	**Reject H0**
				Merge type	-8.562	-2.66	-1.95	-1.6	7.41E-08	**Reject H0**
		Oman	0.010	With Tendency	-6.386	-4.38	-3.60	-3.24	3.29E-06	**Reject H0**
				With constant	-6.621	-3.75	-3.00	-2.63	4.03E-07	**Reject H0**
				Merge type	-6.854	-2.66	-1.95	-1.6	1.41E-07	**Reject H0**
		Jordan	0.010	With Tendency	-5.863	-4.38	-3.60	-3.24	7.16E-07	**Reject H0**
				With constant	-6.019	-3.75	-3.00	-2.63	9.53E-08	**Reject H0**
				Merge type	-6.102	-2.66	-1.95	-1.6	3.92E-08	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in poultry imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Poultry	Imports	Saudi Arabia	0.012	With Tendency	-5.203	-4.38	-3.60	-3.24	2.62E-06	**Reject H0**
				With constant	-5.350	-3.75	-3.00	-2.63	3.47E-07	**Reject H0**
				Merge type	-5.542	-2.66	-1.95	-1.6	1.20E-07	**Reject H0**
		UAE	0.017	With Tendency	-5.315	-4.38	-3.60	-3.24	4.32E-04	**Reject H0**
				With constant	-5.426	-3.75	-3.00	-2.63	1.21E-04	**Reject H0**
				Merge type	-5.538	-2.66	-1.95	-1.6	7.61E-05	**Reject H0**
		Kuwait	0.010	With Tendency	-4.805	-4.38	-3.60	-3.24	2.64E-05	**Reject H0**
				With constant	-4.987	-3.75	-3.00	-2.63	3.86E-06	**Reject H0**
				Merge type	-5.119	-2.66	-1.95	-1.6	1.70E-06	**Reject H0**
		Qatar	0.062	With Tendency	-5.47	-4.38	-3.60	-3.24	9.92E-07	**Reject H0**
				With constant	-5.682	-3.75	-3.00	-2.63	1.11E-07	**Reject H0**
				Merge type	-5.909	-2.66	-1.95	-1.6	3.53E-08	**Reject H0**
		Oman	0.015	With Tendency	-6.319	-4.38	-3.60	-3.24	1.45E-05	**Reject H0**
				With constant	-6.550	-3.75	-3.00	-2.63	2.22E-06	**Reject H0**
				Merge type	-6.764	-2.66	-1.95	-1.6	9.24E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in swine exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Swine	Exports	UAE	0.010	With Tendency	-6.585	-4.38	-3.60	-3.24	1.31E-05	**Reject H0**
				With constant	-6.797	-3.75	-3.00	-2.63	1.99E-06	**Reject H0**
				Merge type	-6.971	-2.66	-1.95	-1.6	8.73E-07	**Reject H0**
		Oman	0.010	With Tendency	-5.999	-4.38	-3.60	-3.24	5.83E-07	**Reject H0**
				With constant	-6.142	-3.75	-3.00	-2.63	7.09E-08	**Reject H0**
				Merge type	-6.269	-2.66	-1.95	-1.6	2.53E-08	**Reject H0**
		Egypt	0.010	With Tendency	-4.808	-4.38	-3.60	-3.24	6.49E-05	**Reject H0**
				With constant	-4.995	-3.75	-3.00	-2.63	1.04E-05	**Reject H0**
				Merge type	-5.159	-2.66	-1.95	-1.6	4.67E-06	**Reject H0**
		Bahrain	0.011	With Tendency	-5.437	-4.38	-3.60	-3.24	1.43E-05	**Reject H0**
				With constant	-5.539	-3.75	-3.00	-2.63	2.55E-06	**Reject H0**
				Merge type	-5.699	-2.66	-1.95	-1.6	1.07E-06	**Reject H0**
		Morocco	0.290	With Tendency	-11.087	-4.38	-3.60	-3.24	3.06E-08	**Reject H0**
				With constant	-11.312	-3.75	-3.00	-2.63	3.11E-09	**Reject H0**
				Merge type	-11.422	-2.66	-1.95	-1.6	1.02E-09	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in swine imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Swine	Imports	UAE	0.010	With Tendency	-7.499	-4.38	-3.60	-3.24	3.64E-06	**Reject H0**
				With constant	-7.589	-3.75	-3.00	-2.63	6.23E-07	**Reject H0**
				Merge type	-7.684	-2.66	-1.95	-1.6	3.02E-07	**Reject H0**
		Oman	0.015	With Tendency	-4.529	-4.38	-3.60	-3.24	7.40E-06	**Reject H0**
				With constant	-4.778	-3.75	-3.00	-2.63	1.08E-06	**Reject H0**
				Merge type	-4.708	-2.66	-1.95	-1.6	6.31E-07	**Reject H0**
		Bahrain	0.077	With Tendency	-8.166	-4.38	-3.60	-3.24	1.24E-07	**Reject H0**
				With constant	-8.527	-3.75	-3.00	-2.63	1.35E-08	**Reject H0**
				Merge type	-8.652	-2.66	-1.95	-1.6	4.74E-09	**Reject H0**
		Lebanon	0.170	With Tendency	-5.965	-4.38	-3.60	-3.24	9.20E-07	**Reject H0**
				With constant	-6.594	-3.75	-3.00	-2.63	1.02E-07	**Reject H0**
				Merge type	-6.164	-2.66	-1.95	-1.6	9.99E-08	**Reject H0**
		Egypt	0.010	With Tendency	-8.619	-4.38	-3.60	-3.24	1.32E-08	**Reject H0**
				With constant	-8.930	-3.75	-3.00	-2.63	1.05E-09	**Reject H0**
				Merge type	-9.151	-2.66	-1.95	-1.6	2.74E-10	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in goat exports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Goat	Exports	UAE	0.023	With Tendency	-7.558	-4.38	-3.60	-3.24	2.55E-06	**Reject H0**
				With constant	-8.006	-3.75	-3.00	-2.63	3.04E-07	**Reject H0**
				Merge type	-3.995	-2.66	-1.95	-1.6	1.62E-04	**Reject H0**
		Saudi Arabia	0.010	With Tendency	-8.094	-4.38	-3.60	-3.24	5.10E-07	**Reject H0**
				With constant	-8.123	-3.75	-3.00	-2.63	8.22E-08	**Reject H0**
				Merge type	-8.206	-2.66	-1.95	-1.6	3.55E-08	**Reject H0**
		Jordan	0.030	With Tendency	-9.384	-4.38	-3.60	-3.24	4.70E-07	**Reject H0**
				With constant	-9.677	-3.75	-3.00	-2.63	5.29E-08	**Reject H0**
				Merge type	-9.611	-2.66	-1.95	-1.6	2.63E-08	**Reject H0**
		Bahrain	0.010	With Tendency	-6.023	-4.38	-3.60	-3.24	2.41E-07	**Reject H0**
				With constant	-6.227	-3.75	-3.00	-2.63	2.44E-08	**Reject H0**
				Merge type	-6.452	-2.66	-1.95	-1.6	6.98E-09	**Reject H0**
		Oman	0.010	With Tendency	-5.730	-4.38	-3.60	-3.24	1.24E-05	**Reject H0**
				With constant	-5.907	-3.75	-3.00	-2.63	1.82E-06	**Reject H0**
				Merge type	-6.079	-2.66	-1.95	-1.6	7.33E-07	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

Augmented Dickey Fuller Test (ADF) for MENA countries, in goat imports sector

Variable	Category	Country	Dickey-Fuller unit root test							
			H0 = The residuals are non-stationary - HA = The residuals are stationary							
			DF test p=value	Test Type	τ<τlower		τ>τupper		p-value	Result
					τ	1%	5%	10%		
Goat	Imports	UAE	0.010	With Tendency	-4.641	-4.38	-3.60	-3.24	1.30E-05	**Reject H0**
				With constant	-4.844	-3.75	-3.00	-2.63	2.19E-06	**Reject H0**
				Merge type	-4.972	-2.66	-1.95	-1.6	9.47E-07	**Reject H0**
		Saudi Arabia	0.049	With Tendency	-5.344	-4.38	-3.60	-3.24	1.06E-05	**Reject H0**
				With constant	-5.555	-3.75	-3.00	-2.63	1.43E-06	**Reject H0**
				Merge type	-5.7334	-2.66	-1.95	-1.6	5.72E-07	**Reject H0**
		Qatar	0.017	With Tendency	-6.158	-4.38	-3.60	-3.24	1.10E-05	**Reject H0**
				With constant	-6.291	-3.75	-3.00	-2.63	1.74E-06	**Reject H0**
				Merge type	-6.504	-2.66	-1.95	-1.6	6.85E-07	**Reject H0**
		Jordan	0.010	With Tendency	-5.714	-4.38	-3.60	-3.24	2.56E-06	**Reject H0**
				With constant	-5.917	-3.75	-3.00	-2.63	3.16E-07	**Reject H0**
				Merge type	-6.120	-2.66	-1.95	-1.6	1.11E-07	**Reject H0**
		Oman	0.022	With Tendency	-6.775	-4.38	-3.60	-3.24	1.58E-05	**Reject H0**
				With constant	-7.037	-3.75	-3.00	-2.63	2.38E-06	**Reject H0**
				Merge type	-7.247	-2.66	-1.95	-1.6	1.02E-06	**Reject H0**

Elaborated by author, based on stationary series output from R Studio, with methods from Trapletti & Hornik (2023)

9.6. Appendix 6: Cointegration test results for EECA and MENA countries

Phillips and Ouliaris Unit Root Test results for EECA countries

Phillips and Ouliaris Unit Root Test -EECA H0 = There is not cointegration between 2 variables H6 = There is cointegration between 2 variables				
Variable	**Category**	**Country**	**Test results**	**Result**
Fish	Exports	Poland	0.010	**Reject H0**
		Turkey	0.018	**Reject H0**
		Russia	0.020	**Reject H0**
		Croatia	0.011	**Reject H0**
		Lithuania	0.010	**Reject H0**
	Imports	Poland	0.010	**Reject H0**
		Russia	0.010	**Reject H0**
		Lithuania	0.013	**Reject H0**
		Ukraine	0.010	**Reject H0**
		Belarus	0.017	**Reject H0**
Bovine	Exports	Poland	0.010	**Reject H0**
		Belarus	0.011	**Reject H0**
		Lithuania	0.010	**Reject H0**
		Ukraine	0.027	**Reject H0**
		Hungary	0.010	**Reject H0**
	Imports	Russia	0.010	**Reject H0**
		Bulgaria	0.025	**Reject H0**
		Czechia	0.022	**Reject H0**
		Bosnia	0.015	**Reject H0**
		Croatia	0.016	**Reject H0**
Poultry	Exports	Poland	0.014	**Reject H0**
		Turkey	0.010	**Reject H0**
		Hungary	0.010	**Reject H0**
		Ukraine	0.013	**Reject H0**
		Russia	0.010	**Reject H0**
	Imports	Russia	0.010	**Reject H0**
		Kazakhstan	0.010	**Reject H0**
		Czechia	0.010	**Reject H0**
		Romania	0.010	**Reject H0**
		Slovakia	0.010	**Reject H0**
Swine	Exports	Poland	0.024	**Reject H0**
		Hungary	0.010	**Reject H0**
		Russia	0.010	**Reject H0**
		Czechia	0.025	**Reject H0**
		Slovakia	0.010	**Reject H0**
	Imports	Poland	0.023	**Reject H0**
		Czechia	0.012	**Reject H0**
		Romania	0.018	**Reject H0**
		Hungary	0.014	**Reject H0**
		Russia	0.010	**Reject H0**
Goat	Exports	Russia	0.010	**Reject H0**
		Romania	0.010	**Reject H0**
		Bulgaria	0.028	**Reject H0**
		N. Macedonia	0.010	**Reject H0**
		Slovakia	0.010	**Reject H0**
	Imports	Russia	0.010	**Reject H0**
		Croatia	0.010	**Reject H0**
		Bulgaria	0.026	**Reject H0**
		Poland	0.010	**Reject H0**
		Romania	0.150	**Accept H0**

Source: Elaborated by author, based on cointegration test output from R Studio, with method from Pfaff (2008a)

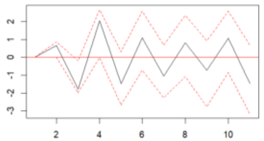
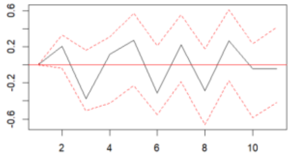
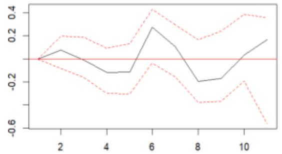
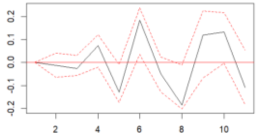
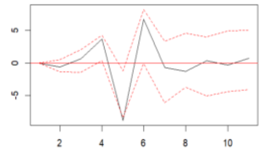
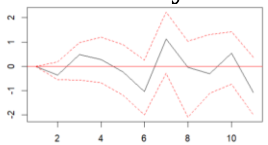
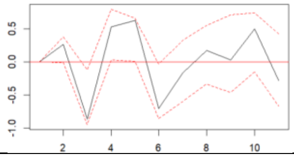
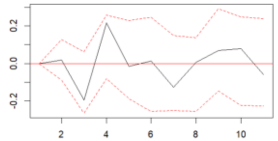
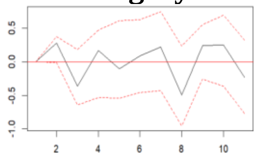
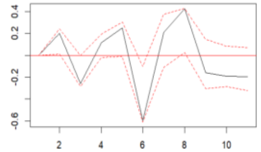
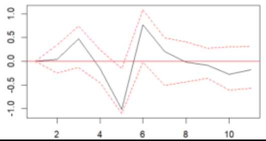
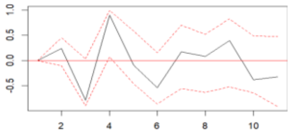
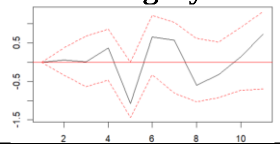
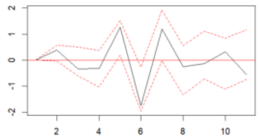
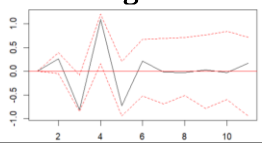
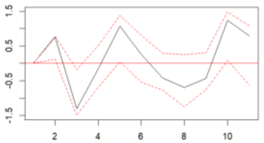
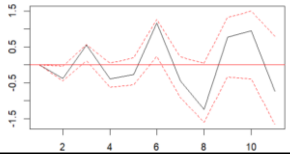
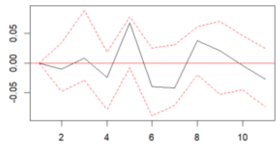
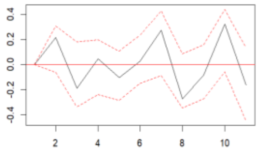
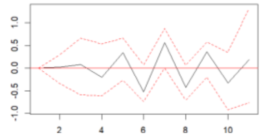
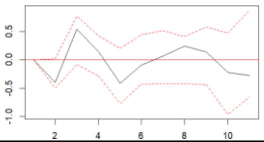
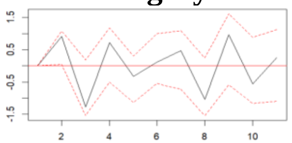
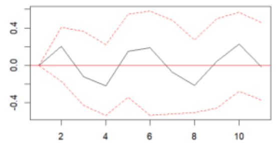
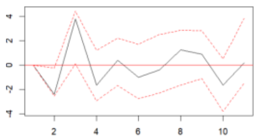
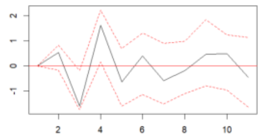
Phillips and Ouliaris Unit Root Test results for MENA countries

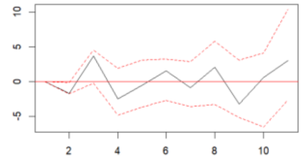
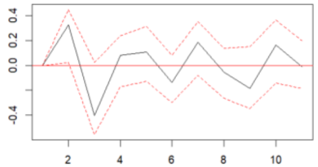
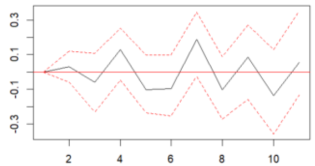
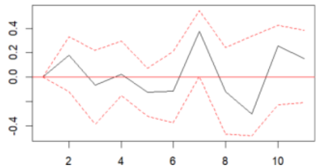
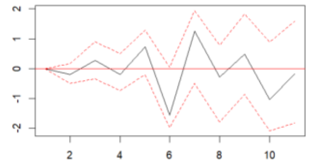
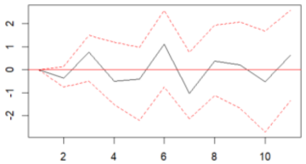
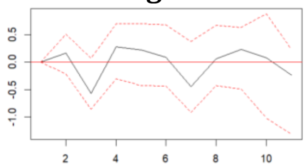
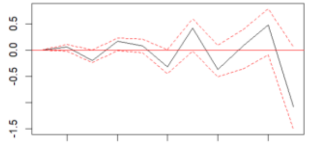
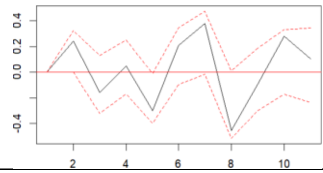
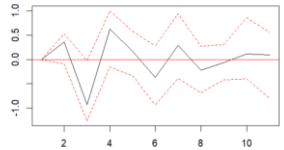
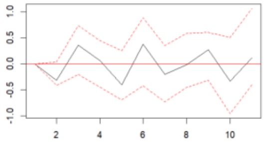
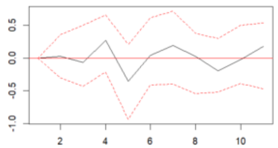
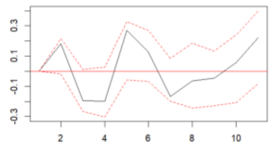
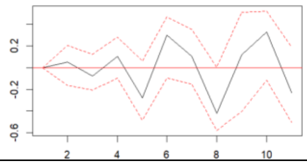
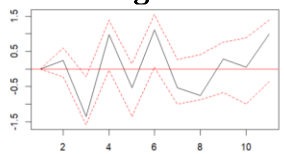
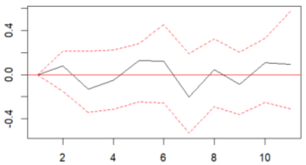
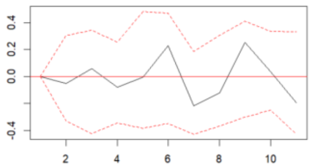
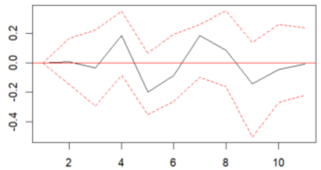
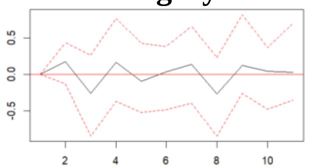
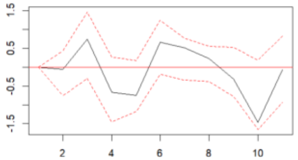
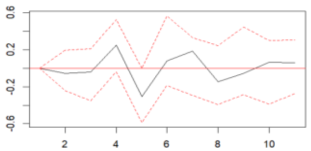
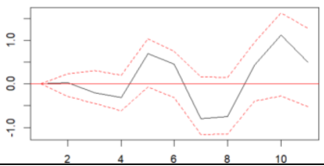
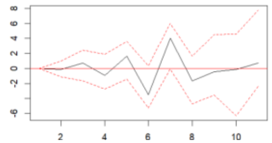
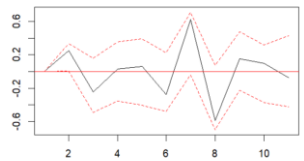
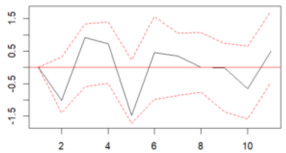
Phillips and Ouliaris Unit Root Test MENA				
H0 = There is not cointegration between 2 variables				
H6 = There is cointegration between 2 variables				
Variable	**Category**	**Country**	**Test results**	**Result**
Fish	Exports	Morocco	0.010	**Reject H0**
		Oman	0.010	**Reject H0**
		Tunisia	0.010	**Reject H0**
		Mauritania	0.010	**Reject H0**
		Saudi Arabia	0.010	**Reject H0**
	Imports	Saudi Arabia	0.010	**Reject H0**
		UAE	0.014	**Reject H0**
		Kuwait	0.010	**Reject H0**
		Lebanon	0.010	**Reject H0**
		Oman	0.010	**Reject H0**
Bovine	Exports	UAE	0.026	**Reject H0**
		Egypt	0.016	**Reject H0**
		Saudi Arabia	0.010	**Reject H0**
		Jordan	0.012	**Reject H0**
		Kuwait	0.010	**Reject H0**
	Imports	Egypt	0.023	**Reject H0**
		Jordan	0.010	**Reject H0**
		Saudi Arabia	0.010	**Reject H0**
		UAE	0.010	**Reject H0**
		Kuwait	0.011	**Reject H0**
Poultry	Exports	UAE	0.010	**Reject H0**
		Saudi Arabia	0.010	**Reject H0**
		Tunisia	0.013	**Reject H0**
		Oman	0.010	**Reject H0**
		Jordan	0.010	**Reject H0**
	Imports	Saudi Arabia	0.010	**Reject H0**
		UAE	0.028	**Reject H0**
		Kuwait	0.010	**Reject H0**
		Qatar	0.010	**Reject H0**
		Oman	0.012	**Reject H0**
Swine	Exports	UAE	0.01591	**Reject H0**
		Oman	0.01	**Reject H0**
		Egypt	0.01044	**Reject H0**
		Bahrain	0.01016	**Reject H0**
		Morocco	0.01	**Reject H0**
	Imports	UAE	0.01087	**Reject H0**
		Oman	0.01	**Reject H0**
		Bahrain	0.01	**Reject H0**
		Lebanon	0.01	**Reject H0**
		Egypt	0.01	**Reject H0**
Goat	Exports	UAE	0.030	**Reject H0**
		Saudi Arabia	0.010	**Reject H0**
		Jordan	0.015	**Reject H0**
		Bahrain	0.010	**Reject H0**
		Oman	0.010	**Reject H0**
	Imports	UAE	0.010	**Reject H0**
		Saudi Arabia	0.010	**Reject H0**
		Qatar	0.011	**Reject H0**
		Jordan	0.010	**Reject H0**
		Oman	0.01268	**Reject H0**

Source: Elaborated by author, based on cointegration test output from R Studio, with method from Pfaff (2008a)

9.7. Appendix 7: Impulse Response Function (IRF) for EECA and MENA countries

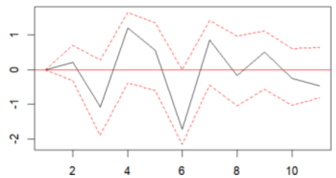
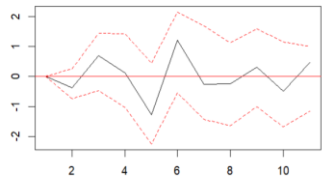
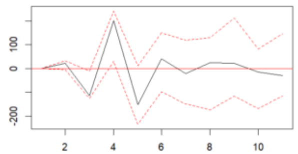
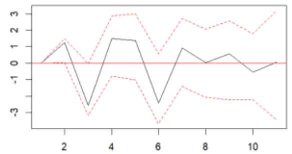
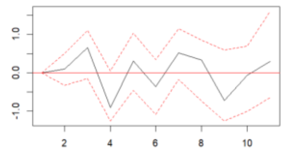
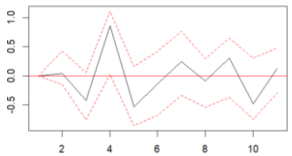
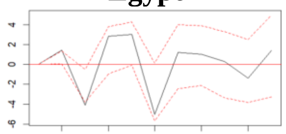
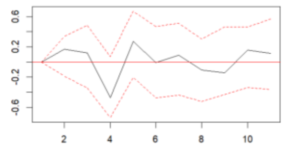
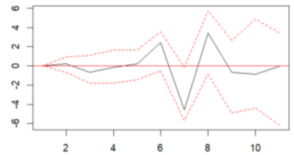
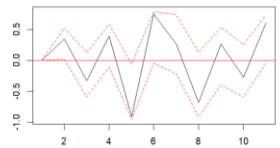
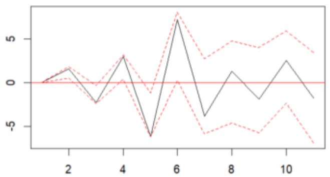
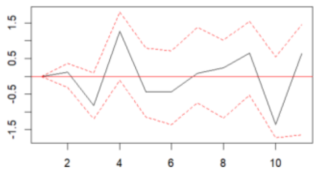
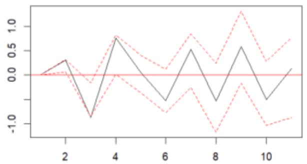
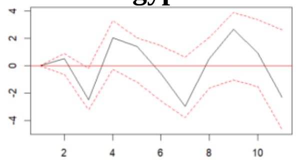
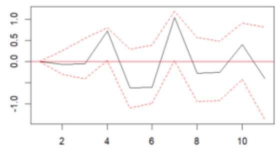
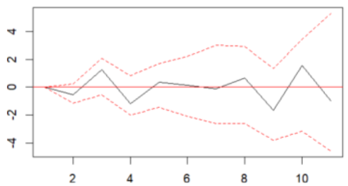
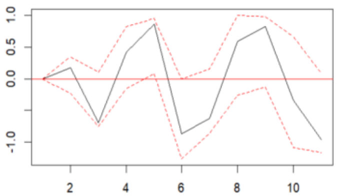
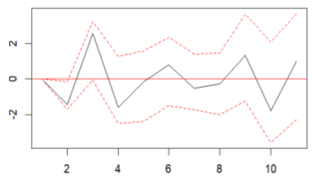
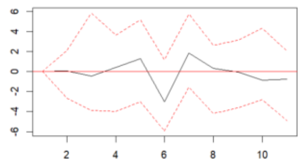
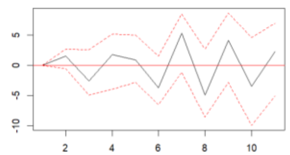
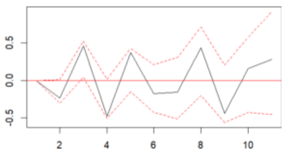
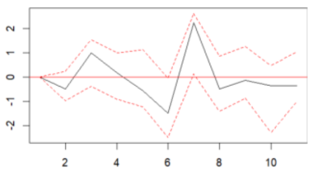
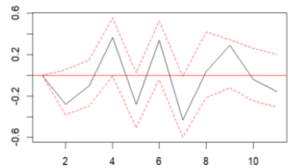
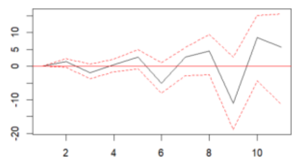
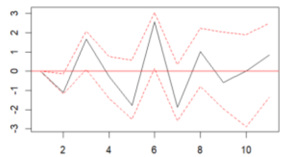
Impulse Response Function (IRF) in EECA countries

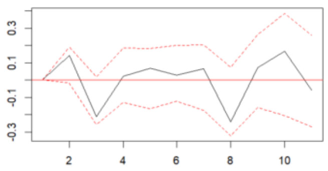
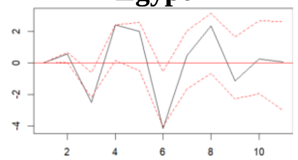
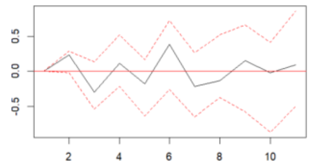
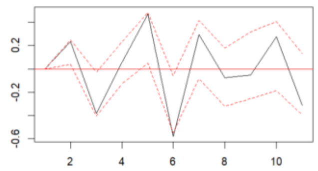
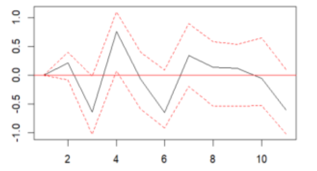
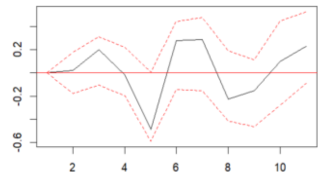
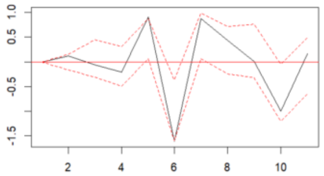
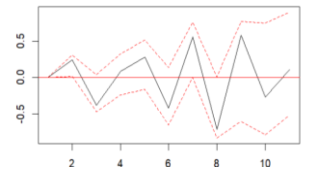
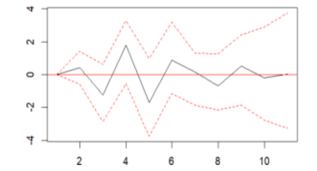
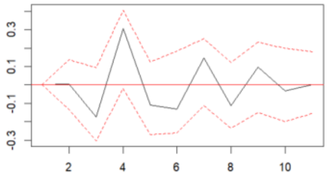
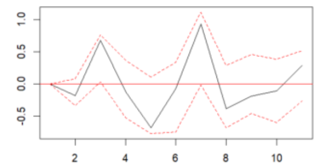
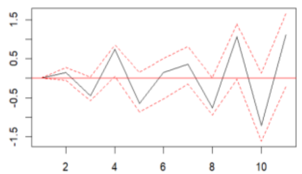
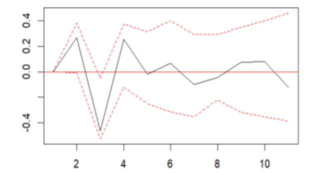
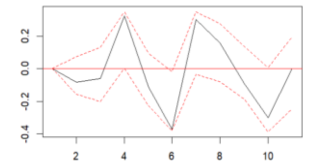
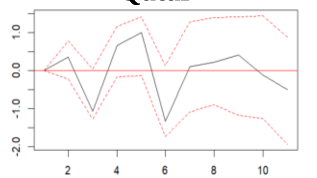
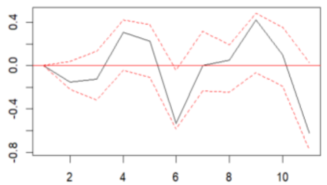
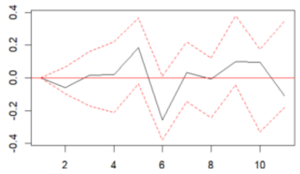
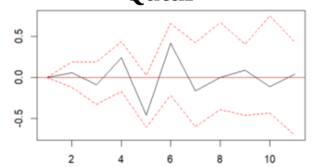
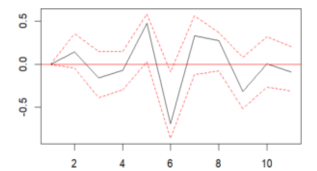
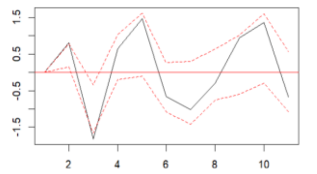
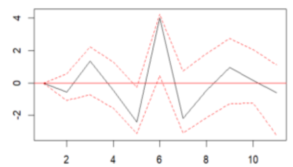
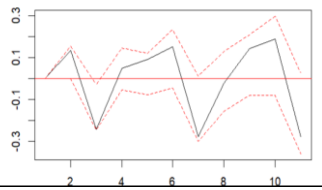
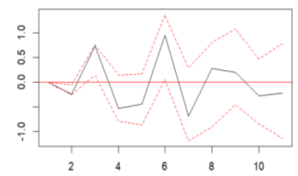
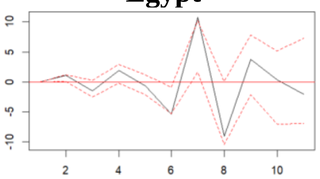
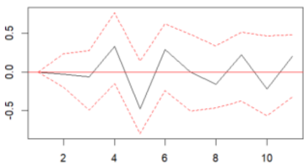
	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORT	**Poland** 	**Poland** 	**Poland** 	**Poland** 	**Russia** 
	Turkey 	**Belarus** 	**Turkey** 	**Hungary** 	**Romania** 
	Russia 	**Lithuania** 	**Hungary** 	**Russia** 	**Bulgaria** 
	Croatia 	**Ukraine** 	**Ukraine** 	**Czechia** 	**North Macedonia** 
	Lithuania 	**Hungary** 	**Russia** 	**Slovakia** 	**Slovakia** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORT	**Poland** 	**Russia** 	**Russia** 	**Poland** 	**Russia** 
	Russia 	**Bulgaria** 	**Kazakhstan** 	**Czechia** 	**Croatia** 
	Lithuania 	**Czechia** 	**Czechia** 	**Romania** 	**Bulgaria** 
	Ukraine 	**Bosnia** 	**Romania** 	**Hungary** 	**Poland** 
	Belarus 	**Croatia** 	**Slovakia** 	**Russia** 	**Romania** 

Source: Elaborated by author, based on IRF outputs from R Studio, with method from Pfaff (2008b)

Impulse Response Function (IRF) in MENA countries

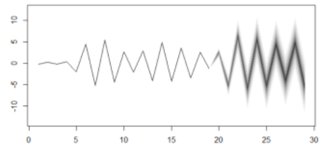
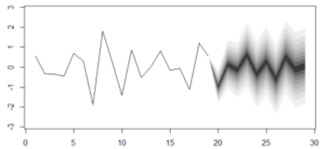
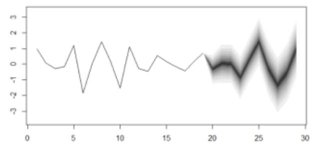
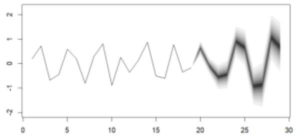
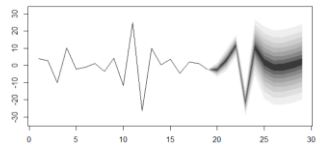
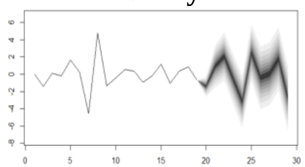
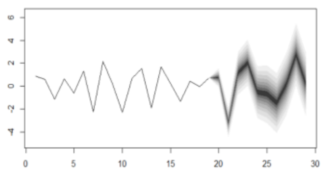
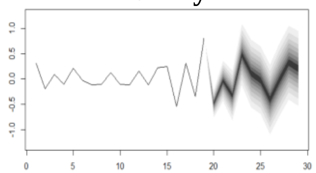
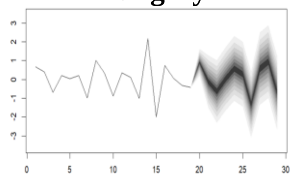
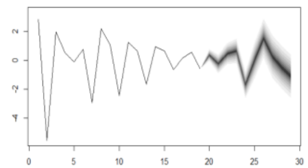
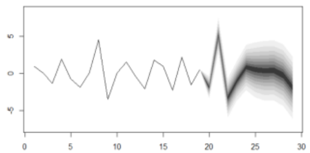
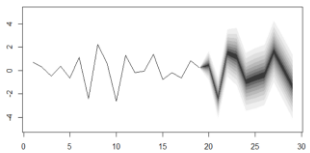
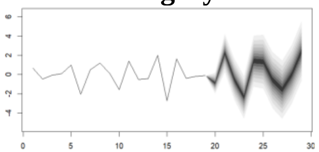
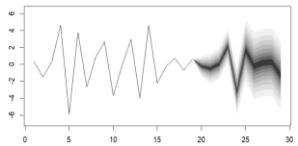
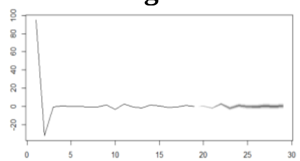
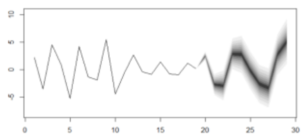
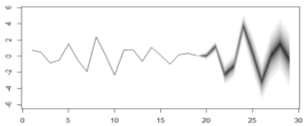
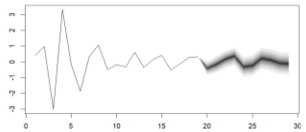
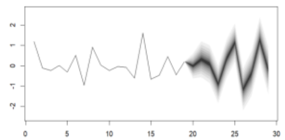
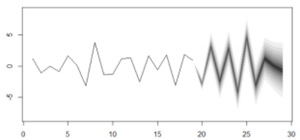
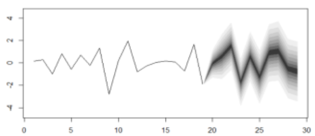
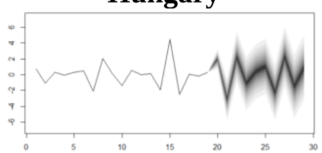
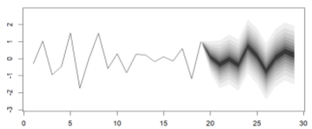
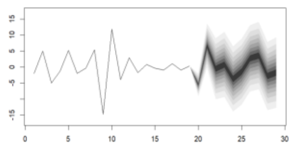
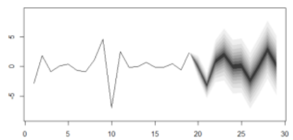
	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORT	**Morocco** 	**UAE** 	**UAE** 	**UAE** 	**UAE** 
	Oman 	**Egypt** 	**Saudi Arabia** 	**Oman** 	**Saudi Arabia** 
	Tunisia 	**Saudi Arabia** 	**Tunisia** 	**Egypt** 	**Jordan** 
	Mauritania 	**Jordan** 	**Oman** 	**Bahrain** 	**Bahrain** 
	Saudi Arabia 	**Kuwait** 	**Jordan** 	**Morocco** 	**Oman** 

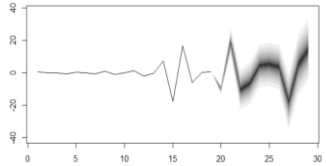
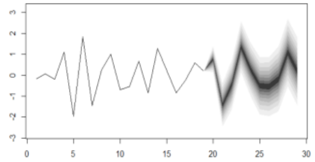
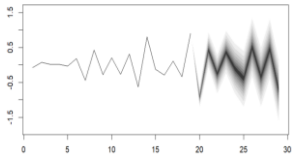
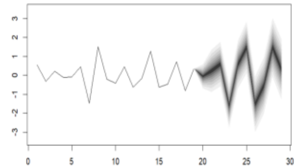
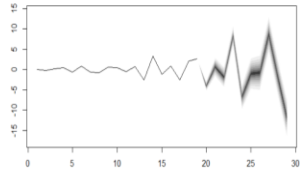
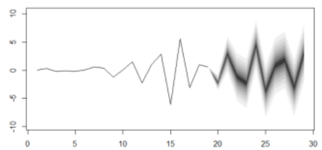
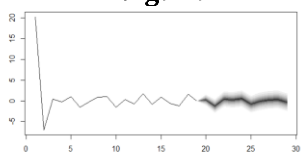
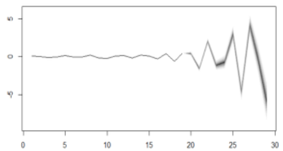
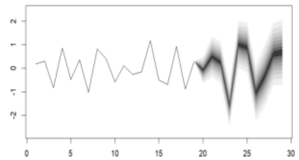
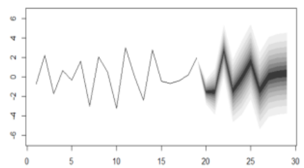
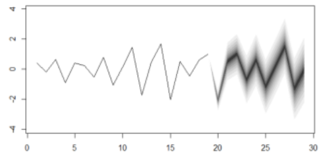
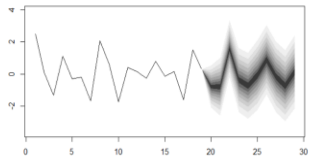
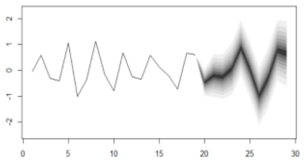
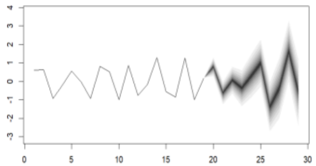
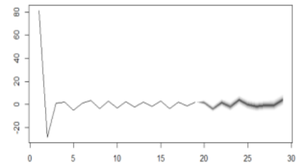
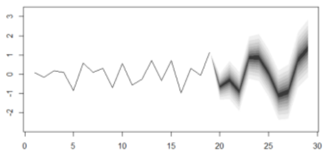
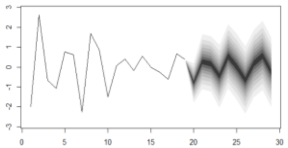
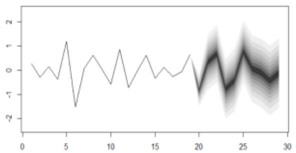
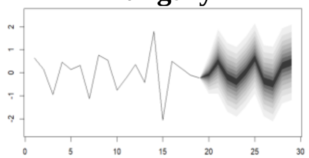
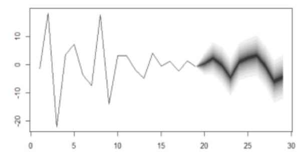
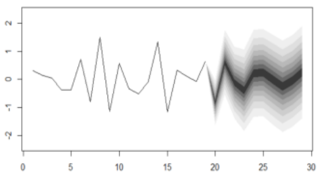
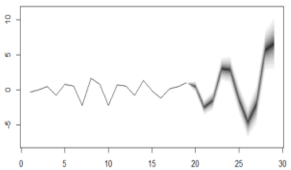
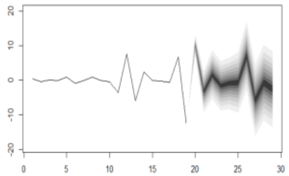
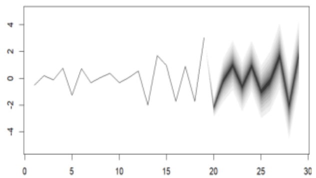
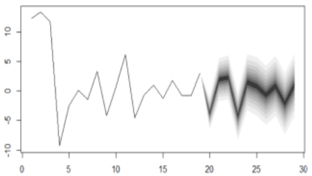
	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORT	Saudi Arabia 	Egypt 	Saudi Arabia 	UAE 	UAE 
	UAE 	Jordan 	UAE 	Oman 	Saudi Arabia 
	Kuwait 	Saudi Arabia 	Kuwait 	Bahrain 	Qatar 
	Lebanon 	UAE 	Qatar 	Lebanon 	Jordan 
	Oman 	Kuwait 	Oman 	Egypt 	Oman 

Source: Elaborated by author, based on IRF outputs from R Studio, with method from Pfaff (2008b)

9.8. Appendix 8: VAR Forecasting for EECA and MENA countries

VAR Forecasting for EECA countries

	FISH	BOVINE	POULTRY	SWINE	GOAT
EXPORT	**Poland** 	**Poland** 	**Poland** 	**Poland** 	**Russia** 
	Turkey 	**Belarus** 	**Turkey** 	**Hungary** 	**Romania** 
	Russia 	**Lithuania** 	**Hungary** 	**Russia** 	**Bulgaria** 
	Croatia 	**Ukraine** 	**Ukraine** 	**Czechia** 	**North Macedonia** 
	Lithuania 	**Hungary** 	**Russia** 	**Slovakia** 	**Slovakia** 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORT	Poland 	Russia 	Russia 	Poland 	Russia 
	Russia 	Bulgaria 	Kazakhstan 	Czechia 	Croatia 
	Lithuania 	Czechia 	Czechia 	Romania 	Bulgaria 
	Ukraine 	Bosnia 	Romania 	Hungary 	Poland 
	Belarus 	Croatia 	Slovakia 	Russia 	Romania 

Source: Elaborated by author, based on VAR forecasting output from R Studio, with method from Pfaff (2008b)

VAR Forecasting for MENA countries

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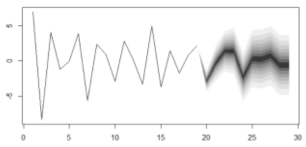
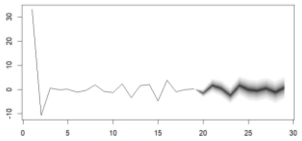
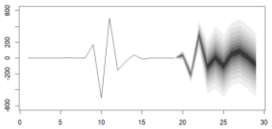
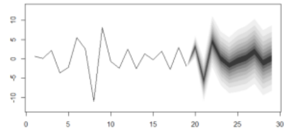
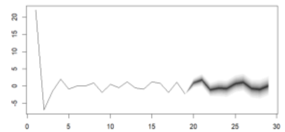
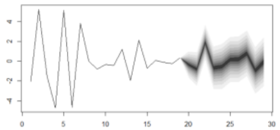
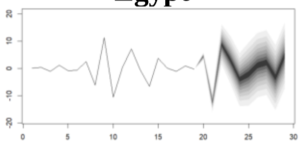
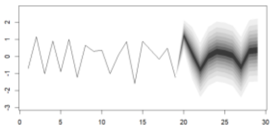
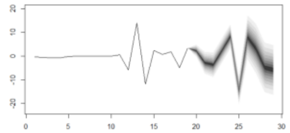
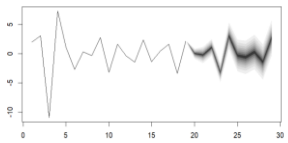
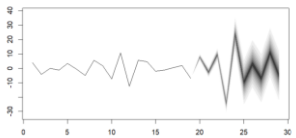
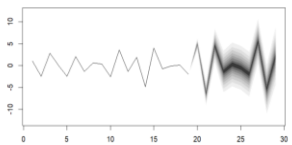
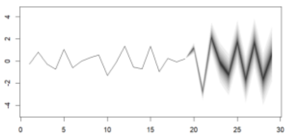
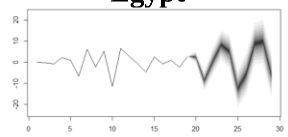
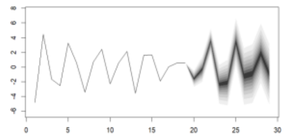
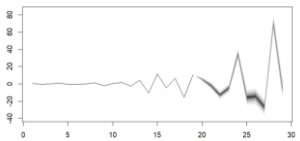
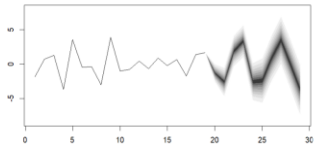
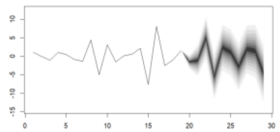
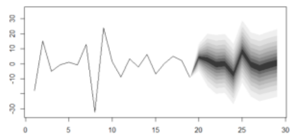
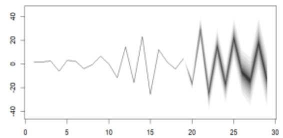
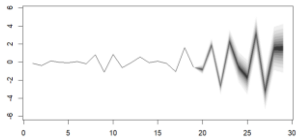
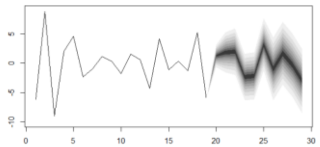
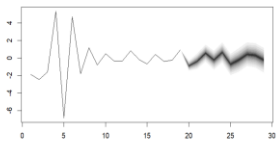
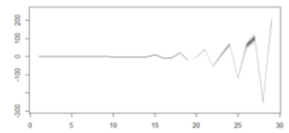
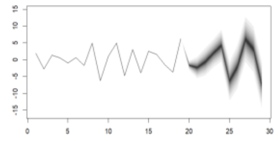
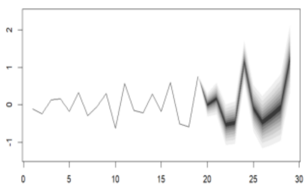
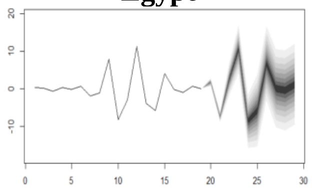
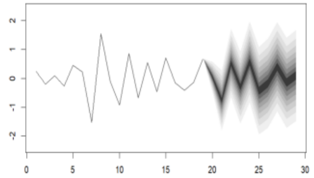
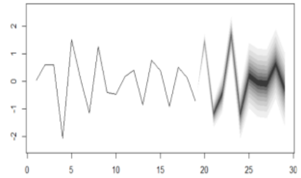
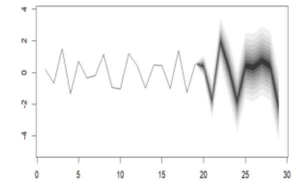
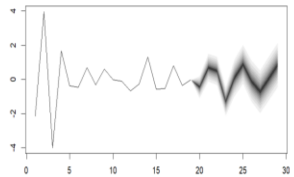
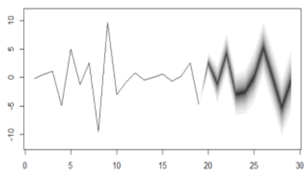
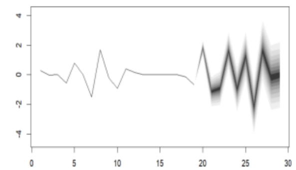
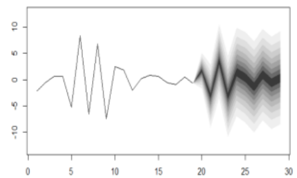
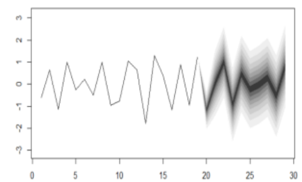
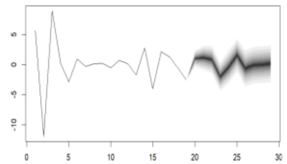
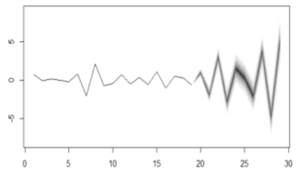
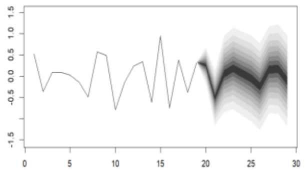
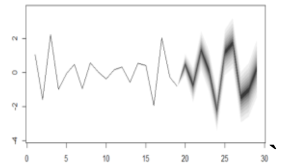
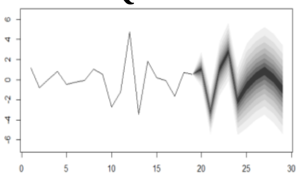
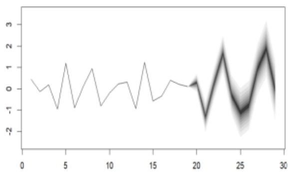
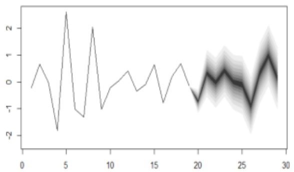
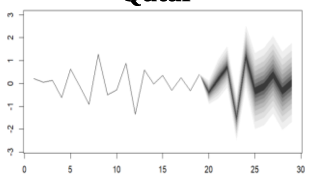
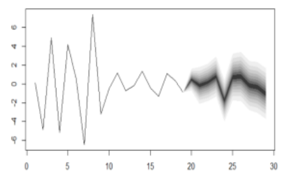
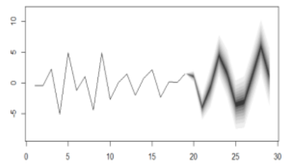
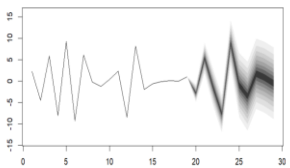
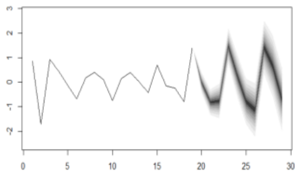
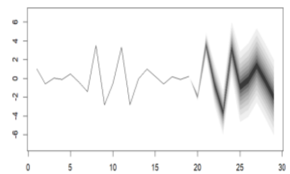
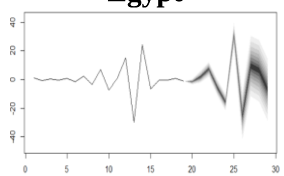
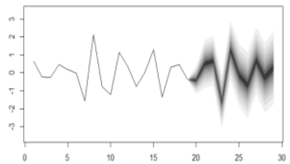
EXPORT	Morocco 	UAE 	UAE 	UAE 	UAE 
	Oman 	Egypt 	Saudi Arabia 	Oman 	Saudi Arabia 
	Tunisia 	Saudi Arabia 	Tunisia 	Egypt 	Jordan 
	Mauritania 	Jordan 	Oman 	Bahrain 	Bahrain 
	Saudi Arabia 	Kuwait 	Jordan 	Morocco 	Oman 

	FISH	BOVINE	POULTRY	SWINE	GOAT
IMPORT	**Saudi Arabia** 	**Egypt** 	**Saudi Arabia** 	**UAE** 	**UAE** 
	UAE 	**Jordan** 	**UAE** 	**Oman** 	**Saudi Arabia** 
	Kuwait 	**Saudi Arabia** 	**Kuwait** 	**Bahrain** 	**Qatar** 
	Lebanon 	**UAE** 	**Qatar** 	**Lebanon** 	**Jordan** 
	Oman 	**Kuwait** 	**Oman** 	**Egypt** 	**Oman** 

Source: Elaborated by author, based on VAR forecasting output from R Studio, with method from Pfaff (2008b)

9.9. Appendix 9: Granger causality between Oil prices and animal protein prices for EECA and MENA region

Granger causality of EEAC countries

Granger causality test						
H0 = Variable Oil Prices does not cause price of animal protein.					**H0: No instantaneous causality between variables**	
H7 = Variable Oil Prices cause price of animal protein.					**H8: Instantaneous causality between variables**	
Variable	**Category**	**Country**	**Granger P-value**	**Result**	**P-value**	**Result**
Fish	Exports	Poland	0.410	Accept H0	0.172	Accept H0
		Turkey	0.250	Accept H0	0.057	Accept H0
		Russia	0.351	Accept H0	0.097	Accept H0
		Croatia	0.008	Reject H0	0.109	Accept H0
		Lithuania	0.499	Accept H0	0.408	Accept H0
	Imports	Poland	0.412	Accept H0	0.622	Accept H0
		Russia	0.830	Accept H0	0.049	Reject H0
		Lithuania	0.492	Accept H0	0.055	Accept H0
		Ukraine	0.605	Accept H0	0.053	Accept H0
		Belarus	0.570	Accept H0	0.012	Reject H0
Bovine	Exports	Poland	0.742	Accept H0	0.009	Reject H0
		Belarus	0.042	Reject H0	0.052	Accept H0
		Lithuania	0.609	Accept H0	0.013	Reject H0
		Ukraine	0.012	Reject H0	0.373	Accept H0
		Hungary	0.220	Accept H0	0.416	Accept H0
	Imports	Russia	0.047	Reject H0	0.163	Accept H0
		Bulgaria	0.790	Accept H0	0.163	Accept H0
		Czechia	0.977	Accept H0	0.018	Reject H0
		Bosnia	0.980	Accept H0	0.015	Reject H0
		Croatia	0.447	Accept H0	0.020	Reject H0
Poultry	Exports	Poland	0.799	Accept H0	0.037	Reject H0
		Turkey	0.370	Accept H0	0.189	Accept H0
		Hungary	0.703	Accept H0	0.167	Accept H0
		Ukraine	0.776	Accept H0	0.010	Reject H0
		Russia	0.930	Accept H0	0.082	Accept H0
	Imports	Russia	0.327	Accept H0	0.022	Reject H0
		Kazakhstan	0.631	Accept H0	0.056	Accept H0
		Czechia	0.570	Accept H0	0.230	Accept H0
		Romania	0.760	Accept H0	0.062	Accept H0
		Slovakia	0.659	Accept H0	0.291	Accept H0
Swine	Exports	Poland	0.024	Reject H0	0.008	Reject H0
		Hungary	0.533	Accept H0	0.046	Reject H0
		Russia	0.042	Reject H0	0.072	Accept H0
		Czechia	0.323	Accept H0	0.011	Reject H0
		Slovakia	0.115	Accept H0	0.083	Accept H0
	Imports	Poland	0.492	Accept H0	0.019	Reject H0
		Czechia	0.233	Accept H0	0.034	Reject H0
		Romania	0.276	Accept H0	0.014	Reject H0
		Hungary	0.923	Accept H0	0.034	Reject H0
		Russia	0.130	Accept H0	0.987	Accept H0
Goat	Exports	Russia	0.015	Reject H0	0.084	Accept H0
		Romania	0.050	Accept H0	0.071	Accept H0
		Bulgaria	0.110	Accept H0	0.024	Reject H0
		N. Macedonia	0.915	Accept H0	0.034	Reject H0
		Slovakia	0.120	Accept H0	0.028	Reject H0
	Imports	Russia	0.490	Accept H0	0.999	Accept H0
		Croatia	0.518	Accept H0	0.018	Reject H0
		Bulgaria	0.267	Accept H0	0.531	Accept H0
		Poland	0.821	Accept H0	0.059	Accept H0
		Romania	0.537	Accept H0	0.143	Accept H0

Source: Elaborated by author, based on granger causality output from R Studio, and method from Zeileis & Hothorn (2002)

Granger causality of MENA countries

Granger causality test							
H0 = Variable Oil Prices does not cause price of animal protein.						H0: No instantaneous causality between variables	
H7 = Variable Oil Prices cause price of animal protein.						H8: Instantaneous causality between variables	
Variable	**Category**	**Country**	**Granger P-value**	**Result**		**P-value**	**Result**
Fish	Exports	Morocco	0.195	Accept H0		0.424	Accept H0
		Oman	0.563	Accept H0		0.038	Reject H0
		Tunisia	0.001	Reject H0		0.019	Reject H0
		Mauritania	0.443	Accept H0		0.050	Accept H0
		Saudi Arabia	0.294	Accept H0		0.026	Reject H0
	Imports	Saudi Arabia	0.477	Accept H0		0.108	Accept H0
		UAE	0.430	Accept H0		0.129	Accept H0
		Kuwait	0.188	Accept H0		0.049	Reject H0
		Lebanon	0.119	Accept H0		0.026	Reject H0
		Oman	0.041	Reject H0		0.045	Reject H0
Bovine	Exports	UAE	0.679	Accept H0		0.225	Accept H0
		Egypt	0.001	Reject H0		0.091	Accept H0
		Saudi Arabia	0.380	Accept H0		0.017	Reject H0
		Jordan	0.416	Accept H0		0.851	Accept H0
		Kuwait	0.285	Accept H0		0.976	Accept H0
	Imports	Egypt	0.001	Reject H0		0.075	Accept H0
		Jordan	0.032	Reject H0		0.009	Reject H0
		Saudi Arabia	0.764	Accept H0		0.107	Accept H0
		UAE	0.478	Accept H0		0.035	Reject H0
		Kuwait	0.337	Accept H0		0.017	Reject H0
Poultry	Exports	UAE	0.004	Reject H0		0.249	Accept H0
		Saudi Arabia	0.753	Accept H0		0.190	Accept H0
		Tunisia	0.152	Accept H0		0.260	Accept H0
		Oman	0.119	Accept H0		0.307	Accept H0
		Jordan	0.045	Reject H0		0.382	Accept H0
	Imports	Saudi Arabia	0.407	Accept H0		0.086	Accept H0
		UAE	0.484	Accept H0		0.064	Accept H0
		Kuwait	0.271	Accept H0		0.069	Accept H0
		Qatar	0.517	Accept H0		0.017	Reject H0
		Oman	0.006	Reject H0		0.012	Reject H0
Swine	Exports	UAE	0.340	Accept H0		0.109	Accept H0
		Oman	0.058	Accept H0		0.430	Accept H0
		Egypt	0.147	Accept H0		0.281	Accept H0
		Bahrain	0.941	Accept H0		0.010	Reject H0
		Morocco	0.776	Accept H0		0.125	Accept H0
	Imports	UAE	0.137	Accept H0		0.060	Accept H0
		Oman	0.938	Accept H0		0.162	Accept H0
		Bahrain	0.392	Accept H0		0.678	Accept H0
		Lebanon	0.522	Accept H0		0.013	Reject H0
		Egypt	0.000	Reject H0		0.170	Accept H0
Goat	Exports	UAE	0.593	Accept H0		0.901	Accept H0
		Saudi Arabia	0.070	Accept H0		0.084	Accept H0
		Jordan	0.492	Accept H0		0.056	Accept H0
		Bahrain	0.403	Accept H0		0.509	Accept H0
		Oman	0.008	Reject H0		0.235	Accept H0
	Imports	UAE	0.338	Accept H0		0.153	Accept H0
		Saudi Arabia	0.771	Accept H0		0.032	Reject H0
		Qatar	0.276	Accept H0		0.032	Reject H0
		Jordan	0.008	Reject H0		0.295	Accept H0
		Oman	0.950	Accept H0		0.195	Accept H0

Source: Elaborated by author, based on granger causality output from R Studio, and method from Zeileis & Hothorn (2002)