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Analysing Purchase Preference Towards Geographical Indications (GIs) Using Consumer Segmentation Approach

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Abstract

Consumers of local food products often face a dilemma regarding their purchase decisions due to the non-availability of information that is required to assess the quality of the product. To reduce this information asymmetry, the Geographical Indication Registry in India issues a Geographical Indication tag (GI tag) as a community right to the growers of local special products originating from a region, town or country. The GI tag symbolises uniqueness, curtails counterfeit products' spread, and reduces information asymmetry. This study has taken a select case of Udupi Mattu Gulla Brinjal, a GI horticulture produce grown by a community-based enterprise (CBE) in the Udupi District of South India. This research work aims to study and analyse consumer preference towards Udupi Mattu Gulla Brinjal (GI) using a consumer segmentation approach. The Principal Component Analysis technique has been used to identify statements with discriminatory power. Subsequently, the statements of research importance have been used to identify consumer segments using a two-step clustering approach. The study results have identified three important consumer clusters based on the analysis of consumer preference characteristics. Thereafter, marketing strategies have been proposed after analysing the profile of each segment. The study is undertaken as a response to an initiative from the Sustainable Development Goals (SDGs) Coordinating Centre, Government of India, to partner the development of agriculture in the local area of Udupi District. The objectives of the study are consistent with SDG goal 11 (sustainable communities) and SDG goal 12 (responsible consumption).

Keywords

Consumer preference, consumer segments, rural markets, rural marketing, Geographical Indications (GIs), Community-Based Enterprises (CBEs).

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Introduction

Consumption of fruits and vegetables with Geographical Indications (GIs) have received significant literary attention in recent years. Consumers are willing to buy innovative, high-quality (Zhao at al., 2014; Lopez-Bayon at al., 2020; Niederle and Gelain, 2013) and health -guaranteed products (Mattas at al., 2020), at a premium price enabling agri-business to evolve and compete (Mesic at al., 2017) in the market place (Uzar, Pejanovic, 2022). In recent years, increased focus on healthy eating habits has encouraged consumers to seek more information regarding characteristics of products, their place of origin (Alphonce at al., 2015) and production methods. Consumers have become more aware and informed and have developed a curiosity to know more about geographical indication tagged fruits and vegetables and its value-added products (Russo at al., 2021; Cardoso at al., 2022). However, the tastes and preferences of the consumers may not be consistent with the specifications that these GIs provide, leading to information asymmetry between consumer preferences (Savelli at al., 2021; Arora and Gupta, 2020) and producer offerings. Moreover, consumers maintain a positive attitude towards the consumption of GI products towards a reconnection to the local region, both for identity, safety, and environmental reasons. These patterns of preferences and attitudes of consumers' reconnection can provide a detailed understanding into the purchase intention and behaviour. Thus, Geographical Indications identifies its benefits on consumer markets whose specific quality comes with a strong link to its territory of origin (Fandos-Herrera, 2016).

Geographical Indications as a community right provide the growers with the necessary incentive to increase margins and contribute to local development (Alphonce at al., 2015). The extent to which these GI tags can contribute to local agri-business development would depend on the nature of consumer demand. GIs can increase the visibility of producers' products and bring higher returns on investments. Benefits derived from GIs encourage producers to increase their production (Lopez-Bayon at al., 2020). The Government of India is promoting geographical indications through production, technological and marketing-linked interventions to boost the acceptance and sales of these unique products across the country. (Torok et al., 2022). However, in the case of some GIs, particularly horticulture-based produces have seen limited marketing push (Mederios and Passador, 2021) to promote exports in international markets.

Studies have highlighted the advantages that local producers derive from the GI tag. GIs provide a distinct regional identity and add value to the products, thereby confining a competitive edge to the local producers (Stasi at al., 2011). To increase the value of GI products in the domestic market and subsequently scale up in the world market (Torok and Moir, 2018), a developing country like India should study and understand consumer preferences for its less-known GIs in the local market (Cei and Stefani, 2018). Many studies have reported that higher prices for their produce are the main attraction to participate in a GI for producers (Traversac at al., 2011; Jena and Grote, 2012; Lamarque and Lambin, 2015). Consumers are willing to pay a higher price for products with superior quality (Ghosh, 2016; Quiñones-Ruiz at al., 2017; Mattas et al., 2020).

According to the Ministry of Commerce and Industry, India has issued 432 Geographical Indications as on December, 2022. The States of Karnataka, Tamil Nadu, Uttar Pradesh and Kerala hold the maximum number of GIs in the country. The Department for Promotion of Industry and Internal Trade (DPIIT) issues these special tags to promote the transfer of diverse products amongst the states to contribute in building a vibrant cultural society. GI is a premium recognition to various regional products, arts and crafts mastered by many generations over the years. Several activities have been undertaken by the Department for Promotion of Industry and Internal Trade to promote these special tags by collaborating with state apparatus (prominently National Bank for Agriculture and Rural Development) and local stakeholders to create sustainable consumer markets.

The present study is conducted in Udupi District in the state of Karnataka, India. The State of Karnataka has 48 GIs registered as on November, 2022 in the category of manufactured products, handicrafts, sweets, agriculture and food stuff. Udupi District is home to three GIs, namely Udupi Jasmine, Udupi Mattu Gulla Brinjal and Udupi Sarees. This research paper examines the consumer preferences towards the famed Udupi Mattu Gulla Brinjal to understand the nature of consumer preferences, identify key consumer segments and propose marketing strategies to increase producer margins and contribute to local development (Belletti at al., 2017).

Distribution inefficiencies, inability to develop market linkages and networks, lack of market infrastructure (Lamarque and Lambin, 2015) and extension facilities are some of the key problems faced by the Udupi Mattu Gulla Brinjal growers. The inability to work with an open mindset towards positive change and the lack of team work on the part of the Mattu farmers has also obstructed the sustainable development of Udupi Mattu Gulla Brinjal. This aspect of lack of coordination and team skills among local farmers has been reported by other studies in South India (Anson and Pavithran, 2013; Bashir, 2020).

Over the recent years, several interventions have been designed and implemented by the Government of Karnataka through its special apparatus (Niederle and Gelain, 2013) aimed to promote and develop the activities of the association in Mattu village. Of this, the most noteworthy scheme is the creation of Farmers Producer Organization (FPOs) introduced by the National Bank for Agriculture and Rural Development in 2018, an initiative by the Government of India to foster rural development. This initiative has been unable to gain momentum due to a lack of coordinated efforts on the part of the farmers. However, the farmers strongly believe that demand creation in the local, domestic and international markets, as a challenge, by far outweighs the other problems that they encounter. Given this background, the researchers have taken up this study to undertake an analysis of consumer preferences towards Udupi Mattu Gulla Brinjal, a unique Brinjal variety grown in the west coast line of Karnataka State in South India. Due to its unique taste, the Geographical Indication tag was awarded to the Mattu Gulla

Growers Association as a community right. Brinjal is also called 'gulla' in the local region due to its round shape.

The succeeding sections of this paper is presented as follows: First, a literature review of earlier studies on consumer preferences towards Geographical Indication agricultural produces is presented. In the next section, the methodology is explained, which includes the research instrument, sample design and the process of identifying consumer segments using factor analysis and cluster analysis techniques. Finally, the results on key consumer segments identified are discussed to draw inferences and conclusions on deploying marketing strategies that will help stakeholders like producers, consumers, marketers and policy makers.

Literature review

Udupi Mattu Brinjal Growers Association - A Community-based Enterprise (CBE)

Peredo and Chrisman extensively reported about the concept of community-based enterprises (CBE) in their seminal research work in 2006. In this work, the authors argued that the community members engaged in businesses like farming, weaving, pottery, fishing, and other such occupations collectively form an enterprise called as the CBE. It requires genuine community participation from the beginning: identification and acceptance of the problem, an agreement that it needs to be addressed, an understanding of the target group's socio-economic situation and a hunger to collectively solve business problems and the engagement of influential people in the set up to build a network of community groups. Whole-of-community (schools, parents, leaders, adolescents) are engaged in collaborative effort (Fotu et al., 2011). Such an enterprise naturally evolves an economic and social form (Handy at al., 2011) to achieve sustainable development of the local region. The members of the community launch the CBE as a solution to alleviate themselves from poverty and target economic and social development (Welsch and Kunhs, 2002; Parwez, 2017). Similar to the characteristics of the CBE conceptualized by Peredo and Chrisman and other authors, the workings of the Udupi Mattu Brinjal Growers Association embark on mutual trust and cooperation (Powe, 2019) driven by its members. Dissatisfied by the lack of success as individual units, the farmers chose the collective approach to come out of the distress sale. In 2011, the growers' association was conferred the Geographical Indication tag as a community right. Thus, Udupi Mattu Brinjal Growers Association is a special case, where a Geographical Indication of horticulture produce is grown, marketed and sold by a community-based enterprise.

Problem statement

The Mattu farmers prefer to sell the crop through intermediaries as they transport the produces to other regions as aggregators (mainly Karnataka and Maharashtra State). The farmers, mostly from low-income families, do not have the financial wherewithal to establish a distribution system and transport facility on their own. The first crop reaches the market between the end of September and early October every year, and fetches the maximum price (Rs. 150/kg). The prices reduce gradually as the season continues. Around the end of March, the last crop is grown, which is small in size. During this time, the farmers are forced to sell at lower prices (as low as Rs. 10 per kg) and resort to distressed sales as the demand continues to dwindle. Until 2018, there was no transparency in price fixation, as the agents controlled the market dynamics. Agents look after their self-interest and do not allow farmers to sell their produce to market directly. However, the scenario has changed after 2018 when National Bank for Agriculture and Rural Development (NABARD) introduced the Famers Producer Organization (FPO) as an intervention focussed on sustainable agriculture development in Mattu village. Under this arrangement, NABARD appointed Producers Organization Promoting Institutions (POPIs) led by Non-governmental Organizations and other local partners with a clear mandate of forming and nurturing Famers Producers Organizations to improve market linkages and encourage the benefits of cooperation. To address the demand side of the problem, studies should investigate consumer preferences towards Udupi Mattu Gulla Brinjal, a local GI. The sustainability of these community-led enterprises will depend upon the efforts directed towards increasing sales driven by a strong consumer demand. In the Indian context, several well-known GIs, like Darjeeling tea, Nagpur Orange, etc., have made a mark and become popular brands in the domestic and international markets. Palakkad Rice (Anson & Pavithran, 2013) is another GI from Kerala State with a strong presence in South India. Comparatively, Udupi Mattu Gulla Brinjal has not been able to achieve the distinction that it deserves both in terms of awareness and acceptance of its products (produce and value additions) in the domestic and international markets. Therefore, this study examines the reasons why consumers

prefer Udupi Mattu gulla Brinjal in its raw and value-added form. This study is a response to the call that the researchers received from Government Support Institutions engaged in the development of agriculture in the State of Karnataka. A broad vision statement is envisaged by the Government of Karnataka to make Community-based Geographical Indications financially independent. Udupi Mattu Gulla Brinjal is one such case under study in the district of Udupi (267 villages, census, 2021). In recent years, the popularity of Udupi Mattu Gulla Brinjal has grown immensely due to the wide coverage of its production, packaging and labelling and its promotion in the local print media. But this popularity is limited to the local area of Udupi and Dakshina Kannada district. Marketing efforts to popularize it in neighbouring states need to increase. Hence, a study on consumer preferences towards horticulture-based geographical indications will help marketers to design and deploy marketing strategies. In the long run, Mattu farmers will stand to gain by selling more to consumers and thereby increase margins.

Consumer preference towards Geographical Indications

GIs are considered as key assets of growing relevance, particularly in the case of developing countries as it has significant potential to lift these countries from weak economic conditions. The year 2022-23 has witnessed a sharp rise in agriculture-based geographical indications in India. The Department for promotion of Industry and Internal Trade (DPIIT) awarded GIs to three more products like Mysore Silk, Kandra Tea, and Thanjavur Paintings to the exclusive list of existing GI products, taking the total tally to 429 in March, 2023, up from 349 GIs in August, 2022. Many studies have reported that consumers tend to highly regard quality, originality and authenticity in their purchase and therefore prefer Protected Geographical Indications (PGIs) over other products (Glogoveţan et al., 2022; Likoudis at al., 2016; Barska and Wojciechowska-Solis, 2018). It has been found that consumer perception about sensory attributes of Geographical Indications is influenced by Product Designation of Origin Labels (PDO labels) (Savelli at al., 2021; Bonetti et al., 2020; Pikturnienė and Treigytė, 2009). The combined effect of Brand name and PDO labels enhances consumer acceptance (Savelli at al., 2021). Hence, sensory analysis of consumer preference is of significant research importance. In the case of GIs, studies can explore the relationship between sensory-driven product preference and acceptance of GI value-added products. Therefore, studies should examine the nature of consumer awareness programs and its ability to promote knowledge about the advantages of consuming these products to encourage consumption. Studies have also highlighted the role of government agencies to run consumer education programs and communicate the merits of consuming original and authentic agricultural products, which seemingly are lacking in developing countries. Prior research (Teuber, 2011; Uzar et al., 2022) has highlighted that consumers' perceptions, expectations, and willingness to pay for protected geographical indications are motivated by the positive impacts such consumers' purchases can bring to the local economy. Consumers desire to buy GIs and pay for it and are motivated by higher quality and their interest in local-origin products (Van der Lans et al., 2001; Alcalde et al., 2013; Pilone et al., 2017; Purwanto et al., 2019). Studies on Protection Geographical Indications have perceived labelling as a mark of quality. To exceed consumer expectations, geographical indications are expected to develop a positive brand image among target segments by providing value-additions (De Canio and Martinelli, 2021; Arfini and Bellassen, 2019). More research work is required to examine consumer motivation towards the preference and purchase of value additions arising out of GIs. In a highly competitive food products market with other varieties of horticulture-based food products competing with the GI brand, labelling may be used as a weapon for product differentiation. Research in packaging and the use of labels as a tool of product differentiation is scarce in GI marketing literature. A study (Verbeke, at al., 2016) reveals that consumers regard the symbolic and cultural value of geographical indications more than intrinsic value and utilities. However, the researcher’s interaction with consumers and growers of local horticulture GIs has shown a different view where preference is motivated by the benefits derived from purchase. In search of various options, consumers - seek freedom in their purchase and fulfil their desires based on origin, unique products, environment-friendly products, traditional growing methods, and concern for local development (Likoudis et al., 2016). Other papers (Prakash, 2016; Belletti et al., 2017; Barska and Wojciechowska-Solis, 2018) discuss quality certifications carried by GIs are considered positively by consumers as they contribute to improved health conditions. Consumption of certified agri-products improves

quality of life and help consumers to stay fit despite increasing age. Research can be carried out to identify those aspects of quality-rich products that improve health, like nutritional value, comfort food, and faster digestion which inspire consumer preference. Increased efforts go into purchasing special products (GIs) during free time like holidays, festivals, special occasions in the family, religious celebrations and so on (Likoudis et al., 2016). Studies have acknowledged that there is a higher likelihood among European consumers to recognize quality labels and their logos. Indian consumers fail to understand the 'power of uniqueness' carried by GIs. In the case of horticulture-based GIs, buyers cannot identify and pick GIs when placed among other non-GI varieties of fruits and vegetables due to poor marketing efforts of the agriculture-producing promoting agencies. As a result, logos (Brands) fail to unlock the true potential of GIs in India. Studies have covered practical issues, hurdles in processing, convenience and speed of purchasing food products. More literary attention is required to analyse the way in which convenience is relevant in the preparation of dishes and delicacies. India is a place known for its ethnic cuisines due to its geographical spread and cultural diversity. Celebrations often conclude with dining, which connotes a feeling of togetherness. Special food items (value additions) are arranged for outstation family members and guests, with specialty products introduced with love to dear ones and detailed descriptions given to them on its superiority compared to other products. Hence, preference patterns motivated by consumption towards GI value-adds need more literary work. Moreover, limited studies analyse consumption preferences based on consumer segments. Many studies have reported that segments differ in their demographic composition, factors affecting purchase, health and nutrition, price-sensitivity, quality, and benefit-based segmentation (Gindi et al., 2018; Raaijimakers et al., 2018; Montero-Vicente et al., 2019; Haley, 1968). Studies have used cluster analysis as a segmentation technique to group consumers and analyse behaviour. Classical studies (Haley, 1968) used cluster solutions to group consumers based on the benefits they derive from their purchases. Yankelevich (1964) segmented consumers into groups based on what they look for in daily necessities. Segmentation studies have stood the test of time over five decades, and researchers have used cluster solutions as an appropriate method to group and profile consumers (Bertail and Caillavet, 2008; Demydas, 2011; Gindi, Abdullah et al., 2018; Raaijmakers et al., 2018; Ghosh, 2016; Quinone's-Ruiz et al., 2017; Hoang et al., 2020; Mattas et al., 2020). Hence, the segmentation approach can provide more literary insights in the case of GIs, as they emphasize unique consumption preference patterns specific to a local region. Segmentation may be an interesting approach as producers use these special tags to increase consumers' confidence in their products (Mesic et al., 2017; Nugraha et al., 2022). Therefore, when the segmentation approach is employed, consumer groups having unique characteristics will emerge, which will further bolster the idea of deploying marketing strategies for relevant segments. Moreover, several other studies also suggest that consumers are willing to pay a premium price for GI products because of their special characteristics. Based on the background of these observations, our research aims to analyse consumer preference towards Udupi Mattu Gulla Brinjal (GI) using a consumer segmentation approach. Given this scenario, the research aims to answer the following research questions:

RQ 1. What issues do farmers growing Udupi Mattu Gulla Brinjal encounter that force them to resort to distressed sales?

RQ 2. What are the main reasons to consume Udupi Mattu Gulla Brinjal?

RQ 3. Can consumer segments be identified based on the reasons influencing the purchase of Udupi Mattu Gulla Brinjal?

RQ 4. What is the purchase preference of each consumer segment? Are the differences in the purchase preferences between segments statistically meaningful?

RQ 5: What marketing strategies can be formulated and deployed to various segments to achieve increased consumption of Udupi Mattu Gulla Brinjal?

The next section presents the survey design and methodology aspects used in the study.

Materials and methods

Survey area and product description

Mattu village is located on the West Coast of Karnataka in India with GPS coordinates of 13.2592° N, 74.7366° E. In this area, around 200 families are engaged in the seasonal farming of Mattu Gulla Brinjal, a unique eggplant (vegetable) variety (solanum melongena L). This

Brinjal variety is famous locally due to its special taste. It has unique features with green colour, thin skin, few seeds, and thorns on the crown of the Brinjal. Due to its round shape, it is popularly known as 'Gulla' among the locals of the region. There is a folk lore that the great seer of the Udupi Krishna (deity) temple, Sri Vadiraj, gave the seeds of Mattu Brinjal to the local farmers of the Billava community to help them come out of acute poverty. This characteristic, whereby the farmers belonging to a community engaged in a particular occupation come together to solve a business problem by collectively setting up an enterprise, is known as a Community-based Enterprise (CBE). In the year 2011, the growers' association applied to the Geographical Registry for a GI tag to gain market advantage and superiority over other types of Brinjal grown in the local area. Subsequently, the Registry awarded the GI tag as a community right to the Mattu Brinjal Growers Association. Currently, in the local market, this produce is offered for sale in three grades (A, B and C) demarcated based on size and quality (pest attack), with 'A' grade sold at a higher price than other grades certifying premium quality.

Survey design and methodology

According to the data published by the Udupi District Statistics Office 2021, Udupi district has 2,78,058 households. Since the purpose was to study the reasons for consuming Udupi Mattu Gulla Brinjal, the investigation has targeted an 'individual purchaser' who visits the warehouse owned and operated by the Mattu Gulla growers association for household consumption. The individual purchaser is a member of the household who is responsible for the act of purchasing vegetables and fruits for his family. Loyal consumers of Udupi Mattu Gulla Brinjal visit the warehouse to get fresh and premium produce harvested directly from the Mattu fields. As the requirement was to collect data from consumers who purchased Udupi Mattu Gulla Brinjal, the researchers decided to stand in front of the warehouse cum office of the Udupi Brinjal Growers Association in Mattu village of Udupi District. Therefore, other purchasers who buy for the purpose of resale, like agents, wholesalers, retailers and those who are purchasing on others behalf, are excluded from the final analysis. A structured questionnaire was developed to collect the data from the 'individual purchaser' visiting the warehouse. The researchers used a purposive sampling method to select the sample, as the units had the characteristics that the researchers were looking for. The warehouse of the growers association stocks and sells Udupi Mattu Gulla in 'A, B and C Grades of Brinjal produce to retail customers, hoteliers, wholesalers and retailers. The different levels of grades are decided based on the size of the produce and the extent of pest attack. The main aim of our research was to study consumer preference, and therefore the researchers preferred to reach out only to buyers who came out of the warehouse with a 'paid receipt' with them. The warehouse exclusively sells only Udupi Mattu Gulla Brinjal and does not deal with other Brinjal varieties or vegetables. In this warehouse, other tasks such as processing, cleaning, sorting, and grading are done by local women (4 Nos) who belong to the family of local farmers. After satisfying all the criteria of exclusions detailed above, a total of 355 questionnaires were collected from the respondents during October-December, 2022. This period is most suited for the survey as the yield of Udupi Mattu Gulla Brinjal is robust and highly preferred by consumers. 355 original survey answers were scrutinized for completeness and were considered for final analysis after data cleaning.

The questionnaire contained thirty-eight statements which invited responses on consumer preferences towards Udupi Mattu Gulla Brinjal. These statements were included in the questionnaire after considering the variables extracted from the literature review and also after consulting experts in the area of agriculture to suit local consumer preferences. The research instrument had three parts which included socio-demographic details, questions on product features and quality, and consumer preference-based statements anchored on a 5-point Likert scale. The statements have been set by using the benefit segmentation theory approach (Haley, 1968), as it is the researcher's belief that consumption is motivated by the benefit that a consumer seeks in their purchase. The first section of the questionnaire included details on the social-demographic aspects of the respondents, such as age, gender, family income, marital status, and occupation. The second section included questions on grading, processing, sorting, cleaning, GI tag, expiry date, purchase frequency, seasonality, distribution, point of purchase and distance from purchase. The final section was dedicated to acquiring information about the consumers' preferences towards Udupi Mattu Gulla Brinjal and its value-added products. The preferences were presented in the form

of statements on items which included price, nutritional value, preference towards local produce, taste, size, aroma, shape, colour, freshness, variety of preparations, the convenience of purchase, comfort food, availability aspects, ready-to-eat aspect, product features, quality, consumption safety aspect, packing and packaging. To assess statements measuring consumers' preference towards local GIs, the study used a 5-point Likert Scale with anchors 1 = very low and 5 = very high. The responses collected from 353 participants were used for subsequent analysis. Thirty-eight items from the questionnaire gave a Cronbach's alpha value of 0.74, confirming that the inter-item reliability was statistically significant and the data was ready to run the Principal Component Analysis. In this study, we have used Principal Component Analysis as a suitable data analysis technique as its relevance is found in product acceptance research. Here, we have used it to retain variables of significant research interest to get an insight into the preferences of various Udupi Mattu Gulla Brinjal consumers. Thus, empirical analysis, was performed using principal component analysis (varimax rotation method) to identify important factors that determined consumers' preference towards Udupi Mattu Gulla Brinjal. Factors with higher factor loadings were retained for the final analysis. These factor loadings were further employed to perform cluster analysis to segment consumers. Further, in determining the number of clusters, we adopted the Bayesian Information Criteria as this method optimizes consumer choices in an acquisitive fashion based on the internal complexity present in the data. Two-step cluster method is used to segment consumers as this is consistent with the researcher's objective of identifying relevant segments to determine marketing needs and increase sales (Chawla and Sondhi, 2011). The two-step cluster analysis technique is employed on the basic premise that the clusters are likely to have differences in the behavioural characteristics of consumers among them. Hence, this study has used the Kruskal-Wallis one-way analysis of variance to test whether the clusters were significantly different, and to examine these differences and for better interpretation of results. Examining similarity among groups and/or differences between groups provides ample scope to devise concentrated marketing strategy for each group. The following sections provide a results, interpretations and discussion of the study.

Results and discussion

The research has used principal component analysis to determine variables with high factor loadings. The study has adopted a greater than 0.70 KMO (Kaiser-Meyer-Olkin Measure) as a threshold value to perform a factor analysis test. The strength of the factor analysis solution by ascertaining that the correlation matrix (KMO) statistics 0.71>0.50; Bartlett's test p <0.05) of the variables is statistically meaningful. Three consumption -led factors explained 20.86 percent, 19.88 percent, and 17.59 percent of the variance, respectively, explaining 58.34 percent of the total variance. Based on the higher factor loadings, the study proceeded towards the naming of factors. Table 1 presents the values of factor loadings after performing the Principal Component Analysis.

Benefits sought from purchase (Statements)	Health benefits	Product appeal	Utility value	Communality scores
It has minerals, vitamins, antioxidants, and phytochemicals good for health	0.85			0.712
It has good taste		0.83		0.733
It has nutritional value	0.86			0.723
It is a light food			0.69	0.587
It is appealing to buy when in big size		0.78		0.612
Its recipes have good aroma		0.68		0.576
Recipes are easy and convenient to prepare			0.70	0.596
It digests fast	0.79			0.628
It is appealing to buy without pest attack			0.71	0.602
It is a comfort food and gives a soothing feeling after being consumed			0.72	0.611

Source: Survey data Notes: (KMO statistics 0.71>0.50; Bartlett's test p <0.05)

Table 1: Factor scores using Principal Component Analysis.

The variance explained by each factor is calculated based on Eigen values using the factor loadings ascertained from the rotated component matrix. Thus, the factors have been labeled (or named) as 'Health benefits (20.86 percent), Utility value (19.88 percent), and Product appeal (17.59 percent).

Further, the study employed the analysis of variance (ANOVA) test (refer Table 2) to determine the discriminatory power of the extracted statements. We observed that the Anova values of ten statements (which also had a factor loading cut-off of more than 0.70) were significant at 5% level of significance. This strengthened our belief in running cluster analysis techniques and analyse behavioural interpretation using a consumer segmentation approach.

Statements (variables)	F	Sig.
It has minerals, vitamins, antioxidants, and phytochemicals good for health	45.689	.000
It has good taste	24.868	.000
It has nutritional value	52.736	.000
It is a light food	154.223	.000
It is appealing to buy when in big size	51.363	.000
Its recipes have good aroma	92.101	.000
Recipes are easy and convenient to prepare	51.571	.000
Gives a feeling of quick digestion	65.723	.000
It is appealing to buy without pest attack	38.543	.000
It is a comfort food and gives a soothing feeling after being consumed	97.235	.000

Source: Survey data

Table 2: Anova table for consumer purchase preference statements for Udupi Mattu Gulla Brinjal.

Subsequently, cluster analysis is used for groupings based on the results produced by the factor loadings. The two-step cluster analysis approach revealed three groups (refer Table 3). Consumer clusters characterised by statements on 'presence of minerals, vitamins, antioxidants, and phytochemicals', 'nutritional value' and 'feeling of quick digestion', were labeled as "Health-conscious" segments after inferring the common characteristics present in these statements. Going by our field survey experience, we observed that product appeal prompts consumers to buy Udupi Mattu Gulla Brinjal's value-added products. Hence, statements with good taste, big size, and good aroma were grouped together into one consumer segment and labeled as 'value-add' seekers. The third group showed liking towards the usefulness of purchase with statements characterized by light food, the convenience of purchase, quality aspects, and consumption comfort and hence was labeled as 'utility seekers.

Further, we analysed the socio-economic and demographic profiles of the groups (Table 4) using Kruskal Wallis test and Chi-square test to facilitate better interpretation of results. Kruskal-Wallis test was employed to examine differences in groups by comparing the mean values of metric variables. Chi-square test (X2) was used to examine the differences of segments for nominal variables.

The consumption of Udupi Mattu Gulla Brinjal is influenced by age, marital status and income of the consumer groups as statistically significant differences are observed. When we analyse each

Statements (variables)	Clusters		
	Health conscious	Value-add seekers	Utility seekers
It has minerals, vitamins, antioxidants, and phytochemicals good for health	4.59	2.05	2.64
It has good taste	2.17	4.77	1.72
It has nutritional value	4.47	2.22	1.36
It is a light food	2.23	2.23	3.96
It is appealing to buy when in big size	1.67	4.32	2.74
Its recipes have good aroma	2.34	3.98	2.98
Recipes are easy and convenient to prepare	2.08	1.98	4.51
Gives a feeling of quick digestion	4.17	1.87	3.03
It is appealing to buy without pest attack	2.86	2.62	4.70
It is a comfort food and gives a soothing feeling after being consumed	2.65	2.43	4.08

Source: Survey data

Table 3: Cluster centroids for Mattu Brinjal consumer survey.

Respondents	Consumer segments			Statistical significance of differences in segments (Kruskal-Wallis/Chi-square (X2))
	Health conscious	Value-add seekers	Utility seekers	
No of consumers Total	53 -15%	147 -42%	153 -43%	
Frequency of purchase				
Regularly	41	113	127	
Occasionally	12	34	26	
Gender				
Male	28	76	78	Chi-square value:
Female	25	71	75	X^2 (2) = 1.068, p > 0.05
Age				
18-25	5	6	7	Kruskal-Wallis test:
26-35	6	35	29	p < 0.05*
36-45	12	41	40	(H=6.86)
46-60	14	30	38	
60 & above	16	35	39	
Marital status				
Single	8	22	20	
Married	36	107	117	Chi-square value:
Divorced	9	18	16	X2 (5) = 18.912, p < 0.05*
Occupation				
Students	3	4	3	
Farmers	4	5	3	Kruskal-Wallis test:
Laborers	3	4	2	p > 0.05
Teachers	9	14	13	(H=2.73)
Professionals	10	65	68	
Businessmen	4	17	27	
Self-employed	8	10	7	
Retired	12	28	30	
Family income (in INR per annum)				
Upto Rs 3,00,000				
3,00,000 -5,00,00	15	11	36	Kruskal-Wallis test:
5,00,000 – 7,50,000	8	13	23	p < 0.05*
7,50,000 -10,00,000	9	46	42	(H=7.65)
Above 10,00,000	11	38	40	
	10	39	12	

Note: *- indicates that the association is statistically significant
Source: Survey data

Table 4: Demographic and socio-economic profile of segments.

segment in detail, it is found that the 'Health Conscious' segment had an older consumer profile (56.6%) when compared to the other two segments, i.e. value-add seekers (44.2%) and Utility seekers (50.32%). The value-add segment was represented mainly by middle-aged (51.7%) consumers as this group had a special liking for Mattu Brinjal recipes and snacks. Further, we also found statistical differences ($H = 7.65$, $p < 0.05$) in the family income of the segments. It is observed that, majority (52%) of the value-add seekers are from a high-income family (> Rs.7,50,000), making them the most potential group to buy A-grade Mattu Brinjal variety and its premium value-adds products. Results revealed that the occupation of the respondents did not show statistically meaningful differences between segments. It has been observed that Udupi Mattu Gulla Brinjal is

regularly consumed by all the segments (Health conscious 76%; Value-add seekers 77% and Utility seekers 83%). This pattern is largely characterized by the availability and seasonality of the produce. Moreover, all segments put together had 52 percent male and 48 percent female respondents. Therefore, deeper insights into the purchase preferences of these consumer segments will serve as a basis to formulate marketing and branding strategies to promote consumption of this GI crop in untapped local markets, domestic markets (other districts and states of the country) and international markets.

The 'Health Conscious' segment showed higher mean values for nutritional value and quick digestion aspect of Udupi Mattu Gulla Brinjal consumption. Marketers should offer Mattu Brinjal salad (locally termed as Gojju) to the 'health consciouses because of its 'healthy recipe' feature. The 'value-add segment' was insensitive to the health benefits side of consumption. This segment was strong on the sensory side of consumption as they showed greater preference towards value-added products made of Mattu Brinjal, especially Brinjal fritters (locally known as podi) and Brinjal sambar (which tastes like thick soup). These differences in preferences among the 'Health Conscious' and 'Value-add' segments were found to be statistically meaningful based cluster centroid values (refer Table 4). The third segment is influenced by the convenience of consumption, comfort food and visual appeal. This segment should be targeted using a salesmanship strategy by training the salesman at purchase point with unique selling tactics. The consumers of this segment expect the retail shop to be closer to their place of stay so that it is convenient for them to pick their produce when they require them. They are also attracted by fresh produce without pest attack and feel that Mattu Brinjal recipe is a comfort and light food. On the other hand, the 'Health-Conscious' segment is largely from the low- and middle-income families with majority of the consumers in middle and old age category. Health conscious are regular in their purchase, and are influenced by nutritional value, dietary habits and overall health and well-being. Value-add seekers favour value added products of Udupi Mattu Gulla Brinjal and are mostly from middle-income category, mainly constituting teachers and working professionals. Finally, 'Utility seekers' look for convenience in cooking and comfort food and are keen on safe food with focus on quality. Thus, it is observed that the three segments are made of consumers who have different patterns of preference towards Udupi Mattu Gulla Brinjal and its value-added products.

Discussion and managerial implications

The results of this study have provided reflections on how marketing efforts can be designed for an agriculture-based GI product using consumer segmentation approach (Bertail and Caillavet, 2008; Demydas, 2011; Gindi, 2018; Raaijmakers et al., 2018). To transform Community-based Geographical Indications like Udupi Mattu Gulla Brinjal into sustainable enterprises, there is a need to develop market linkages in the local markets. Therefore, locally focused marketing interventions can serve the most relevant consumer segments as identified by the study. In this study, we have observed significant differences in the preference patterns of various segments (Clay et al., 2005; Boca, 2021; Isaak and Lentz, 2020). Studies on GIs which have used consumer segmentation approach have reported that quality, originality and authenticity of GIs motivates consumer preference (Glogoveţan et al., 2022; Likoudis et al., 2016; Barska and Wojciechowska-Solis, 2018). Earlier studies have analysed utility from the lens of economic benefits accruing to producers (Torok et al., 2020; Niederle et al., 2013: Cei et al., 2018). To assist marketers and expand the scope of marketing activities, this study has highlighted the profile and nature of consumer segments most suited to purchase Udupi Mattu Gulla Brinjal value additions. Greater emphasis is given to the demand side by covering the utilitative aspect of Brinjal consumption applicable to product acceptance research. Studies have reported that consumers give more importance to cultural value and intrinsic dimensions than to utility dimensions (Verbeke et al., 2016). However, it is the firm belied of the researchers that utility as a concept is central to the theme of consumer acceptance in case of GIs and is consistent with the concept of benefit segmentation. Hence, this study has introduced two important utility items 'convenience of preparation' and 'comfort food' as motivations for consumers to buy horticulture-based GIs. Also, safe consumption with no pest invasion on crops introduces a unique dimension to how GIs are perceived as ambassadors of quality. During field survey, the researchers have observed cases where buyers have spent reasonable time in inspecting every crop carefully to check pest attack, making the safe consumption criteria, a very prominent parameter in the purchase preference aspect. In another study, (Savelli et al., 2021) it has been

found that Brand name and PDO labels increase the possibility of consumer acceptance. The findings of our study provide greater importance to the grading aspects of GI produces based on the size of the produce and process-oriented functions like cleaning and sorting. It is felt that these grading related aspects can also be viewed as utility-based activities that can bring economic benefits to consumers. Comparatively, we have found economics benefits overarching quality-oriented benefits in GI product acceptance research.

A large majority (62 percent) of 'utility seekers' segment is made of professionals and businessmen, who are in the higher income groups. Moreover, 39 percent consumers in this group live within municipal limits, and the remaining 61 percent live in village panchayath limits. From a marketing strategy viewpoint, a digital marketing strategy (Vijay and Raju, 2019) using the co-branding approach with local e-commerce players are more suitable for convenience (aspect of utility) seekers. The earlier study (Vijay and Raju, 2019) emphasized the role of social media as a tool to effectively market farm products. Continuing and agreeing with the findings of this study, we have advocated a co-branding approach as a suitable marketing strategy in the digital space for GIs. We visited the local offices of three leading cellular operators and obtained the smartphone penetration data in the Udupi district. It is found that more than 95 percent of the urban households had at least one smart phone, whereas only 58 percent of the rural households had at least one smart phone. On this basis, the growers' association should take the support of local e-commerce platforms (apps) like Manipal Grocers, e-Samudaya, Swiggy, and Zomato to sell Udupi Mattu Gulla Brinjal in urban households. Udupi district has a 31:69 urban/rural household proportion. Continuing the urban consumer marketing strategy, the co-branding (Mattu Brinjal Growers Association and Online food players) aspect can be effectively promoted on social media platforms. Fresh Mattu Brinjal produces can be displayed on the dashboards of Manipal Grocers and e-Samudaya with daily price pops. Value-added products can be marketed through the food delivery apps of Swiggy, Zomato and e-Samudaya.

It is observed that utility seekers prefer Udupi Mattu Gulla Brinjal preparations because they are comforting, give a 'light body' feeling, and can be prepared quickly. If one needs to grab something quickly with a cup of tea or coffee, he looks for a nearby snack point. These snack points sell fritters with a cup of hot tea or coffee. Fritters are usually made of potatoes or chillies as the price (per kilogram) of these vegetables is affordable. Brinjal fritters are not regularly tried as a variant in the menu in most local restaurants. However, they are a very popular and most tried item locally as evening snacks. This characteristic of the vegetable has not been popularised as a promotion plan by local food marketers and owners of local hotels and tea/coffee shops. Very rarely do we see restaurants in the Udupi district include Brinjal fritters in their menu as evening snacks. To include Brinjal fritters in the menu, the Udupi Hoteliers Association and the Mattu Brinjal Growers Association need to negotiate a deal on the sale price of B and C grades of Mattu Brinjal. Grade A can be retained for a premium class of customers. Thus, for a utility-driven consumer segment, marketers and sellers of horticulture-based GI should look at the convenience of preparation and intake of comfort food as the main elements of marketing strategy.

'Health-Conscious' are mainly from middle-aged groups and senior citizens (Buscail, 2018). Previous studies (Dias, 2012; Kowalkowska et al., 2018; Lemamsha et al., 2022) have reported the nutritional aspects of consumption and its overall benefits to human health. In this study, we have highlighted the role of marketers such as health agents in promoting and achieving the target of increased consumption. To promote the consumption of horticulture-based GIs like Udupi Mattu Gulla Brinjal, health marketing campaigns should be organized in the local region. For a developing country like India, health marketing campaigns will ensure an increase in vegetable and fruit intake, especially when the consumption is way below the recommended intake as prescribed by the WHO guidelines. Previous studies have referred to health marketing campaigns (Appleton et al., 2016; Demydas, 2011) to promote consumption and public health. Concurring with the views of these authors, this study has detailed an appropriate setting where these marketing strategies can be ideally executed considering the rural market environment. As an addition to the body of literature, we advocate the process by which these campaigns can be implemented on ground for a typical rural marketplace. As a result of this action, the producers of GIs will be benefited as health marketing campaigns will translate into higher sales for the producers. India has a strong chain

of health care workers through the Primary Health Care Centres and Community Health Care centres. Hence, the network of health activists can be used to promote special GIs. The Ministry of Health and Family Welfare commenced the National Health Mission and provided a trained female health activist or Accredited Social Health Activist (ASHA) to promote rural health. The ASHA worker concept is introduced as an interface between the community and the public health system. Consistent with the advice provided by the World Health Organization to consume at least 400 grams of fruits and vegetables every day, the ASHA workers can be used as agents to achieve this target by encouraging such consumption at the Primary Health Care Centre level. Special training can be offered to them on how to promote and sell GI fruits and vegetables as a task favouring national interest. This marketing strategy is a win-win for all stakeholders, i.e., the producers of GI who gain extra revenue, consumers who are likely to increase the intake of vegetables and fruits, and the health activists who can accomplish their mission of promoting public health and welfare.

Further, there are limited studies that explore social embeddedness in all its forms. Niederle, Paulo, and Gelain. (2013) explores institutionalization of communities. Another study (Handy et al., 2011) states that social capital is formed as a result of communities' unified approach in business formation, operational functioning and meeting issues and challenges. Other studies (Welsch and Kunhs, 2002; Parwez, 2017) examine communities' effort to alleviate themselves from poverty for the sake of social development. This research work has laid greater emphasis on social interactions as it is having a 'multiplier' effect on patronising a larger customer pool. Therefore, we suggest that developing countries with a dominant rural market type, having active social life, should take up outdoor health marketing campaigns by leveraging social interactions. India has a higher proportion of rural population (Rural 69%; Urban 31%). Active social interactions can be encouraged through street play, folk dance, drama, exhibitions, road shows, car festivals etc. which take place in an outdoor environment. Therefore, it is easier to promote health marketing campaigns amidst large gatherings through public announcements during such events. Street plays should be organized in the locality of fishermen, weavers, farmers, potters, carpenters, women's self-help groups, and other occupations to gain popularity. The core theme should convey the nutritional benefits derived from healthy Brinjal value-added products (Ali et al., 2010) like gojju (salad), sambar (dish), and brinjal bartha (pudding) which are vacuum baked health friendly preparations. In the case of GIs, health marketing campaigns will be successful if executed in an outdoor environment where the members of the community participate and interact.

For the value-add seekers, we suggest the categorization of consumers on the basis of age. Young and middle-aged consumers can be targeted with 'taste' and 'flavour' rich products like Udupi Mattu Brinjal fritters (fried snack) and Brinjal yennekai (oil and grated coconut dish). Both these products are very tasty but do not find a place in the rice plate regularly in homes and restaurants. A personal salesmanship approach should be used to convince hotel owners to introduce fritters and yennekai regularly in restaurants and local eateries. Udupi Mattu Gulla was awarded the GI tag for its unique taste. We feel that it is easy to market fritters, yennekai and Brinjal gojju (salad) by leveraging the unique taste aspect by mounting wall signs in restaurants. Wall signs are an easy way to attract potential customers to know about a hotel's offerings.

Previous studies have highlighted the aspects of competitive advantage a GI can offer considering the place of origin (Lamarque and Lambin, 2015; Rahmah, 2017; Egelyng et al., 2017). This study has emphasized the need to undertake innovative marketing strategies to gain consumer confidence and improve producer's margins. A few innovative marketing strategies for horticulture GI value-adds can be introduced in the local market. Value-add products and recipes with high demand, like Brinjal gojju (salad), Brinjal pickle and Brinjal yenne kai (coconut-jaggery dish), will gain acceptance over time if they are offered as samples initially. The idea to introduce ready-to-eat product forms like sambar and rasam powder (available as soup variety with local brands MTR, Maiyya's, and Nayak's) were initially served as items on the rice plate or the banana leaf (food is also served on banana leaf). Later, due to excess demand, the ready-to-eat form was introduced. It then moved on to packets and sachets in-store shelves of local outlets. Likewise, Mattu Brinjal Growers Association has a great opportunity to start their entrepreneurial venture under the banner of the existing CBE as packaged foods like salads, sambar, pickle, curry, and chutney. If the ready-to-eat form must be successful, more efforts must go into the packing and packaging of raw Udupi Mattu Brinjal and value-add products.

Few studies in food products marketing report

packaging utility as the least influential factor consumers consider in food quality (Chamuri and Batt, 2014; Gindi et al., 2018; Raaijmakers, 2018; Ali et al., 2010; Pilone et al., 2017; Shruthy et al., 2023). However, we differ from these findings from previous research considering our field experience in the case of horticulture GIs. Consumer acceptance towards GIs (especially horticulture-based GIs) have evolved over the last decade, and it is observed that packing and packaging play a great role in providing safe products, particularly when pest attack is a frequent menace in the local fields. All products should be sorted, processed, and packed with assured quality before they reach the hands of the customers. The packing, packaging and quality assurance aspect of Udupi Mattu Gulla Brinjal needs a makeover if it has to attract more customers.

Earlier studies have observed that consumers are motivated to purchase GIs due to the positive impacts that such purchases can bring to the development of the local community (Teuber, 2011; Uzar et al., 2022). This study has examined GIs through the lens of Community-based Enterprises and suggests that marketing should be led by a strong branding and packaging function. Developing countries with a dominant rural market should enhance branding efforts and focus on superior packaging design. We suggest 'place branding' (Pucci et al., 2017; Florek, 2013) and 'leveraging the potential of the existing GI logo' to achieve greater visibility and acceptance.

Source: https://www.indiamart.com/mattu-gulla/products.html

Figure 1: Logo of Udupi Mattu Gulla Brinjal.

Research work on GI marketing has highlighted the importance of labelling as a mark denoting the quality of products (De Canio and Martinelli, 2021; Savelli et al., 2021). These studies have analysed consumer preferences (Kosiciarova et al. 2020; Ahmadi et al., 2019) using quality labels and sensory analysis. In India, selling of vegetables and fruits in open air is a common practice without giving importance to deterioration in quality. Safety of produces and food safety led by packing is a growing area of research importance in the Indian context. Therefore, we feel that the growers' association should widen the scope of marketing and adopt a superior packaging strategy. In India, packing and packaging have gained importance in recent times with stricter norms followed in food safety and food hazard analysis. There is a lack of urgency among local food entrepreneurs towards food safety management and quality assurance. All food establishments like hotels, restaurants, or cloud kitchens (who later go for field delivery), irrespective of whether they offer fresh or packaged foods, must follow food safety management principles as defined by HACCP (Hazard Analysis and Critical Control Point). From the point of view of food safety, every food organization is required to obtain an IndiaHACCP certification – a standard based on the general principles of food hygiene. This certificate is obtained under the Voluntary Certification Scheme for food safety operated by the Quality Council of India (QCI). The level of awareness of Mattu farmers about the concepts of packing and packaging, the focus on safety, and the level of agility to adapt to change are low. Udupi Mattu Gulla Brinjal is sold in open air conditions exposed to sunlight, heat and dust and therefore is often subject to quality deterioration. Thus, the main area of focus for enabling agencies (operated by the government and local setting) is to train the members of the association on packaging and branding. Thus, a robust packing and packaging plan to unlock the true market potential of Udupi Mattu Gulla Brinjal is the way forward. Our views are also seconded by the officials of the local agri-development promoting agencies. From marketing parlance, the value-add seekers segment is the ideal group to sell uniquely packaged GIs, as this segment has high purchasing power. An in-store merchandising strategy at retail stores that provides discounts and offers is a good strategy to attract buyers for packaged, ready-to-eat Brinjal products as an introductory offer.

There is growing literary attention given to sustainability of business ventures (Arfini and Bellassen, 2019; Boca, 2021; Cei et al., 2018; Glogoveţan et al., 2022; Hoang et al., 2020; Török

et al., 2020. In the case of horticulture GIs like Udupi Mattu Gulla Brinjal, institutions that promote local agriculture have been consistently striving to achieve the sustainability of CBEs. While earlier research work has focused on sustainability intended to mean preserving future needs, this research has emphasized the challenges faced by Community-based Enterprises (CBEs) in staying relevant and profitable during testing times. To protect GIs grown by CBEs, government-backed institutions like the National Bank for Agriculture and Rural Development (NABARD) and Agricultural and Processed Food Products Export Development Authority (APEDA) should join hands and launch market extension activities to empower the Udupi Mattu Gulla Brinjal and its value-added products. The Government can select a suitable partner as a CBE Support Agency (CBESA). Such partners should have local knowledge about consumer markets and should be able to design and implement market extensions and create market linkages.

We feel that the food marketers, along with the support of the CBE Enabling Agency, should engage the services of packaging experts to introduce a solution for safe and healthy food products. Packing and packaging strategies should be crafted for fresh produce and value-added products separately and should address packaging solutions at the brand level, grade level, description level and information level. The design and placement of the GI logo, nutritional information, date of production, packing and expiry, nutritional information etc are some aspects that need attention to attract buyers. Although health marketing campaigns are targeted towards the general public, concentrated marketing efforts can be designed on the 'utility seekers' segment as their purchase intention is motivated by benefits derived and consumption value.

The role of this CBESA can be envisaged as follows:

a) partner with locally operating CBEs (Godrich, et al., 2020), government-owned and promoted institutions, and non-governmental organizations build synergies in the local area to accelerate agriculture development activities of the CBE.
b) collaborate with CBEs on the implementation of projects using project management skills and design thinking.
c) Support local food entrepreneurs, food marketers and state-owned agencies to innovate, train to prepare and launch value-added products
d) design and support policy making
e) train local salesman in the art of selling, convincing, negotiation and salesmanship.

There is adequate literature in the area of marketing of GIs (Mattas et al., 2020; Gana Shruty et al., 2016; Vijay and Raju, 2019). However, in-depth insights are required to analyse the role played by salesman in the Agri-value chain (Gal and Jambor, 2020). This research work has examined the pivotal role played by a salesperson as a brand ambassador of local-origin GI products. We feel that there is a scarcity of literature which emphasises the ability of the salesman positioned at retail shops who can act as an ambassador cum change agent and nourish the GI brand to the consumers. These regional specialty items are picked based on the trust placed on the sellers on their knowledge on the quality, which is mainly characterized by grade, seasonality, and expiry of the product. They are also well-informed about various types of value-added products that can be prepared from these unique products. Therefore, the seller is an important partner in the value chain who can influence the buyer's purchase decision in the case of locally grown GIs. Through this study, we address the value chain aspect of GI marketing which is not been discussed in previous studies. In the case of Udupi Mattu Brinjal, Buyers trust the salesman for the correct information that he/she gives regarding the freshness, grade, harvest date, and originality (GI tag). The CBE enabling agency should take up the task of training salespersons on salesmanship skills. Further, the CBE Enabling Agency could join hands with the state-run entities and promote entrepreneurial intent among the local food entrepreneurs, and sell Udupi Mattu Gulla Brinjal value-added products. The Mattu Brinjal Growers Association can benchmark the success story of locally grown (Amasebail village, Kundapura taluk) Okra vacuum fry by a local private firm, a small agri-food unit. A local food entrepreneur from Kundapura taluk introduced a unique okra (vegetable) value-add product that is health friendly and affordable. Launched as an alternative to the traditional okra oil fry, this product received mass acceptance and patronage due to its health benefits and functional value as it compliments well with 'ganji oota' (bowl of porridge). Okra vacuum fry is today a retailers (also local hotels selling porridge) favourite item on the shelf. Udupi Mattu Gulla Brinjal fritters can replicate the Okra vacuum fry success story as it can be positioned as an evening snack by local hoteliers and retailers. However, there is a lot to be achieved if it has to be offered

as a ready to eat a snack in terms of packaging. From a marketing perspective, this product can be offered to all three consumer segments identified by this study.

Currently, food marketers in India are faced with the challenge of responding to the actions of buyers of food products swiftly, considering stiff competition on one hand and public health on the other. Young consumers largely prefer packaged food, which is readily and conveniently available, while the older population avoids them, considering the risks it brings to health. Furthermore, all consumers are willing to eat fresh vegetables, indicating a strong willingness to maintain a healthy diet. This stresses the need to organize social marketing campaigns. An advertisement in the local newspaper can be a good technique to communicate the message of organizing a Brinjal mela (exhibition in the local market) to implement GI branding efforts and make it more acceptable in the local markets. Recently in May 2022, a Jackfruit mela (exhibition organized by local growers) was successfully organized in a public setting, which not only highlighted the value-added products that can be prepared out of jackfruit but also delivered sessions on its nutritional value and health benefits. Using the exhibition as a tool for mass campaigning, food entrepreneurs, marketers, and health workers can join together and promote the health benefits arising from vegetable consumption. Such rural marketing strategies for local-origin GIs can be replicated in emerging economies with similar consumer characteristics.

Conclusion

The findings of this study will be useful for future academic research in consumer segmentation literature in the marketing of Geographical Indications. Our research reveals that CBEs like Udupi Mattu Gulla Brinjal Association grow superior quality products but fail to unlock true market potential mainly due to production, operational, and marketing-related inefficiencies. Therefore, this study has identified relevant consumer segments and analysed their preference to develop and deploy marketing strategies and help local farmers. The research findings will help marketers and policymakers employ suitable interventions in marketing local GIs. Food marketers can use these marketing strategies to target appropriate consumer segments and promote food consumption. Further, by identifying value-add seekers and 'utility seekers' as separate segments for a local GI product, food entrepreneurs and marketers can target each of these segments separately by using a marketing mix and patronise sales. Such segment-strategy mix can also be extended to other horticulture GIs and vegetables in different geographies of the world, especially developing countries having a similar socio-cultural and economic profile of consumers. The findings and analysis of this study will be useful to develop marketing strategies and policies for those economies having dominant rural consumer markets like Asian and African countries. Increased awareness of food safety is also important to improve consumer knowledge on safe consumption. Hence, this study has highlighted the need for a focussed marketing approach for food safety and packaging technology aspects in the case of horticulture GIs.

In developing economies, the concentration of agri-based enterprises is mostly seen in the rural areas. Therefore, our research urges the need to introduce an incubation centre at the Taluk level. To achieve this end, the agencies launched by the State Government working on promoting agriculture in the district should take the lead in designing a collaborative approach. It is found that agri-businesses are most susceptible to rapid market movements. Therefore, farmers do not have the desired level of technical know-how and skills and competencies required to face business-related challenges. Importantly, incubation centres are required to address the needs on CBE sustainability aspects like pooling intellectual capital, identifying sources of funds, addressing marketing problems, leveraging social capital etc. Academic institutions, Government-owned agencies and non-governmental organizations with financial wherewithal, infrastructure and research capabilities are the most suitable players who can participate as 'partners' to commence this collaborative approach along with the local government.

To summarise, at the farm level, the study's results will help farmers to commence new marketing techniques and generate additional revenue. As a specific case example, a marketing intervention was commenced by the research team in the study area of Mattu village. It was decided to label 'A' Grade crop of Udupi Mattu Gulla Brinjal as a 'premium variety' (priced at Rs. 160/per kg) and sell in the local market on a test basis. Over a period of four months, prices stabilized in the local markets (Rs. 150-160/per kg)

as a result of this labelling intervention. On analysing the reasons for the stability in price, it was observed that the consumers perceived 'brand label' as a quality assurance tool against other local Brinjal variety. Thus, branding a logo, term, certificate or a sign may work as a tool to achieve price stability in the case of GIs. The learnings may be adopted to other fruits and vegetables as well. This, in turn, will bring new value-added products to the eating table for the consumers and increase the intake of fruits and vegetables. By following strict dietary habits focused on good health, improvement in public health can be seen in the long run. At the policy level, marketing decisions can be taken to leverage the collaborative approach proposed by this study involving farmers, agriculture development agencies operated by the state in the local region, and the CBE agency suggested by the study. The elements of the collaborative approach are likely to bring momentum to the overall mission of achieving agriculture development in the state. The study is conceived at a time when the Government of India is keenly focussing on unlocking the market potential of geographical indications in the country as an agriculture development priority. Furthermore, the relevance of the study is consistent with the United Nations Sustainable Development Goals (3, 11, and 12) of building sustainable communities, establishing good public health and well-being, and influencing responsible consumption. The results of the study can also be generalised to a typical rural market in a developing country, aiming to promote the development of local farmers and targeting sustainable agriculture. The generalization and applicability of the marketing strategies proposed may work well for a market with a high rural population proportion, as in the case of India. The urban-rural population proportion in the Udupi district (38:62) is almost consistent with that of the proportion of the entire nation (30:70).

We observe a few limitations in this study. The nature of the urban market (town limits) in the Udupi district cannot be compared to an ultra-urban set-up prevailing in other cities in the country. This may prevent generalization in the urban context. In our opinion, the findings of this study are suitable for a typical rural Indian market, and therefore, can be generalized to the markets of emerging economies of Asia and Africa. Indian cities are classified as Tier I, II and III, and a comparative difference is observed in the income level and lifestyles of people living in these cities. Future research can analyse consumption behaviour based on such classifications of urban markets. As per the census records of 2021, over 70% of the population in the Udupi district are Hindus. We feel that, a religion-based classification may significantly impact consumer behavior, given that Udupi Mattu Gulla Brinjal is a favoured vegetable offered (as his grace) to Lord Krishna (deity) at the mutt temple in Udupi. Locals from the Muslim community also serve special dishes made of Udupi Mattu Gulla Brinjal. Especially in the case of locally grown horticulture GIs, researchers should analyse the influence of religion as a factor that influences the consumption of fruits and vegetables. From a consumer's point of view, our research limits the findings and analysis to preference-based analysis and deeper insights on religion and caste-based studies, and its impact on the consumption of vegetables and fruits is likely to provide interesting results. Future studies can focus on religion and caste-based classification approaches using a mixed-method approach. Future research can also test whether utility, value-added products and health-related factors positively affect consumer preference using regression analysis and structural equation modelling. We have limited our findings to the extraction of variables of research importance and identification of consumer segments as there is an urge from the agriculture support agency to market select GIs and promote farmers' interest. As GIs are linked to a specific geography, it is also likely that place branding may mediate the relationship between utility and value-added products and consumer preference. This may provide marketers with breakthroughs to establish a focused branding strategy for horticulture GIs.

Given the impetus provided by the current government for agriculture development, there is vast scope to introduce interventions, particularly in marketing, innovation and technology. Many CBEs at the rural level in India are desperate for attention as they have reached the stage of distress and closure. Enabling agencies should play the role of a change agent to revitalize the landscape of such CBEs. For example, Kari Ishad mangoes in Ankola village in Uttara Kannada district, Udupi Jasmine and Udupi Mattu Gulla Brinjal in Udupi District, and superior quality kiwi fruit in Arunachal Pradesh are some prominent local cases waiting for intervention. It is heartening to see that Kari Ishad mangoes are awarded with a GI tag in April 2023 as we conclude this

research work. Future researchers can take each of these CBEs as case examples and work towards their development. There is also a scarcity of academic work in customer loyalty in case of locally grown horticulture produce. Empirical work may explore the factors determining customer loyalty using a causal research approach.

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Factors Affecting the Adoption of Recommended Fertilizer Doses by Wheat Farmers in the Casablanca-Settat Region of Morocco

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Abstract

Despite the economic advantages of introducing new agricultural technologies into the production system, their rate of adoption in Morocco remains relatively low. The objective of this article is to study the factors that hinder the adoption of these new technologies. We address the case of the recommended fertilizer doses (RFD). The study employs a probit model with a stratified random sampling approach.The data were collected from 297 farmers in the Casablanca-Settat region using a face-to-face interview method and analyzed through R software. The results of the study show that the main barriers are related to access to information and bank credit, government incentive, production orientation, distance to the market as well as age, and level of education.

Keywords

Adoption, obstacle, new technology, fertilizer recommendation, probit.

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Introduction

Agriculture is considered one of the key sectors of the Moroccan economy, it contributes about 17.3% of the national Gross Domestic Product (GDP) and employs 39% of the population (Harbouze et al., 2019). In Morocco, the majority of the rural population depends directly or indirectly on agriculture for their livelihoods and is likely to be three times poorer than people living in urban areas (Ghanem, 2015). The importance of this sector is transmitted in the efforts that Morocco has been making since its independence (Toumi, 2008). Special interest has been given to cereals because of their place in the country's agricultural system. Indeed, wheat is considered the most important cereal crop in Morocco. This crop contributes significantly to the livelihoods of the farming community. The average consumption of wheat in the country is estimated at 255 kg/year/capita (Bishaw et al., 2019), which makes the Moroccan citizen one of the highest consumers of wheat in the world, knowing that the world average is around 152 kg/year/capita.

However, the analysis of the situation of cereals in Morocco indicates that there is a big gap between the expected and actual production achieved by farmers. Indeed, to improve the productivity of cereals among farmers in the Casablanca-Settat region, the National Institute for Agronomic Research (INRA) has developed a set of innovative practices to introduce them into the production system.

Thus, several technologies have been introduced into the agricultural production system such as the introduction of new seed varieties, the introduction of new seeding systems, in particular direct seeding (Yatribi, 2020), the application of recommended doses of seeds, basic fertilizer and cover fertilizer, adoption of the recommended date for sowing, weeding, application of phytosanitary products and for harvesting and finally agricultural mechanization (Alaoui, 2005). Recommendations for these techniques are summarized in the following Table 1:

Production technique	Recommendation for new technology
Tillage	Zero tillage and/or direct seeding
Date of sowing	Between 01 November and November 20
The sowing dose	160 kg/ha (+/- 5 kg)
The sowing method	Sowing with seeder
The recommended fertilizer dose (RFD)	150 kg/ha (+/- 10 kg/ha)
The cover fertilizer	200 kg/ha (+/- 20 kg/ha)
Crop rotation	Rotation with food legumes
Herbicide treatment	1 time
Fungicide treatment	1 time
Harvest date	Between May 30 and June 30

Source: Compiled by the authors according to the researchers of the National Institute for Agronomic Research (INRA)

Table 1: Recommendations for new wheat production.

In this study, we are interested in the recommended fertilizer dose (RFD). This choice is made because of the place occupied by basic fertilizer in the technical management of wheat, the importance of the turnover generated by the fertilizer market in Morocco, and finally, the low levels of adoption achieved. Previous studies estimate that the level of adoption of RFD is the lowest of all the components of the technology package. These results were confirmed by those obtained in the present study. In addition, basic fertilizers are a very important element in the production of wheat. Its efficient use is therefore crucial for improving wheat yield in quantity and quality (Eddine et al., 2022).

In fact, usually, farmers use fertilizer doses based solely on their own experience. They apply more than 150 kg/Ha. If the farmer applies 150 Kg/ha (with 10 kg/ha more/less) of the RFD he's qualified as an adopter. The farmer must apply the exact recommended dose no more no less. The main reason for adopting this new technology is to improve the yield production of cereals and to decrease the cost of inputs.

The advantages of new agricultural production technologies have been proven by theoretical studies, empirical studies, and field experiments. A multitude of studies has been conducted in this sense. All these studies agree on the fact that the adoption of new agricultural production technologies is a necessity to ensure the continuity of farms. The analysis of this work reveals that the adoption of new technologies depends on several determinants, such as the socio-demographic characteristics of the farmer, the structural characteristics of the farm, and institutional factors (Bouzid et al., 2020).

The socio-economic characteristics of farmers could influence their decision to adopt new agricultural production technologies. Among these characteristics, we cite the farmer's age (Adesina and Zinnah, 1993; Sunny et al., 2022), human capital (Chirwa, 2005), gender (Atibioke et al., 2012; Chirwa, 2005), farming experience (Maniriho et al., 2022), family size (Challa and Tilahun, 2014), participation in non-farm activities (Chirwa, 2005), home-farm or home-market distance (Hailu et al., 2014) and social capital acquired via social networks (Bandiera and Rasul, 2006).

On the other hand, commercialization can be considered a determining factor in the decision to adopt innovation in agriculture (Bouzid et al., 2020; Diagne, 2020). Research on the problem of adoption of new agricultural technologies has revealed the existence of several other factors such as access to credit and extension services (Akudugu et al., 2012; Geta et al., 2013), off-farm income, farm size, types of crops grown, the destination of production, access to subsidy, and the cost of purchasing and installing the technology. The main studies are summarized in Table 2.

Previous studies have mainly focused on technical efficiency, fertilizer management techniques, fertilizer application comparisons, fertilization strategies for higher yields, and the effects of fertilizer diffusion (Choudhury et al., 2013; Rahman and Zhang, 2018).

Indeed, studies that have been conducted on agricultural innovations have shown that they allow farms to increase their efficiency and achieve economies of scale (Pépin, 2020). However, despite these advantages, their dissemination and adoption by Moroccan farmers are still problematic. Especially for the production of cereals in areas where conditions are not favorable.

Thus, although several studies have focused on the factors of adoption of new technologies in different regions of the globe, there are few studies conducted in Morocco that have mainly focused on the adoption of new technologies and the factors associated with the process of adoption. Thus, this study tries to identify the factors affecting the adoption of the recommended fertilizer doses (RFD) in an important region such as Casablanca-settat.

Authors	Form of technology/ practice adopted	Crop	Sample size	Location	Model	Results
(Uddin et al., 2016)	Conservation agriculture practice	Different types of crops	300 farmers	Five districts in Bangladesh	Logit model	The educational level of the household head, farm size, farm income, extension contact, and farming experience were found as significant factors.
(Nazu et al., 2021)	Improved management practices	Wheat	320 farmers	North of Bangladesh	Tobit model	Adoption rate is influenced by their educational level, farming experience, amount of labor (family and hired both) used, amount of land under wheat cultivation, extension services, organizational membership, training, and market distance from the farm.
(Akudugu et al., 2012)	Modern agricultural production technologies	No specification	300 farmers	Bawku West District of Ghana	Logit model	Results showed that farm size, expected benefits from technology adoption, and access to credit and extension services are significant factors.
(Diiro and Sam, 2015)	Improved maize seed	Maize	1218 maize farming households	Uganda	Semiparametric estimator	Nonfarm income has a positive and significant effect on the adoption of improved maize seed.
(Challa and Tilahun, 2014)	Modern technologies	No specification	145 households	Gulliso district in Ethiopia	Logit model	Household heads' education level, farm size, credit accessibility, perception of farmers about the cost of the inputs, and off-farm income positively and significantly affected the farm households' adoption decision; while family size affected their decision negatively and significantly.
(Geta et al., 2013)	Soil fertility management practice	Maize	385 farmers	Southern Ethiopia	Multinomial Logit model	The size of the farm, access to credit, availability of extension services, and training pertaining to soil fertility management were important factors affecting the decision to use a particular soil fertility management practice.
(Hagos and Zemedu, 2015)	Rice improved varieties	Rice	151 households	Fogera District of Ethiopia	Probit model	Households labor availability, education level of the household head, land holding, distance to the nearest village market, proximity to the main market, distance to access agricultural extension, access to the source of rice seeds, access to new cultivars of rice and off-farm income affects significantly the participation in improved varieties.
(Atibioke et al., 2012)	Grain storage technologies	Different types of crops	120 farmers	Ilorin West LGA of Kwara State in Nigeria	Logit model	Sex, level of education, and occupation are significantly related to the adoption of grain storage technologies.
Zhou et al., 2010)	Fertilizer use	Maize	349 farmers	Chaobai watershed in Northern China	OLS	Results show that irrigation, gains in crop yield, and higher earning goals are positively correlated with fertilizer use intensity, while farm size, manure application, soil fertility, and the distance to fertilizer markets are negatively correlated.
(Reza and Hossain, 2013)	Fertilizer Use	Rice	90 farmers	Rajshahi District in Bangladesh	Probit and Tobit Models	Type of land, irrigation facility, and access to credit had a positive and significant influence on fertilizer use but extension service is significantly and negatively related to fertilizer adoption. There were no significant relationships between adoption and education, distance from the market, and farm income.
(Adesina, 1996)	Chemical fertilizers	Rice	120 farmers	Côte d'Ivoire	Tobit model	Results show that the cultivation of lowlands, use of mechanization, farm size, land pressure, and availability of non-farm income positively influence farmers' use of fertilizers. On the opposite, the distance of the field to the village, the distance of the village to the major market, and if the cultivator is a female have a negative effect.
(Nigussie et al., 2017)	Sustainable andmanagement technologies	No specification	300 farm households and 1010 farm plots	North-western Ethiopia	Multivariate Probit and Poisson regression models	Results indicated that farmers' adoption of SLM measures depends on the gender of the household head, the availability of labor, and some plot characteristics, including soil fertility, soil depth, watershed position, and tenure.
(Caffey and Kazmierczak, 1994)	Flow-through or RAS technology	Crab production	61 producers	Louisiana in USA	Multinominal Logit model	The adoption of flow-through was significantly related to a producer's involvement in a full-time soft-shelled crab operation that relied solely on family labor and employment outside the seafood industry.
(Atry et al., 2009)	Integrated pest management (IPM) techniques	Wheat	72 wheat growers	Varamin County in Iran	Stepwise multiple regression analysis	The results showed that the level of knowledge is the key obstacle to the adoption level of sustainable IPM practices.
(Ntshangase et al., 2018)	No-till conservation agriculture	Maize	185 farmers	Sisonke District in South Africa	Logistic model	Findings show that an increase in extension visits, age, education, and farmers' positive perceptions significantly increased the likelihood of a farmer adopting no-till CA, and an increase in land size was negatively related to no-till CA adoption.

Source: Own compilation

Table 2: Studies on the factors affecting the adoption of new technologies. (To be continued).

Authors	Form of technology/ practice adopted	Crop	Sample size	Location	Model	Results
(Bhuiyan and others, 1987)	Improved seed-fertilizer-irrigation technology	No specification	100 part-tenant farmers	Mymensingh district of Bangladesh	Chi_square and t-test statistics	Adoption of improved production technology tended to be the highest on owned land followed by cash-rented land, crop-share rented land with input cost-sharing and crop-share rented land without input cost-sharing.
(Chuchird et al., 2017)	Water wheel (WW), water pump (WP), and weir (WR) irrigation technologies.	Rice	207 farmers	Chaiyaphum province in Thailand	Probit model	The results revealed that the land holding size, farm income, and water use association membership factors were highly positively associated with the WW adoption but negatively correlated with WP and WR. Also, age was positively associated with WR but negatively correlated with WP.
(Huang and Karimanzira, 2018)	Soil testing and fertilizer recommendation facilities (STFRF)	Different types of crops	176 farmers	North of Bangladesh	Logit model	Results show that being young farmers with less farming experience, being small-scale farmers, having higher education, having more farming income, and having more knowledge about these facilities and the fees of these facilities were found to have a significant effect on the adoption. On the opposite, gender, land ownership, and secondary income were found to be insignificant for the adoption.
(Alauddin and Tisdell, 1988)	High Yielding Varieties (HYV)	No specification	58 farmers	Bangladesh	OLS	Irrigation emerges as the key determinant of HYV adoption followed by farm size and education.
(Sunny et al., 2022)	Recommended fertilizer doses	Boro rice	405 farmers	Dinajpur district of Bangladesh	Probit model	Age, land typology, soil water retention, knowledge, and availability of cow dung significantly influenced farmers' decisions to apply fertilizers.

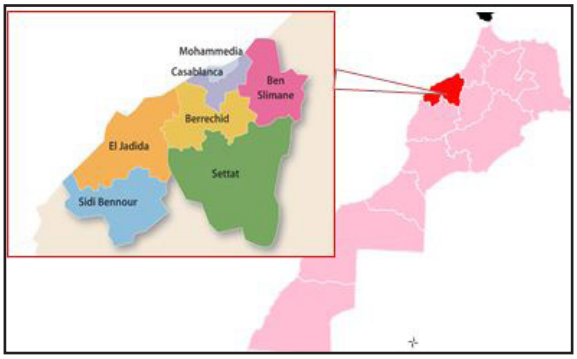
Source: Own compilation

Table 2: Studies on the factors affecting the adoption of new technologies (continuation).

Materials and methods

Study areas and data

The Casablanca-Settat region is considered one of the main cereal regions in Morocco, it is located in the center-west of the kingdom and has 6.862 million inhabitants (HCP, 2014), i.e. a density of 353 inhabitants per km and an area of 2.7% of the national territory.



Source: Ministry of equipment and water in Morocco (2022), www.equipement.gov.ma

Figure 1: Study area.

The region belongs to semi-arid areas with an annual average rainfall ranging from 333 mm to 398 mm depending on the province (Essalek et al., 2019). Most of its cultivable land is dedicated to a wheat-based cereal/legume food cropping system. During the 1960s and 1970s, it was called "the granary of Morocco in cereals ".

In order to collect data from a representative sample, we adopted a stratified random sampling design. The first step is to collect information on the number of farmers producing cereals and on the total area devoted to wheat in the two areas of the Casablanca-Settat region. In the second, the required subsample sizes were determined. Our basic sample is composed of 297 farmers. The questionnaire was administered individually to the farmers from two governorates (Settat and Benslimane) by a team of well-trained interviewers. Hence, the study was conducted in 2018 under the direction and coordination of researchers/engineers from the regional center for agricultural research in Settat (INRA) based on estimated rates of adoption levels in the two areas of the Casablanca-Settat region. The Sample size determination under Stratified Sampling Technique is as follows:

$$n = \frac{\sum_{j=1}^{k} N_j * P_j(1-P_j)}{N * \left(\frac{l}{Z\alpha/_2}\right) + \frac{1}{N} * \left(\sum_{j=1}^{k} N_j * P_j(1-P_j)\right)} \quad (1)$$

where,

l = 2.5: precision level

N = 65746: Total wheat growers in the study area

N_j = population in governorate j

P = 5%: The maximum adoption level we want to capture

Z0.95 = 1.96

The sample size: n = 297

With this sample size we can achieve all of the combinations of precision and adoption levels with 95% confidence, and 2.5% precision for capturing adoption levels of up to 5% in all study areas.

Empirical framework

The analysis of the adoption of new cereal production technologies, as is the case of the recommended doses of fertilizers (RFD), considers that the farmers adopting this technology are agents who make decisions in their interest (Ghimire et al., 2015). The adoption of the agricultural technology in question is therefore only the result of an optimization made by heterogeneous farmers (Foster and Rosenzweig, 2010). According to Ghimire et al. (2015), this optimization is done when farmers are supposed to maximize their utility function under many constraints. The difference between the utility of adopting the recommended fertilizer doses U_{iAdop} and the utility of not adopting this technology $U_{iNonadop}$ is denoted U_i^*. Farmer i will choose to adopt the new technology when the utility acquired by adopting is greater than that by not adopting it:

$$U_i^* = U_{iAdop} - U_{iNonadop} > 0 \quad (2)$$

This decision can be modeled as follows:

$$U_i^* = X_i'\alpha + \varepsilon_i \quad (3)$$

With $U_i = \{1 \text{ if } U_i^* > 0 \; 0 \; Else$

Where, U_i^* is the latent variable that expresses the probability that a farmer decides to adopt the new technology. This probability takes the value "1" in case of adoption and "0" in case of non-adoption. The term X_i' represents the explanatory variables of the adoption decision or those that express factors that hinder this adoption, as is the case of our study, α is a vector of parameters to be estimated, and ε_i is the term of error assumed to be independent and is normally distributed as follows: $\varepsilon_i\ N(0.1)$.

By definition, the Probit model defines the probability associated with the decision to adopt the RFD technology $(U_i = 1)$ as the value of the distribution function of the standard normal distribution $N(0.1)$ considered at point $x_i\ \alpha$.

The individual marginal effect of an explanatory variable on the probability of adopting the RFD technology is, by definition, the variation in the probability of adoption following the increase in this variable by an additional unit (Keita, 2015). This translates mathematically into the derivative of the expression of the probability function $P(y_i = 1/X_i)$ with respect to x_{ik}.

Where $P(y_i = 1/X_i)$ is the probability of adopting the RFD conditional on the characteristics of x_{ik}, α is a vector of k+1 parameters.

Declaration of variables

The bibliographical analysis that we carried out above enabled us to group the obstacles that hinder the adoption of new agricultural production technologies into three main categories. Thus, we distinguish obstacles linked to the technology itself, internal obstacles linked to the operation and the farmer, and other obstacles which are external and which are linked to institutional factors. The following Table 3 illustrates the variables which will be introduced into the model and which represent all the obstacles in question.

Description of the variable	Code of the variable	Nature of the variable
Adoption of RFD	ADOPENGRAIS	Boolean (1: Yes; 0: No)
Obstacles related to technology		
Purchase price of fertilizers in MAD/q	COST	Quantitative
The problem of commercialization	Rejection due to lack of data	
Availability of fertilizers at the right time	TECH_DISPONIBILITE	Boolean (1: Yes; 0: No)

Source: Own processing

Table 3: The variables of the Probit model. (To be continued).

Description of the variable	Code of the variable	Nature of the variable
Internal obstacles linked to the farm and the farmer		
The age of the farmer in years	AGE	Quantitative
Work rate on the farm in %	PERC_TOTAL_WORK_FARM	Quantitative
size in ha	FARM_SIZE	Quantitative
Gender	GENDER	Boolean (1: Yes; 0: No)
Farming experience	Rejection due to multi-collinearity	
The level of education in years of schooling	EDU	Quantitative
Membership of a cooperative	MEMBER_COOPERATIVE	Boolean (1: Yes; 0: No)
The orientation of the farm's production	PROD_SEED_MARKET	Boolean (1: market; 0: Self-consumption)
The type of land	TYPE_FONCIER	Boolean (1: Individual ownership; 0: rented or in association)
External obstacles linked to institutional factors		
Political incentives	GOV_INCITATION	Boolean (1: Yes; 0: No)
Access to credit	CREDIT_EASY	Boolean (1: Yes; 0: No)
Proximity to market in Km	DIST_MARKET	Quantitative
Participation in field days	FIELD_DAY	Boolean (1: Yes; 0: No)
Visit by extension agents	VISIT_EXTENSION	Boolean (1: Yes; 0: No)

Source: Own processing

Table 3: The variables of the Probit model. (Continuation).

Results and discussion

Descriptive statistics

Descriptive statistics of the variables, carried out by R software, are presented in Table 4 according to the decision to adopt agricultural technology. Results revealed that among the 297 farmers surveyed, only 18.18% (n=54) adopted the recommended fertilizer doses. The average age of adopters is 44 years against 51 years for non-adopters. These adopters farmers are characterized by a level of schooling that is close to 8 years, exceeding farmers who do not adopt the RFD by more than 5 years of schooling. The difference in terms of age and years of education is significant at the 1% level according to the results of the Student test that we carried out.

Our results indicate that 57.5% (31) of the adopters produce cereals for marketing purposes, while only 29.22% (71) of the non-adopters go to market their final products. Moreover, the descriptive statistics that we established showed that there is no great difference between the two groups of farmers concerning the nature of land ownership. About 70% of the land is 'individual property'. On the other hand, adopters own slightly larger farms than non-adopters (18.27 hectares (Ha) among adopters versus 15.17 Ha among non-adopters). This difference is not too significant because the standard deviation is high in both groups of farmers. In addition, farmers in both groups spend between 87% and 91% of their working time on their farms.

The results indicated that 46.30% (25) of adopters attended a trial and demonstration day on new technologies as part of a research project, while only 23.05% (56) of non-adopters did so. Another result that seems interesting is related to the availability of technology. The results show that more than 80% (259) of respondents declared that fertilizers are available at various points of sale. In addition, 29.63% (16) of adopters received a government incentive for the adoption of new agricultural technologies including the RFD, on the other hand, only 11% (27) of non-adopters declared having received it. Moreover, statistics indicate that about 52% (28) of farmers who adopted RFD reported being visited at least once by an extension agent, yet only 13% (33) of non-adopters received such a visit. Both differences are statistically significant at the 1% level.

Furthermore, reading these results leads us to focus on the question of social groups in peasant communities. The results indicated that 22.22% (12) of adopters are members of an agricultural cooperative or association. Whereas, only 9% (23)

	mean/ frequency		Significance	
	Adopters (n = 54)	Non-adopters (n = 243)	Student	Khi2
Adopengrais	18.18	81.82		
fertilizer_quantity (kg)	149.26	204.81	30.93***	
age (years)	44.02	50.71	3.73***	
genre (1= male)	98.15	100.00		4.51**
education (years)	8.05	5.23	-3.98***	
prod_seed_market (1= yes)	57.42	29.22		15.57***
type_foncier (1= (individual propriety)	68.52	70.78		0.11
field_day (1= yes)	46.30	23.05		12.04**
tech_disponibilite (1= yes)	81.48	88.48		1.94
gov_incitation (1= yes)	29.63	11.11		12.24***
visit_extension (1= yes)	51.85	13.58		39.65***
member_cooperative (1= yes)	22.22	9.47		6.91***
credit_easy (1= yes)	27.78	6.17		22.71***
dist_market (km)	5.10	7.81	3.43**	
farm_size (ha)	18.27	15.17	-0.74	
perc_total_work_farm (%)	91.85	87.721	-1.45	
primary_income (1= agri)	87.04	92.59		1.77
cost (mad/100kg)	279.20	275.278	0.48	

Note: Signif. codes: 0 '***', 0.001 '**', 0.01 '*', 0.05 '.', 0.1 ' ' 1
Source: Own calculation

Table 4: Descriptive statistics.

of non-adopters integrate such an organizational structure. This difference is statistically significant. Additionally, our estimates indicate that 27.78% (15) of adopters have easy access to bank credit, compared to only 6% (15) of non-adopters. A difference is also significant at the 1% level according to the Khi2 test.

Model results and discussion

The results obtained, by the binary Probit model, affirm that most of the variables used in the model had the expected signs. The model developed has a high explanatory power (Hu et al., 2006), as indicated by McFadden's Pseudo R-squared (R^2=0.38). The Wald statistic indicates that the model has significant explanatory power (X2= 106.3, P(> X2) = 1.1e-16). The final model retained in this study will not take into account the variables: gender, type of land, availability of technology, and farm size due to the presence of multicollinearity. Thus, our final model is presented in the Table 5.

Variables	Coefficients		Marginals	
	Value	SE	AME	SE
Age	-0.02**	0.009	-0.004	0.002
Edu	0.06**	0.023	0.11	0.005
prod_seed_market	0.39.	0.231	0.068	0.040
field_day	0.73**	0.236	0.127	0.039
gov_incitation	0.68*	0.292	0.118	0.050
visit_extension	0.70**	0.249	0.121	0.041
member_cooperative	0.29	0.316	0.051	0.054
credit_easy	1.00**	0.354	0.173	0.060
dist_market	-0.06*	0.027	-0.011	0.005
perc_total_work_farm	0.008	0.006	0.001	0.001
primary_income	-0.71.	0.381	-0.123	0.065
Cost	-0.001	0.003	0.0002	0.005
Constant	-0.37	1.180		

Note: Signif. codes: 0 '***', 0.001 '**', 0.01 '*', 0.05 '.', 0.1 ' ' 1 / SE = Standard error
Source: Own calculations

Table 5: The Probit model results.

The results provided by the Probit model, carried out by R software, indicate that the age of farmers has a negative and significant impact at the level

of 1% on the decision to adopt the RFD. Thus, the more the age of a farmer increases, the more his probability of adopting the RFD decreases. This means that young farmers tend to use new technologies in the service of agricultural activity, and older farmers are less adept at new agricultural technologies. Also, the calculation of the marginal effects shows that increasing the age of the farmer by one year will reduce the probability of adopting the technology in question by 0.4%. These results are consistent with those of Irungu et al. (2015) that young people are technologically receptive compared to older people. These results also agree with those of Kalantari-Dahaghi (2010) who showed that young farmers are more receptive to accepting new technologies than older farmers (El Intidami and Benamar, 2020). Other studies, such as that of Roussy et al. (2015), confirm our result and indicate that age is a brake on the adoption of agricultural innovation.

The model indicates that the level of education of the farmer influences positively and significantly, at the level of 1%, the decision to adopt the RFD. This means that a low level of literacy is a real obstacle to the adoption of RFD. One less year of schooling will result in a 1.1% probability of refusing the new technology. This result agrees with those of Hadjimanolis (1999), the latter explains that the major obstacles to innovation are linked to the education system and the skilled labor force (Segarra-Blasco et al., 2008). Thus, our result shows how the level of literacy is an important human capital that influences the adoption of technologies, especially among farmers in rural areas.

The rejection of agricultural technology by farmers in the Casablanca-Settat region is also explained by the orientation of production. Indeed, smallholder farmers who produce cereals only to meet their consumption needs tend not to adopt RFD technology. Thus, if a farmer switches from marketing as the main orientation of his cereal production to an orientation towards self-consumption, he is more likely to refuse the adoption of the RFD technology, with a probability of 6.8%. This result agrees with that of Tene et al. (2013). In this sense, Lefranc (2008) indicates that the real obstacle that hinders the adoption of new agricultural technologies lies in the difficulties encountered at the level of marketing.

Also, the results of our model revealed that financing is a barrier that hinders the adoption of new agricultural technologies. Indeed, the credit easy variable has a negative and significant impact on the decision not to adopt the RFD. Also, the inaccessibility to bank financing reduces the chances of adopting the technology in question by 17.3%. Our result agrees with those obtained by several researchers, in particular with de Janvry et al. (2015) for whom liquidity constraints constitute a major obstacle to the acquisition of agricultural technology. Bellon-Maurel and Huyghe (2016) consider that funding leads actors to act at different levels of the innovation process. It is a factor that facilitates the process of agricultural technology transfer and therefore innovation in general. For his part, Richefort (2008) stipulates that financial constraint is decisive in the choice of agricultural technology. On the other hand, our result is in disagreement with that of (Karlan et al., 2014) who explain that as soon as the farmer is insured, he would be able to find the financial means to acquire the technology.

Moreover, our model indicates that the distance from the nearest market has a significant impact on the rejection of new technology. Indeed, the more the distance between the farm and the market increases, the more the farmer tends to refuse the RFD technology. Our estimates show that an extra mile between the firm and the market will result in a 1.1% probability of rejection.

The results of our modeling indicate that farmers who consider agricultural activity as their main source of income are more likely not to adopt RFD. Moreover, the calculation of marginal effects indicates that switching to agriculture as the main activity will reduce the probability of adopting the RFD by 12.3%. The results obtained, which are statistically significant at the 10% level, agree with those of Amir et al. (2016) and Richefort and Fusillier (2010).

The low rate of adoption of the RFD is also explained, according to the model, by the absence of government incentives. Our results revealed that at the 5% level, this lack of political incentives negatively affects the adoption of the new RFD technology by 11.8%. This agrees with the results of the study that was conducted by Richefort (2008). The latter explains that government incentives can be in the form of subsidized pricing as they can take the form of an incentive for technical change through investment aid, advice, and guidance on the implementation of the technology in question (Richefort, 2008). It should be noted that, in our case, we mean by government

incentives, the satisfaction of farmers with the efforts made by government authorities in terms of communication, advice, guidance, and encouragement for farmers to adopt new production technologies in general and the RFD in particular.

Finally, the result of the Probit regression indicates that the farmers who did not attend the demonstration days and/or who were not visited by the extension agents do not adopt the RFD technology. Moreover, at the 1% threshold, the probability of not adopting the technology in question decreases by more than 12% among the farmers in question. This indicates that the lack or insufficiency of reliable information concerning the RFD constitutes a major obstacle to its adoption. This result shows how essential advisory and extension agents are in the process of agricultural technology transfer in general and in the adoption of new technologies in particular. The latter are known for their role as facilitators of access to agricultural information (El Boukhary and Benamar, 2020). The results obtained agree with those of the studies cited above. Studies on the adoption of new technologies consider that contact with agricultural advisory and extension agents reduces the uncertainty expressed by farmers about the performance of these agricultural innovations. They also serve as intermediaries between the field and the laboratory (Tene et al., 2013).

Conclusion

In this article, we have tried to determine the obstacles that hinder the adoption of RFD technology for cereal producers in the Casablanca-Settat region. Data was collected from 297 farmers. The Probit model developed for this purpose showed the impact of farmer-related barriers such as age and level of studies, others linked to the farm such as the orientation of production and the distance from the market, others of an institutional nature such as access to bank credit and government incentives and others related to access to information on new agricultural technology such as contact with agricultural advisory and extension agents and participation in field days. The latter are the main obstacles that hinder the adoption of the RFD according to the model. This result emphasizes the crucial role that access to information plays in the dissemination and adoption of new agricultural production technologies. This information is generally provided by researchers from agricultural research centers, agricultural researchers within the framework of research programs, and agricultural advisory and extension agents.

However, the current situation indicates that the services offered within the framework of agricultural advice suffer from several constraints, in particular those related to financing (El Bilali et al., 2013). Extension agents are limited: an extension agent covers an average of 24,000 hectares (ha) of land and reaches 1,930 farmers (El Bilali et al., 2013). This indicates that extension agents are limited in serving farmers, hence the need to adopt technological innovation even in advisory and extension work such as the use of digital platforms, the creation of phone applications for providing mobile-based extension services, setting up advertising campaigns in radio and television channels to promote these new technologies and disseminate them to a large community of farmers. This could be accomplished through the exchange of experiences with the European countries, especially in terms of digitalization, the use of new information technologies and forecasting based on the economic model used by the European commission. The latter suggests adopting amended fertilizer regulation which is possible by harmonizing definitions and quality standards for all types of fertilizing products that can be traded across the European Union.

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Increasing or Decreasing Scale? The Pros and Cons of Farm Size for Financial Sustainability

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Abstract

The article focuses on the question of optimal farm size in the context of contemporary agricultural challenges such as rapid population growth, climate change, and limited natural resources. The analysis shows that farm economic size can have a significant impact on financial performance indicators including productivity, profitability, liquidity, solvency, and sustainability. The article provides a detailed overview of the pros and cons of different farm economic sizes and their impact on financial sustainability, drawing on academic literature, available data, and statistical methods. The results indicate that larger farms have lower factor productivity but higher solvency. Smaller farms on the other hand have higher profitability and productivity. Medium-sized farms are characterized by high liquidity and financial autonomy.

Keywords

Economic size, farms, financial sustainability .

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Introduction

In the contemporary context of increasing demands on agriculture and ensuring food security, the task of achieving efficient and sustainable production arises. This task necessitates comprehensive debates and research. In light of these challenges, the question of the optimal scale for farms emerges, attracting attention and prompting profound reflections on the interconnection between farm size and financial sustainability.

Modern agricultural challenges – such as rapid population growth, climate change, and limited natural resources – require new approaches to food production. In this new context, farm size emerges as a key factor influencing both the efficiency of production processes and the sustainability of agricultural systems. Striving for an optimal farm size represents a delicate balance between economic benefits and environmental protection, while the social aspect of agriculture must not be neglected either.

In academic literature and in the practice of agricultural entrepreneurs, a clear duality in approaches to farm size stands out. Some strive for large-scale expansion by investing in new technologies and methods to increase productivity and dominate the market. Others focus on sustainability and responsible resource-efficient production, preferring smaller scales and emphasizing measures like diversification, organic farming, or biodiversity restoration. These diverse approaches necessitate discussions regarding the impact of farm size on business efficiency, income, competitiveness, and sustainability.

In this context, the purpose of this article is to provide a thorough and analytical overview of the pros and cons of different economic sizes of farms, focusing on their financial sustainability. Through analysis of academic literature, available data, and various statistical methods, the article establishes the basis for more detailed research on the impact of farm size on several key factors, including productivity, profitability, liquidity, solvency, and sustainability of agricultural activities.

By conducting this analysis, the article seeks to contribute to resolving this important issue by providing a new perspective and additional dimensions to the debate. The expected outcome of the study is to create a foundation for a detailed comparison between different approaches to farm size and their impact on financial sustainability.

Such a comparison can serve as a valuable tool for informed decision-making by agricultural entrepreneurs, investors, policymakers, and all stakeholders whose activities are related to the development of agriculture.

Farm size can be a key factor when it comes to financial sustainability. However, there is no consensus in the literature on whether larger farms are more financially sustainable or vice versa.

The concept of economies of scale is related to the idea that increasing production will lead to decreasing costs of producing a unit of output (Teece, 1980). Multiple studies (Duffy, 2009; Kim, 2012; Roest, 2018; Bojnec and Fertő, 2021) have indicated that larger farms can achieve economies of scale, meaning lower average costs per unit of output. Błażejczyk-Majka et al. (2012) examined the influence of farm size in EU countries and concluded that the highest efficiency is achieved by the largest farms, though this is more pronounced in economically more developed countries.

Large farmers are more likely to adopt innovative methods, invest more resources and efforts in acquiring agricultural knowledge, and focus more on production methods rather than processing technologies (Mignouna, 2011; Hu, 2022). According to Bielik and Rajčániová (2004), farm size has a significant influence on the efficiency of land use as a key production factor.

Ren et al. (2019) found that increasing farm size has a positive impact on farmers' net profits, as well as on economic, technical and labor efficiency. At the same time, increasing farm size was associated with a statistically significant decrease in the use of fertilizers and pesticides per hectare, demonstrating clear environmental benefits. The net profit margin of farms increases with economic size, but it is unclear how long this increase continues (Celik and Emre, 2014).

Large farms have greater resources and capacity to introduce new technologies like automation, remote monitoring, precision agriculture, using drones for crop monitoring, and other such innovations. These can improve productivity, reduce costs, and increase revenues (Čechura et al., 2022).

Some studies (Henderson, 2014; Helfand et al., 2015; Sheng et al., 2019; Muyanga and Jayne, 2019) find a negative relationship between farm size and productivity in developing country agriculture, which they mainly attribute to imperfections in labor markets. Assunção and Ghatak (2003) relate the inverse farm size-productivity relationship to differences in farmers' abilities.

Rada and Fuglie (2019) examined the relationship between farm size and productivity across several countries (poor and rich) and found that in economically lagging countries, smaller farms have a productivity advantage. However, with economic and market growth this advantage diminishes, shifting to constant and subsequently increasing returns to size.

Bojnec and Latruffe (2013) found that small farms are less technically efficient but more allocatively efficient and profitable. They state that medium-sized farms accumulate all the disadvantages in terms of productivity: they are too small to be economically efficient but too large to be profitable. According to Galluzzo (2022), farm economic size does not constrain technical efficiency. In fact, small farms are technically more efficient than large farms in terms of economic size. This suggests a more efficient resource allocation in small farms.

Larger farms may be more vulnerable in crises because they have larger volumes of fixed costs. A study found that small farms cope better in economic downturn phases (Czyzewski and Majchrzak, 2017).

Small farms are often more flexible and can respond quickly to changes in the market environment (Akimowicz et al., 2013; Brenes-Muñoz et al., 2016). Bakucs et al. (2013) examined the relationship between farm size and growth in France, Hungary and Slovenia, providing evidence that smaller farms grew faster than larger ones over the studied period (2001-2008) in all three countries.

Farms of relatively modest size may achieve much of the potential cost savings related to size. Hall and Le Veen, (1978), examining different sources of efficiency, argue that factors other than labor-saving technology can make important contributions to economic efficiency. Small farms have advantages over medium-sized ones regarding access to land, natural resources, human resources, raw materials, and equipment. However, many competitiveness indicators for small farms are below industry standards (Bachev, 2023).

Small farms cannot afford significant investments. They can compensate through improvements in scale and technical efficiencies. This may mean optimizing the use of proper tillage techniques, better water management, or improved pest and disease control. Using these techniques can help small farmers offset the lack of new technologies or large scale.

Small farms protect the rural environment from the socio-economic marginalization of rural areas and reduce rural depopulation (Galluzzo, 2016). Small farms developing their own agribusiness also develop their rural areas and territorial communities, partially solving the unemployment problem (Manolova end Penov, 2014; Gorikhovskyi, 2017). Their long-term viability may be critical for the global competitiveness of European agriculture (Kryszak et al., 2021).

Small farms sometimes find it difficult to access large markets or price premiums and may encounter problems trying to obtain credits (Buckwell and Davidova, 1993; Kusek et al., 2017). Some researchers (Collier and Dercon, 2014; Adamopoulos and Restuccia, 2014; Otsuka et al., 2016) suggest that the presence of numerous smallholdings may hamper agricultural growth and competitiveness in the long run.

The main research questions that this study focuses on are:

1. To what extent does the economic size of agricultural holdings correlate with key financial indicators such as profitability, productivity, liquidity and solvency?
2. How does the financial efficiency of agricultural holdings vary depending on their economic size? In which economic size classes do holdings have the highest or lowest profitability, liquidity and solvency?
3. What is the relationship between the scale of the agricultural holding and the risk of financial instability? How does the scale of the holding affect its resilience to external economic and financial shocks?

The aim of this study is to identify whether and how the economic size of agricultural holdings correlates with their financial sustainability, stability and ability to cope with financial challenges. Based on the established correlations and dependencies, the optimal farm sizes for achieving maximum financial efficiency and sustainability will be determined.

Materials and methods

A literature review is conducted, focusing on publications from highly-regarded, peer-reviewed journals and extracted from academic databases such as Scopus and Web of Science, to provide comprehensive information on the research topic. Key insights from the literature facilitate understanding of the discussed issue.

The study utilises annual financial and production data at the individual farm level from the Agricultural Accountancy Data Network (AADN) of the Ministry of Agriculture and Food of Bulgaria for the period 2014-2020. The AADN data are selected due to their representativeness for the sector, granularity at individual farm level, and availability of data for a series of years. The annual data allow tracing the dynamics in financial indicators for different farm categories. Six categories of economic size of holdings are analysed: below 8 thousand euros, 8-25 thousand euros, 25-50 thousand euros, 50-100 thousand euros, 100-500 thousand euros and above 500 thousand euros. The economic size is measured in euros and represents the total standard output. The annual representative samples of the AADN vary from 2,229 to 2,272 number of agricultural holdings for the individual years.

The study analyses the relationship between the economic size of holdings and their financial indicators through three methodologies: correlation analysis, multinomial logistic regression and decision tree modelling. The combination of linear, categorical and non-linear modelling provides in-depth and multifaceted insights into the research question. The consistent application of multiple methods also validates and cross-verifies the findings from different statistical perspectives.

The financial indicators examined in this study are key metrics that help assess the financial health of the farm:

1. Current Ratio: This ratio measures the farm's ability to cover its short-term liabilities with available assets. It is important for ensuring solvency in case of unexpected expenses or difficulties;
2. Financial Autonomy Ratio (Equity Ratio): This indicator shows how much of the farm's assets are financed through equity. A higher ratio indicates less reliance on external debt and greater stability;
3. Debt Ratio (Leverage): This ratio measures the share of debt in the farm's total financing structure. Higher leverage can increase financial risk due to larger liabilities to creditors.
4. Profitability Ratio (Return on Assets): This metric reflects the farm's ability to generate profits relative to invested capital. Higher profitability indicates more efficient use of resources;

5. Factor Productivity Ratio: This ratio compares the farm's output to the sum of labour and capital costs. A higher ratio means better utilisation of resources;
6. Solvency Ratio: This ratio assesses the farm's ability to meet its current obligations (e.g. payments to suppliers) with its current assets. A higher ratio indicates financial stability.

The correlation analysis determined the linear relationship between farm size and different financial indicators using the Pearson coefficient. Analysis of variance (ANOVA) is applied to study differences in financial indicators according to farm size.

The multinomial logistic regression investigates the relationship between financial indicators and the economic size of holdings, categorised into six groups. The regression model identifies statistically significant differences between financial indicators and farm size categories, providing logarithmic (or log-odds) coefficients for interpretation.

The decision tree modelling analyses whether financial indicators can predict farm size, regardless of time characteristics. Using the Classification and Regression Trees (CRT) method, we are able to build a tree-based structure reflecting the interactions between financial indicators and their influence on agricultural producers. Each node in the tree is a decision based on a given indicator, while the leaves represent the producer's category. The use of cross-validation enhances the reliability of the model, ensuring it is not overfitted and provides good generalisation. After applying CRT, key indicators that most effectively predict farm size can be identified. The visual representation of the tree allows observing the hierarchy of interactions and the significance of each variable.

Results and discussion

Correlation analysis and ANOVA of financial ratios by farm size

A correlation analysis is conducted to assess the relationship between farm size and key financial indicators. The financial indicators considered are current ratio, financial ratio, debt ratio, return on assets, factor productivity ratio, and solvency ratio. Farm size is categorised into 6 groups based on annual revenue. Pearson correlation coefficients are computed between farm size and each financial indicator over a 7-year period from 2014-2020 (Table 1).

The correlation analysis reveals weak to moderate correlations between farm size and financial ratios. The strongest correlation is a moderate negative correlation between farm size and factor productivity ratio ($r = -0.42$, $p < 0.05$), indicating that larger farms tend to have lower productivity coefficients. Smaller negative correlations are observed between farm size and return on assets ($r = -0.28$, $p < 0.05$) and debt ratio ($r = -0.21$, $p < 0.05$). No statistically significant correlations are found between the economic size of the agricultural holding and current liquidity, financial autonomy or solvency.

An analysis of variance (ANOVA) is also conducted to compare financial indicators across farm size categories. ANOVA finds significant differences between size categories for factor productivity ratio ($F = 9.62$, $p < 0.001$), return on assets ($F = 4.17$, $p < 0.01$) and debt ratio ($F = 3.24$, $p < 0.05$). Post-hoc Tukey tests reveal that agricultural holdings with an economic size over 500 thousand euros have significantly lower productivity coefficients than all other size categories. As for return on assets, medium-sized farms (25-100 thousand euros) have lower profitability than smaller farms. The results show that financial performance on some metrics varies depending on farm size.

Financial indicator	Correlation with farm size	ANOVA results	Significant difference between groups
Current ratio	r = -0.13, p = 0.24	F = 1.28, p = 0.27	No
Financial autonomy ratio	r = -0.19, p = 0.12	F = 2.05, p = 0.07	No
Debt ratio	r = -0.21, p < 0.05	F = 3.24, p < 0.05	Yes
Profitability ratio	r = -0.28, p < 0.05	F = 4.17, p < 0.01	Yes
Factor productivity ratio	r = -0.42, p < 0.01	F = 9.62, p < 0.001	Yes
Solvency ratio	r = -0.16, p = 0.18	F = 1.47, p = 0.20	No

Source: Own calculations based on Agricultural Accounting Information System data

Table 1: Correlation and ANOVA results for relationship between financial indicators and farm size.

Multinomial logistic regression to assess relationship between financial ratios and farm economic size

Multinomial logistic regression is applied to analyse the relationship between financial ratios and farm economic size over the period 2014-2020. The dependent variable, representing farm economic size, has 6 categories: up to 8 thousand euros; 8 to 25 thousand euros; 25 to 50 thousand euros; 50 to 100 thousand euros; 100 to 500 thousand euros; and over 500 thousand euros. The independent variables include the ratios for current liquidity, financial autonomy, debt, profitability, factor productivity, and solvency. The category of the smallest agricultural producers – up to 8 thousand euros – is chosen as the reference.

The regression results (Table 2) can be interpreted as follows:

The Intercept for agricultural holdings with an economic size of 50-100 thousand euros is 1.52. Applying the exponential function (e^x) gives us exp (1.52) ≈ 4.57. This is the odds ratio between holdings of size 50-100 thousand euros and those up to 8 thousand euros with other variables fixed or controlled. In other words, with other variables held constant, holdings in the "50-100 thousand euros" category have 4.57 times higher odds of being in that category compared to the base category of "up to 8 thousand euros".

The debt ratio coefficient for agricultural holdings of size 50-100 thousand euros is 0.27. Applying the exponential function gives us exp (0.27) ≈ 1.31. This means that for every one unit increase in the debt ratio, the odds of a holding belonging to the "50-100 thousand euros" category are 1.31 times greater compared to the base category, with all other variables held constant. This suggests larger holdings are more likely to have higher debt.

The return on assets coefficient for agricultural holdings of size 50-100 thousand euros is -0.91. The applied exponential function gives exp (-0.91) ≈ 0.40. This indicates that for every one unit increase in profitability, the odds of a holding belonging to the "50-100 thousand euros" category are 0.40 times (or 60% lower) relative to the base category, with other variables held constant. This may imply larger holdings can have lower profitability compared to smaller ones.

The multinomial regression approach provides insight into the variations in the financial profile of agricultural enterprises of different sizes (Table 3).

Farm size category	Intercept	Current ratio	Financial autonomy ratio	Debt ratio	Profitability ratio	Factor productivity ratio	Solvency ratio
up 8 thousand euros	0	0	0	0	0	0	0
8-25 thousand euros	0.34	-0.04	-0.01	-0.03	0.02	0.12	0.34
25-50 thousand euros	0.74	-0.02	0.01	0.11	-0.06	-0.19	0.74
50-100 thousand euros	1.52	-0.16	-0.07	0.27	-0.32	-0.02	1.52
100-500 thousand euros	2.08	-0.20	-0.11	0.39	-0.73	-0.20	2.08
over 500 thousand euros	2.73	-0.23	-0.13	0.43	-0.91	-0.23	2.73

Source: Own calculations based on Agricultural Accounting Information System data

Table 2: Multinomial logistic regression coefficients for predicting farm size category based on financial indicators.

Farm Size Category	Key Financial Ratios	Interpretation
up 8 thousand euros (reference)	-	-
8-25 thousand euros	Lower Factor Productivity Ratio: Higher Solvency Ratio	Smaller farms have a slightly lower productivity ratio and a higher solvency ratio.
25-50 thousand euros	Higher Debt Ratio; Higher Profitability Ratio; Lower Factor Productivity Ratio; Lower Solvency Ratio	Mid-sized farms have a slightly higher debt ratio, a higher profitability ratio, a slightly lower productivity ratio, and a slightly lower solvency ratio.
50-100 thousand euros	Higher Debt Ratio; Higher Profitability Ratio; Lower Factor Productivity Ratio; Lower Equity Ratio	Larger farms have a higher debt ratio, a higher profitability ratio, a lower productivity ratio, and a lower equity ratio.
100-500 thousand euros	Higher Debt Ratio; Higher Profitability Ratio; Lower Factor Productivity Ratio; Lower Equity Ratio	The largest farms have a higher debt ratio, a higher profitability ratio, a lower productivity ratio, and a lower equity ratio.
over 500 thousand euros	Higher Debt Ratio: Higher Profitability Ratio; Lower Factor Productivity Ratio; Lower Equity Ratio; Lower Solvency Ratio	The very largest farms have the highest debt ratio, the highest profitability ratio, the lowest productivity ratio, the lowest equity ratio, and the lowest solvency ratio.

Source: Own calculations based on Agricultural Accounting Information System data

Table 3. Key financial characteristics by farm size category.

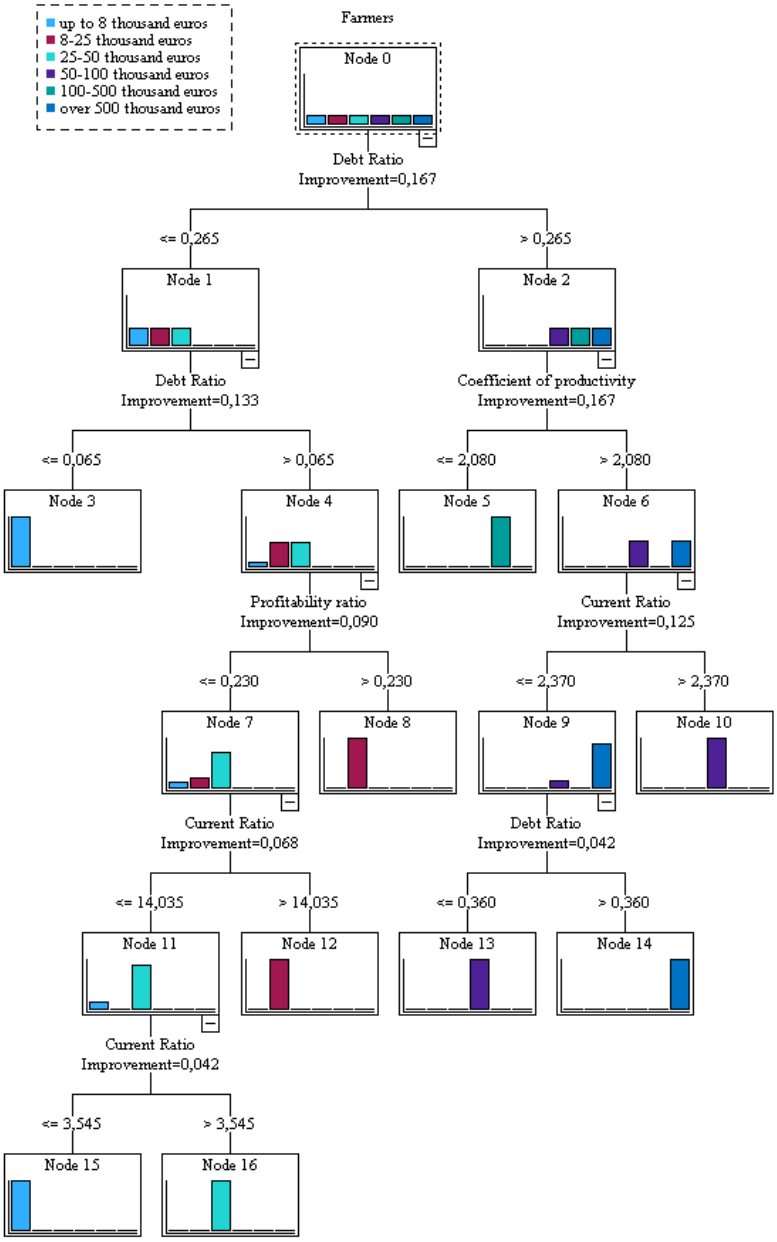
Decision tree modeling to link farm economic size and financial ratios

This study utilises decision tree modelling to categorise agricultural producers based solely on financial ratios, without relying on time characteristics like year. The goal is to understand how financial health predicts farm size.

The dataset contains 6 categories of agricultural producers divided by economic size, and 7 financial ratios related to liquidity, leverage, profitability, productivity, and solvency. Non-financial characteristics like year are excluded to avoid capturing spurious time trends.

The decision tree classifier recursively splits the data by selecting optimal splitting points using Gini impurity to maximise homogeneity in each node (Figure 1).

Specifically, the tree first splits the sample based on the debt-to-assets ratio, indicating leverage is a key differentiator between small and large holdings. Agricultural holdings with an economic size up to 50 thousand euros are distinguished



Source: Own calculations based on Agricultural Accounting Information System data

Figure 1. Decision tree model for linking farm economic size and financial ratios.

by lower leverage than those with economic size over 50 thousand euros. The smallest holdings up to 8 thousand euros economic size have the lowest leverage compared to all other groups, meaning they operate mostly with equity. Agricultural holdings of 8 to 25 thousand euros economic size are distinguished by higher profitability than those over 25 thousand euros economic size, meaning they utilise their resources more efficiently to generate profits. This group of holdings also has the highest liquidity among holdings up to 50 thousand euros economic size, showing they have more short-term assets to meet short-term obligations. Agricultural holdings up to 8 thousand euros economic size have the lowest liquidity.

Among agricultural holdings over 100 thousand euros economic size, those of 100 to 500 thousand euros economic size have the lowest factor productivity. Holdings of 50 to 100 thousand euros economic size have the highest liquidity, while the largest over 500 thousand euros have the lowest liquidity, indicating financial instability risk.

Agricultural holdings of 100 to 500 thousand euros economic size have lower liquidity and lower profitability compared to smaller agricultural holdings.

The largest holdings, over 500 thousand euros economic size, exhibit lower liquidity and profitability but higher solvency. This suggests larger capital reserves and assets but weaker returns.

In summary, this study shows that farm size can be predicted from just a few key financial ratios, without relying on time characteristics. The intuitive decision tree model provides interpretable classification rules that highlight the importance of financial health. The analysis also reveals specific financial traits that distinguish small, medium and large agricultural operations.

A limitation of the study is sample size. Further validation on larger datasets is needed to assess real-world predictive accuracy.

In light of the conducted literature review and in the context of the current study, our findings are confirmed by the existing scientific literature, which adds further validity to our observations.

The observation of the existence of an optimal farm size in terms of efficiency coincides with the conclusions of Rao and Chotigeat (1981), Lamb (2003) and Deininger and Byerlee (2011), who also identify a threshold of diminishing returns when increasing scale. These authors emphasise that after reaching a certain size, further expansion of the holding can lead to reduced marginal productivity.

The finding of differences in indicators depending on farm size is consistent with the results from the studies of Rada and Fuglie (2019) and Kryszak (2021), which highlight the advantages of small farms, especially in less developed economies, particularly in the context of their adaptability and resilience.

The observation of the higher profitability of small holdings due to more efficient use of limited resources is in line with the conclusions of Bojnec and Latruffe (2013) and Koteva (2019), who also note the benefits of small farms in this regard.

The hypothesis of the balance between economies of scale and flexibility for medium-sized farms corresponds with the observations made by Filho and Vian (2016), Jayne et al. (2019) and Galluzzo (2022), who find that medium-sized farms can achieve faster growth thanks to this balance.

Based on these matches, our study further supports existing theories and observations in the field of agricultural economics, while providing a unique perspective on Bulgarian conditions.

Conclusion

The analysis highlights the presence of a positive correlation between the economic size of holdings and their financial results. However, this relationship is not linear and there is an optimal size above which efficiency starts to decrease due to increasing organisational complexity. Factors such as access to financing, technologies and market power also have an influence.

Agricultural holdings of different economic sizes demonstrate statistically significant differences in some of their financial metrics. This underscores the fact that size can play a pivotal role in certain aspects of financial management and performance.

Larger holdings tend to have lower factor productivity, which may be due to the complex interaction of several factors, including increasing organisational complexity, limited applicable capacity of technologies, and diminishing economies of scale. However, they continue to be the most solvent compared to other farm categories. Larger holdings have easier access to bank and other financing sources due to the availability of more assets as collateral. This allows them to invest in upgrading and growth. On the other hand, these holdings also have a greater dependence

on debt financing, which may expose them to greater risk in case of financial shocks.

Smaller economic size agricultural holdings have higher profitability compared to medium-sized ones. This may be due to more efficient use of resources and lower operating costs. They can maximise the benefits from their limited resources through intensive and innovative practices, while maintaining close control over the production process. Smaller holdings often demonstrate greater flexibility and ability to adapt quickly to changing market conditions or climate changes, which can increase their efficiency and allow them to take advantage of market niches. Although larger holdings may have greater access to capital for investing in technologies, smaller holdings can also use innovative technologies to increase efficiency, especially those suited to small scales and with low operating costs. The personal commitment of owners and their participation in the day-to-day running of small holdings can lead to more careful management, high motivation and efficient decision-making, further enhancing efficiency.

Medium economic size holdings demonstrate high liquidity and financial independence thanks to the optimal balance between achieving economies of scale and maintaining flexible management. This balance allows them to effectively implement techniques to increase productivity without leading to excessive increase in organisational complexity. Moreover, the average size of their holdings provides better access to external financing compared to smaller ones due to the availability of more assets as collateral. Additional investments enable them accelerated growth and technological upgrade. Another advantage is the possibility to integrate activities such as transport, logistics and processing. This increases the added value nd profitability of medium-sized holdings. Due to the larger volume of output, these holdings also have stronger negotiating positions for purchase prices with traders and processors. This also leads to revenue optimisation.

While economic size strongly influences agricultural holdings' financial metrics, other factors like management skills, geographic location, technologies, and crops grown also play a decisive role in holdings' financial stability.

What is the optimal economic size for an agricultural holding? There is no unambiguous answer to this question. The optimal farm size balances land, labour, and capital costs against market opportunities and income potential. Optimal size can vary significantly depending on crop, location, management skills, and owner strategies. This makes the question of the "optimal" size very case-specific.

In light of the findings, further research into additional factors influencing agricultural holdings' financial sustainability is warranted. This will aid in understanding the dynamics of these relationships and developing effective strategies to optimise resources and enhance holdings' financial stability.

The current study leads to specific policy recommendations for supporting the sustainability and economic growth of agricultural holdings. The results show that the optimal size of holdings depends on various factors like type of crops grown, available technologies and capacity of farmers. Hence, policies should not focus solely on promoting large holdings, but rather provide flexible support to farmers to develop a sustainable business model according to their needs. Access to finance should be facilitated through specialised credit lines for agricultural producers with suitable interest rates and collateral requirements. This will reduce the risk of over-indebtedness in the industry. Targeted training and advisory services need to be provided to farmers around proper financial planning and management for sustainable production activity. Improving the financial skills of agricultural producers is key to the growth of their holdings. The digitalisation of agriculture should be encouraged through policies introducing tax reliefs and subsidies for adopting modern technological solutions. This will allow agricultural holdings to enhance their efficiency and balance the challenges of increasing scale.

The implementation of such targeted policies in agriculture will help achieve long-term growth of the agrarian sector, based on the principles of economic efficiency and sustainability.

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Modeling Asymmetric Effects of Exchange Rate Fluctuations on Agricultural Trade Balance: Evidence from Iran and Iraq

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Abstract

The exchange rate plays a crucial role in foreign trade and has asymmetric effects. This study examines the asymmetric effects of exchange rate volatility on the trade balance in the agricultural sector between Iran and Iraq, using the non-linear ARDL model from 1998 to 2020. The results show that Iraq's GDP and oil price fluctuations positively affect the trade balance. In contrast, Iran's GDP and the U.S. economic sanctions against Iran have negative and significant effects on the trade balance of Iran with Iraq in the agriculture sector. The results do not confirm the existence of the J-curve effect in the trade relations between Iran and Iraq, because an increase in the bilateral exchange rate, in both the long-run and short-run, improves the trade balance of Iran with Iraq in the agriculture sector. Furthermore, the positive and negative fluctuations of the bilateral exchange rate have different effects on the trade balance. While the devaluation of the national currency does not cause a downward trend in the short run, the exchange rate policy can improve the trade balance from the beginning.

Keywords

Exchange rate, J-Curve, non-linear GARCH model, non-linear ARDL model.

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Introduction

Iran has experienced significant exchange rate volatility and economic instability in recent years, particularly after the United States imposed economic sanctions from 2011 onwards. Due to the long-standing dependence of the Iranian government on oil exports and the strong impact of world oil price fluctuations on Iran's economy, there has been a shift towards developing non-oil exports. As a result, the Iranian government has placed greater emphasis on agricultural exports as a major component of non-oil exports. In 2020, Iran's exports to Iraq weighed 17.6 million tons. During that year, Iraq accounted for 27% of Iran's total exports, surpassing China as Iran's top export market (IRICA, 2021). To enhance trade relations, it is crucial to establish appropriate trade and exchange rate policies and understand the relationship between the exchange rate and trade balance (Bostan et al., 2018). The real exchange rate of the national currency and its fluctuations determine the country's ability to compete globally by affecting its trade balance. Therefore, governments implement proper exchange rate policies to achieve their long-term and short-term goals. Sometimes, increasing the exchange rate is a policy adopted to improve the trade balance and international competitiveness over the long term. In contrast, it leads to the worsening of the trade balance in the short-run, which is known as the J-curve phenomenon (Thom, 2017). Scholars have shown significant interest in understanding the effect of exchange rate fluctuations on trade balance, and have studied different aspects of this issue. Several research has focused on the J-curve effect, such as Halicioglu (2008), which examined the existence of a bilateral J-curve between Turkey and its 13 trading partners using the ARDL model, but the results did not confirm its existence. Similarly, Akbostanci (2004), Narayan (2006), Shahbaz et al. (2012), and Yazgan and Ozturk (2019) found no evidence of the J-curve effect. Bahmani-Oskooee and Harvey (2010) studied the trade balance between Malaysia and its 14 largest trading partners and demonstrated little evidence to support the J-curve phenomenon, except in a few cases. Some scholars achieved opposite results regarding the J-curve phenomenon based on their approach (Harvey 2018). However,

some of them have recognized the J-curve effect (Fuard et al., 2021; Nguyen et al., 2021; Gurtler, 2019; Bahmani-Oskooee et al., 2018; Wang et al., 2012). Another critical issue in the literature is the asymmetry of exchange rate fluctuations, which is discussed in the context of nonlinear analysis. While some scholars examine the relationship between exchange rates and the trade balance in a symmetric frame, the majority focus on the asymmetric impact of exchange rate fluctuations on the trade balance (Bahmani-Oskooee and Fariditavana, 2014; Bahmani-Oskooee et al., 2016; Bahmani-Oskooee and Aftab, 2018; Nguyen et al., 2021; Hunegnaw and Kim, 2020).

Although many studies have been conducted on the impact of exchange rate fluctuations on the trade balance, the literature review confirms that there has been little attention given to examining the asymmetric effect of the exchange rate of the Iranian Rial to the U.S. dollar on Iran's agricultural trade balance. It is important to note that the exchange rate's asymmetric behavior has significant effects on Iran's agricultural trade balance. Therefore, this study aims to investigate the existence of the J-curve phenomenon and determine the short- and long-run asymmetric effects of the exchange rate on the agricultural trade balance between Iran and Iraq, which is its major agricultural trading partner. Specifically, two primary questions will be addressed: i) What are the asymmetric effects of exchange rate fluctuations on the agriculture trade balance of Iran and Iraq in both the short- and long-run? and ii) Dose the J-curve effect occur in the agricultural trading between these two nations?

Materials and methods

Based on the research background of Bahmani Oskooee and Fariditavana (2016), the trade balance behavior of Iran can be expressed as a reduced form (Equation 1), where the agricultural trade balance equation is a function of the exchange rate, real domestic income and real income of Iran's trading partner countries such as Iraq, and world oil prices as follows:

$$Ln\,TB_t = \beta_0 + \beta_1 Ln\,GDP_{IRN.t} + \beta_2 Ln\,GDP_{IRQ.t} + \\ + \beta_3 Ln\,REX_t + \beta_4\,V_t + \beta_5\,Oil_t + \beta_6\,D_{US} + e_t \quad (1)$$

where TB_t is the trade balance of Iran's agriculture sector with Iraq, $GDP_{IRN.t}$ and $GDP_{IRQ.t}$ are the real GDP of Iran and Iraq, respectively, REX_t is the bilateral real exchange rate, V_t is the bilateral real exchange rate fluctuation, Oil_t is the world crude oil price fluctuation, D_{US} is a dummy variable that implies the economic sanctions imposed by the United States that take the value of zero for the period before 2011, the year of imposing the economic sanctions, and one otherwise, e_t is the error term with $iid\sim(0.\sigma_e^2)$ and ln is the symbol of the natural logarithm.

The gross domestic product (GDP) directly affects the import and export of products, so Iran's GDP and Iraq's GDP are expected to be negative and positive, respectively. Exchange rate fluctuations positively affect the trade balance of the agriculture sector; as the exchange rate increases, the value of the domestic currency decreases, and imports decrease. A similar explanation is valid for changes in oil prices. The real exchange rate of the two countries in Equation (1), calculated indirectly by the exchange rates of Iran (Rial) and Iraq (Dinar) currencies in terms of the U.S. dollar, using the consumer price index (CPI) for Iraq and Iran. For measuring exchange rate and oil price fluctuations in Equation (1), the GARCH family models can be utilized. The GARCH model is the most commonly used structure for many financial time series, with limitations such as negative coefficients or failure to show asymmetric effects. To demonstrate the asymmetric effects, Engel (1990) introduced the first non-linear model, called the simple asymmetric GARCH or SAGARCH model, which has the limitation of non-negative coefficients. To overcome these limitations, Nelson (1991) proposed the Exponential GARCH (EGARCH) model by defining conditional variance in logarithmic form, in which the variance always remains positive. This model can explain that negative shocks lead to a greater conditional variance than positive shocks. The threshold GARCH model, TGARCH, has been proposed by Zakoin (1994) and Glosten et al. (1993), which explains the real effects that have occurred in the past, but their effects appear in the present and may be asymmetric. Overall, this model is expressed as Equation (2):

$$h_t^{1/2} = \omega + \sum_{i=1}^{p} \alpha_i |\varepsilon_{t-i}| + \\ + \sum_{i=1}^{r} \gamma_k |\varepsilon_{t-k}|\ (\varepsilon_{t-k} > 0) + \\ + \sum_{j=1}^{q} \beta_j h_{t-j}^{1/2} + v_t \quad (2)$$

where ε_t is the conditional normal distribution, $N(0.h_t)$, $\omega > 0$, $\alpha_i > 0$ and $\beta_i > 0$ for all i, and γ_i shows

asymmetric effects. If γ is significantly opposite to zero, the effect of the news on fluctuations is asymmetric. In other words, positive (good) and negative (bad) news have asymmetric effects on the exchange rate and/or oil fluctuations. The NGARCH model was proposed by Higgins and Berra (1992), where at conditioned standard deviation, it reaches the power δ and is a function of lags of deviation of conditional standards and shocks with the same power as its mathematical form in Equation (3).

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i (\varepsilon_{t-i} - \gamma_i)^2 + \sum_{j=1}^{p} \beta_j h_{t-1} + v_t \quad (3)$$

Engle's ARCH test was used to detect the presence of the linear ARCH effects in the residual terms of the conditional mean model. In this test, the assumption of conditional variance H_0: $\alpha_1 = \alpha_2 = \cdots = \alpha_q$ is made using the LM statistic with the χ^2 distribution. In addition to the linear ARCH test, the non-linear GARCH test should be carried out. Using the non-linear GARCH test, the null hypothesis of conditional variance can be directly tested against the alternative hypothesis of asymmetric ARCH. Engle and Ng (1993) presented some tests to examine the different effects of positive and negative shocks on conditional variance. Due to the stationary property of the variables, multivariate time-series techniques such as VAR, VECM, and ARDL models could be carried out to estimate Equation 1. This equation is a long-run model, and an error-correction model is used to determine the short-run effects. Since the exchange rate and oil price fluctuation variables will be extracted from GARCH models, they are expected to be stationary at the data level. Therefore, according to the literature, the ARDL model is a proper model to estimate Equation (1). The ARDL method proposed by Pesaran et al. (2001) makes it possible to simultaneously estimate long-run and short-run equilibrium relations. In this approach, the existence of a long-run relation between variables is determined using the bound test as in Equation (4).

$$\begin{aligned}\Delta LnTB_t = {} & \alpha_0 + \sum_{i=1}^{m} \delta_i \Delta LnTB_{t-i} + \\ & + \sum_{i=0}^{m} \phi_i \Delta LnGDP_{IRN.t-i} + \sum_{i=0}^{m} \varphi_i \Delta LnGDP_{IRQ.t-i} + \\ & + \sum_{i=0}^{m} \eta_i \Delta LnREX_{t-i} + \sum_{i=0}^{m} \kappa_i \Delta LnOil_{t-i} + \\ & + \sum_{i=0}^{m} \lambda_i \Delta V_{t-i} + \theta_1 LnTB_{t-i} + \\ & + \theta_2 LnGDP_{IRN.t-1} + \theta_3 LnGDP_{IRQ.t-1} + \\ & + \theta_4 LnREX_{t-1} + \theta_5 LnOil_{t-1} + \\ & + \theta_6 V_{t-1} + \theta_7 D_{US} + e_t \end{aligned} \quad (4)$$

Equation (4) is an error-correction model in which the lagged error term of Equation (1) is replaced by the linear combination of lagged level variables as its equivalent. The estimate of coefficients attached to first-differenced variables determines the short-run effects. The estimates of θ_1 - θ_7, which were normalized on θ_1, analyze the long-run effects, because for validation of long-run effects, it is necessary to establish the cointegration. Pesaran et al. (2001) suggested using the *F* test to determine the joint significance of lagged-level variables that indicate cointegration. They tabulate new critical values for the F test, which accounts for integrating properties of all variables; thus, there is no need to test for unit root and being integrated of order (0) or order (1).

In this paper, it is claimed that depreciations and appreciations of the exchange rate may have asymmetric effects on the agricultural trade balance. The fluctuations of the bilateral exchange rate are divided into two negative (NEG) and positive (POS) parts. These are simply defined as a partial sum of negative and positive changes as Equation 5 (Bahmani-Oskooee and Fariditavana, 2015).

$$\begin{aligned} POS_t = LnREX_t^+ &= \sum_{j=1}^{t} \Delta LnREX_j^+ = \\ &= \sum_{j=1}^{t} \max(\Delta LnREX_j, 0) \\ NEG_t = LnREX_t^- &= \sum_{j=1}^{t} \Delta LnREX_j^- = \\ &= \sum_{j=1}^{t} \min(\Delta LnREX_j, 0) \end{aligned} \quad (5)$$

where REX_t^+ and REX_t^- is the positive (POS_t) and negative (NEG_t) parts of the bilateral real exchange rate fluctuations, respectively, Δ, first-order difference, and *ln* is the symbol of the natural logarithm.

Following Shin et al. (2014) and Bahmani-Oskooee and Fariditavana (2015), involving both POS and NEG variables in the error-correction model, a non-linear ARDL model is obtained as Equation (6).

$$\begin{aligned}\Delta LnTB_t = {} & \alpha_0 + \sum_{i=1}^{m} \delta_i \Delta LnTB_{t-i} + \\ & + \sum_{i=0}^{m} \phi_i \Delta LnGDP_{IRN.t-i} + \sum_{i=0}^{m} \varphi_i \Delta LnGDP_{IRQ.t-i} + \\ & + \sum_{i=0}^{m} \eta_i \Delta LnREX_{t-i} + \sum_{i=0}^{m} \kappa_i \Delta LnOil_{t-i} + \\ & + \sum_{i=0}^{m} \lambda_i \Delta V_{t-i} + \sum_{i=0}^{m} \mu_i \Delta POS_{t-i} + \\ & + \sum_{i=0}^{m} \upsilon_i \Delta NEG_{t-i} + \theta_1 LnTB_{t-i} + \\ & + \theta_2 LnGDP_{IRN.t-1} + \theta_3 LnGDP_{IRQ.t-1} + \\ & + \theta_4 LnREX_{t-1} + \theta_5 LnOil_{t-1} + \theta_6 V_{t-1} + \\ & + \theta_7 POS_{t-1} + \theta_8 NEG_{t-1} + \theta_9 D_{US} + e_t \end{aligned} \quad (6)$$

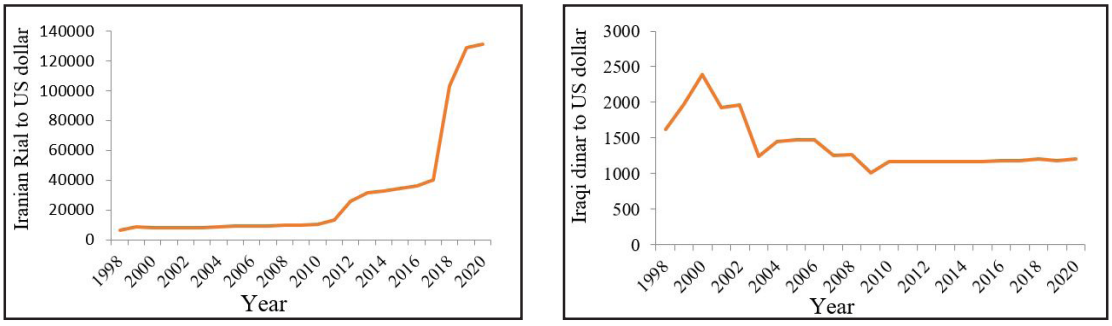
Short-run asymmetry is established if $\mu_i \neq v_i$ for each individual m. Stronger evidence of short-run asymmetry is established if $\sum\mu_i \neq \sum v_i$ and long-run asymmetry is established if $\theta_7 \neq \theta_8$. Adjustment asymmetry is acquired by the pattern of dynamic multipliers. While the first three asymmetries are tested by the Wald test, the last one is evaluated only by observing the adjustment pattern. On the other hand, in the non-linear ARDL model, the hypothesis of the J-curve can be proved if the coefficient of the negative exchange rate changes, θ_8, is positive and significant (Bahmani-Oskooee and Fariditavana, 2015 and 2016).

Data

The study uses annual data covering the period from 1998 to 2020. The required data were extracted from the Customs Administration of Iran (IRICA) based on 20,000 tariff codes. These data cover the annual values of imports and exports of agricultural products in four parts and 24 chapters, separately for all agricultural subsectors: (1) live animals and animal products, (2) vegetable products, (3) animal fats, oils, and fats, and (4) products of the food industry, beverages, etc. Iran's CPI, GDP, and Rial to Dollar exchange rate were gathered from the Iranian Central Bank. Iraq's CPI, GDP, and Dinar to Dollar exchange rate were obtained from the IMF, and the world oil prices were collected from OPEC. The variations in the exchange rate of the Iranian Rial to the U.S. dollar from 1998 to 2020 are shown in the left chart of Figure (1). As seen, the Iranian Rial to the U.S. dollar exchange rate has undergone an utterly steady trend from 1998 to 2010 and then has had an increasing trend since 2011. Most exchange rate fluctuations in Iran have been observed in 2017 until meeting its highest level in 2020, with an average of 25557.7 Rial for 1$ and minimum and maximum values of 6468 and 133850 Rial, respectively.

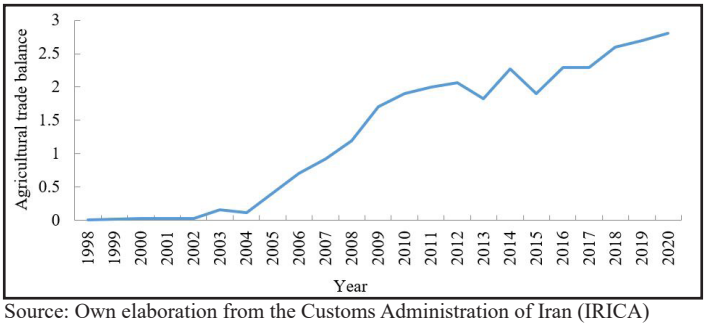
Based on the right chart of Figure 1, the exchange rate of the Iraqi dinar to the U.S. dollar widely fluctuated until 2010 when it met its highest level in 1999 and then declined until 2009. After 2010, the exchange rate was relatively steady. The average exchange rate in Iraq during 1998-2020 was 1400.1 dinars for $1, with minimum and maximum values of 1009.3 and 2453.9 dinars, respectively, during 1998-2020. In this study, the real bilateral trade balance at the base price of 2010 in dollars is defined as the difference between the logarithm of exports and imports of agricultural products between Iran and Iraq.

Figure 2 displays that the trade balance of the agriculture sector between Iran and Iraq was almost constant until 2004 and then had a nearly upward trend. The average real bilateral trade balance of the agriculture sector between Iran and Iraq from 1998 to 2020 was 1.23 billion dollars. The minimum and maximum values were equal to 0.005 and 2.69, which occurred in 1999 and 2020, respectively.



Source: Iranian Central Bank and IMF

Figure 1: The Iranian Rial and the Iraqi dinar to the U.S. dollar exchange rate during 1998-2020.



Source: Own elaboration from the Customs Administration of Iran (IRICA)

Figure 2: The trade balance of the agriculture sector between Iran and Iraq from 1998 to 2020.

Results and discussion

The stationarity of the variables (in logarithmic transformation) was tested using the Augmented Dickey-Fuller (ADF) and Elliott et al. (DF-GLS) unit root tests. The results are presented in Tables 1 and 2, respectively. According to these tables, the bilateral exchange rate, Iran's real GDP, Iraq's real GDP, and the trade balance are integrated of order one, I(1). The variables of positive and negative exchange rate fluctuations and oil price fluctuations are stationary at level I(0). The results of the DF-GLS and ADF tests confirm each other.

The results from Engle and Ng (1993) tests reported in Table 3 include the significant bias test (SB), negative size bias test (NSB), positive size bias test (PSB), and joint test. According to this table, the bilateral exchange rate series exhibit asymmetric behavior due to the significance of coefficient SB. Moreover, the significance of the PSB coefficients shows that the effect of positive shocks on the conditional variance also depends on its size. Considering the results, the null hypothesis in which the coefficients are simultaneously zero is rejected, indicating the existence of the non-linear ARCH effects. This result is in line with Ghahremanzadeh et al. (2022) which revealed that Iran's exchange rate exhibits an asymmetric behavior.

Variables[a]	Data level			First-order difference				
	τ-Statistic	Critical value (5%)	p-value	Results	τ-Statistic	Critical value (5%)	p -value	Results
($LnREX_t$)	1.58	-3.54	0.76	Non-stationary	-5.03	-3.65	0.035	Stationary
(NEG_t)	4.345	-3.54	0.007	Stationary	--	--	--	--
(POS_t)	5.731	-3.54	0	Stationary	--	--	--	--
($LnGDP_{IRN,t}$)	-1.61	-3.54	0.75	Non-stationary	-4.44	-3.65	0.011	Stationary
($LnGD_{PIRQ,t}$)	-2.557	-3.54	0.3	Non-stationary	-3.78	-3.69	0.04	Stationary
(LnTBt)	-2.03	-3.54	0.55	Non-stationary	-6.18	-3.65	0.004	Stationary
(V_t)	-3.58	-3.54	0.04	Stationary	--	--	--	--

Note: [a] Variables are defined based on equation 1.
Source: Own elaboration

Table 1: The results of the Augmented Dicky-Fuller unit root test at the level and first-order difference of the data.

Variables[a]	τ-Statistic (Data level)	Critical value (5%)	Critical value (10%)	Results	τ-Statistic (First-order difference)	Results
($LnREX_t$)	-1.84	-3.19	-2.89	Non-stationary	-2.95	Stationary
(NEG_t)	-3.78	-3.19	-2.89	Stationary	-	-
(POS_t)	-3.25	-3.19	-2.89	Stationary	-	-
($LnGDP_{IRN,t}$)	-1.17	-3.19	-2.89	Non-stationary	-3.77	Stationary
($LnGDP_{IRQ,t}$)	-1.3	-3.19	-2.89	Non-stationary	-2.91	Stationary
($LnTB_t$)	-1.403	-3.19	-2.89	Non-stationary	-3.8	Stationary
(V_t)	-3.11	-3.19	-2.98	Stationary	-	-

Note: [a] Variables are defined based on equation 1.
Source: Own elaboration

Table 2: The results of the DF-GLS unit root test.

	ARCH Test (linear)	Sign Bias Test (SB)	Negative size Bias Test (NSB)	Positive size Bias Test (PSB)	Joint test
Bilateral Exchange rates	2.11* (0.06)	2.47** (0.05)	1.43 (0.2)	4.71** (0.01)	3.35** (0.02)
Oil prices	3.86** (0.04)	1.59 (0.29)	0.08 (0.49)	2.1* (0.073)	2.08 (0.1)

Note: The numbers in parentheses show the levels of significance, and ***, ** and * show the significance at the levels of 1, 5, and 10%, respectively.
Source: Own elaboration

Table 3: The results of the linear and non-linear ARCH effects tests.

In the case of the world oil price series, the effects of the linear ARCH are confirmed. In other words, the error terms of the mean equation have conditional heteroscedasticity variance. Furthermore, except for PSB, none of the statistics SB, NSB, and joint test in the oil price series are statistically significant. Therefore, the non-linear GARCH model was also estimated for oil prices. Different types of linear and non-linear GARCH models, including GARCH, EGARCH, TGARCH, GJRGARCH, and NAGARCH, were estimated to determine the proper model to obtain the fluctuations of bilateral exchange rates and the world oil price. The proper model was selected by satisfying the theoretical conditions and characteristics of GARCH models (e.g., the coefficients of ARCH and GARCH and the sum of the coefficients are positive and smaller than one). In addition, we used the maximum likelihood, AIC, and Bayesian information criterion (BIC). The results of the estimated models are shown in Table 4. The findings suggest that TAGARCH and EGARCH models were appropriate for modeling exchange rate and oil price fluctuations, respectively. Jimo et al. (2024) also showed that the EGARCH model is a proper model for modeling the non-linear effect of the exchange rate in Indonesia, and they indicated that shocks to the volatility of the exchange rate have a symmetrical effect.

The results in Table 4 show that the estimated γ coefficient for these models is positive, indicating that the news of increasing bilateral exchange rates is more volatile than that of exchange rate declines. It can also be noted that the sum of the coefficients α and β, $(\alpha + \beta)$, in the bilateral exchange rate equation is 0.88. Since this value is close to one, the bilateral exchange rate fluctuations are somewhat steady. In other words, the shocks will gradually disappear, and any fluctuation will have a relatively long-run effect on the bilateral exchange rate. Additionally, the sum of coefficients $(\alpha + \beta)$ for the oil price equation is 0.64. Again, the value is less than one, indicating that the oil price fluctuations are steady and that the shocks will disappear over time.

Based on the AIC and SBC criteria, the optimal

	GARCH	EGARCH	TGARCH	GJRGARCH	NAGARCH
Exchange rate					
ω	0.054*** (0.001)	-2.13 (0.13)	0.0021 (0.43)	0.00031*** (0.001)	-0.0003* (0.09)
α_1	0.42** (0.01)	0.63** (0.01)	0.00015** (0.003)	0.238 (0.12)	0.137*** (0.000)
β_1	-0.95*** (0.000)	-0.18** (0.04)	0.88** (0.01)	0.721** (0.02)	0.824*** (0.000)
γ	-	-0.347*** (0.000)	0.31* (0.06)	-0.028** (0.04)	-0.020 (0.4)
AIC	-818.03	-943.7	-919.3	-843.4	-878.2
BIC	-814.66	-928.1	-935.3	-825.7	-852.3
Log likelihood	313.3	386.8	343.2	318.6	343.2
Oil prices					
ω	0.013*** (0.000)	2.03 (0.17)	0.0023*** (0.000)	0.0034 (0.21)	0.0025** (0.02)
α_1	0.28 (0.120)	0.21** (0.023)	0.38*** (0.001)	0.42** (0.012)	0.18 (0.11)
β_1	0.32*** (0.000)	0.43*** (0.005)	0.82* (0.08)	0.61 (0.12)	0.74** (0.012)
γ	-	0.28* (0.09)	-0.5** (0.02)	-0.173** (0.03)	0.176*** (0.000)
AIC	-351.5	-364.6	-321.1	-381.5	-312.4
BIC	-339.9	-351.1	-310.3	-356.4	-303.2
Log likelihood	234.4	243.7	189.5	272.7	194.3

Note: The numbers in parentheses show the levels of significance, and ***, ** and * show the significance at the levels of 1, 5, and 10%, respectively.
Source: Own elaboration

Table 4: The results of the linear and non-linear GARCH models estimation for the exchange rate and oil prices.

number of lags was determined to be two. Therefore, the asymmetric ARDL (1, 0, 1, 1, 2, 0, 1, 0) model (level presentation) was estimated, and the results are given in Table 5. The results showed that the positive and negative real exchange rate fluctuations significantly affected the agriculture trade balance; however, there are different magnitude effects, and the sign of these fluctuations on the agriculture trade balance is consistent with the theoretical basis. Iraq's GDP has a positive and significant effect on the agricultural trade balance of Iran and Iraq.

Table 5 shows the bound test result. Based on this, the null hypothesis of a long-run relation is rejected. This means the variables follow and affect each other in the long run. In other words, Iran's agricultural trade balance is affected by the exchange rate, exchange rate fluctuations, Iran's GDP, Iraq's GDP, and oil price fluctuations in the long run.

The results of the long-run estimation by the asymmetric ARDL method are presented in the upper part of Table (7). Based on this, in the long run, a one percent increase in Iraq's GDP leads to an improvement in the trade balance of the agricultural sector of Iran and Iraq by 22.19%. Bahmani-Oskooee and Fariditavana (2014) achieved similar results. With the increase in Iraq's income, its import demand from Iran will increase. As expected, Iran's GDP sign is negative. In other words, as Iran's GDP declines, Iran's trade balance with Iraq will improve in the long run. If Iran's GDP increases (decreases) by one percent in the long run, then the trade balance between Iran and Iraq will decrease (increase) by 35.03%. It is expected that with an increase in the bilateral real exchange rate, the value of imports to Iran will reduce and exports will increase, which is valid for Iraq, as shown in Table (7). In other words, if the exchange rate increases by 1%, the trade balance between Iran and Iraq improves by 20.85%. This means that a depreciation of the domestic currency and a decrease in the price of domestic agricultural products have increased the purchases of agricultural products by trading partners, thereby improving the trade balance between these countries. These results are similar to those of Nguyen et al. (2021), who concluded that the exchange rate has a negative effect on import demand.

Variable	Coefficient	t-statistic	Probability
LnTB(-1)	-3.85**	-4.406	0.000
LnREX	27.6	1.94	0.112
$LnREX_{POS}$	18.96**	4.388	0.000
$LnREX_{POS}(-1)$	13.08**	2.468	0.023
$LnREX_{NEG}$	-14.45***	-3.227	0.004
$LnREX_{NEG}(-1)$	-11.41	-1.640	0.117
$LnGDP_{IRN}$	-39.9***	-5.188	0.000
$LnGDP_{IRN}(-1)$	-22.1	1.24	0.896
$LnGDP_{IRN}(-2)$	18	1.16	0.53
$LnGDP_{IRQ}$	13.47***	6.619	0.000
LnOil	15.5***	5.916	0.000
LnOil(-1)	7.5*	1.92	0.075
D_{US}	-3.4	1.72	0.15
Constant	15.791***	5.731	0.000

Note: ***, **, and * show significance at the levels of 1, 5, and 10%, respectively.
Variables are defined based on equation 1
Source: Own elaboration

Table 5: The results of the dynamic pattern estimation, ARDL (1,0, 1,1,2,0,1,0).

F(k = 6) = 5.560		
Upper-bound	Lower-bound	Bounds / Sig.
3.757	2.522	10%
4.457	3.046	5%

Source: Own elaboration

Table 6: The critical values of the Pesaran et al. (2001) test.

Variables	coefficient	t-statistic	p-value
Long-run equation			
REX	20.85	1.45	0.137
REX_{POS}	14.79**	-2.01	0.034
REX_{NEG}	-5.76**	-2.87	0.023
$LnGDP_{IRN}$	-35.03**	-2.05	0.07
$LnGDP_{IRQ}$	22.19**	2.67	0.031
LnOil	7.75**	1.99	0.08
D	-6.44	-1.65	0.14
Short-run equation			
dREX	27.6	1.94	0.112
$dREX_{POS}$	18.96***	4.388	0.000
$dREX_{NEG}$	-14.45***	-3.227	0.004
$dLnGDP_{IRN}$	-39.9***	-5.188	0.000
$dLnGDP_{IRN}1$	18	1.16	0.53
$dLnRGDP_{IRQ}$	13.47***	6.619	0.000
dLnOil	15.5***	5.916	0.000
D	-3.4	1.72	0.15
ECM(-1)	-0.614***	-7.024	0.000

Note: ***, **, and * show significance at the levels of 1, 5, and 10%, respectively. Variables are defined based on equation 1
Source: Own elaboration

Table 7: The results of estimating the long-run relation of agricultural trade balance by the non-linear ARDL model.

As the estimation results show, the long-run coefficients of positive and negative exchange rate fluctuations are equal to 14.79 and 5.76, respectively, indicating that in the long-run, the appreciation in the real bilateral exchange rate (decrease in the Rial against the dinar) has had a greater effect on the Iran-Iraq trade balance compared to the decrease in the real bilateral exchange rate, leading to more exports to Iraq than imports from it. This means that a one percent increase in the real bilateral exchange rate has led to a 14.79% increase in the trade balance between Iran and Iraq. Therefore, the appreciation in the real bilateral exchange rate has had a greater effect on the Iran-Iraq trade balance than the depreciation in the exchange rate. Based on Table 7, the trade balance improves with an increase in oil price fluctuations, so the Iran-Iraq trade balance will rise by 7.75% with a one percent increase in oil price fluctuations. The increase in oil price fluctuations has increased the uncertainty about income from the sale of crude oil, leading to the implementation of policies that help increase the exports of other products and reduce imports to the country, which will improve the trade balance.

In recent years (from 2011 to the present), the imposition of economic sanctions by the United States on Iran has caused some trading partners to limit or completely cut off trade relations with Iran, resulting in a decrease in the volume of imports and exports from or to these countries. The coefficient of the dummy variable of economic sanctions is negative, confirming that the imposition of economic sanctions worsens the trade balance. A Wald test was employed to evaluate if there exists a significant difference between positive and negative fluctuations in the exchange rate. The result showed a value of 5.561, suggesting that exchange rate changes have an asymmetric long-term impact on the agriculture trade balance. This result is consistent with the findings of Bahmani-Oskooee et al. (2016), Bahmani-Oskooee and Aftab (2018), Nguyen et al. (2021), and Hunegnaw and Kim (2020). This matter was one of the questions explored in the current research. The results from the estimation of the error correction model are given in the lower part of Table (7). Based on the results, the coefficient of error correction is negative, significant, and equal to -0.614, showing that in the case of shock and deviation of the exchange rate from the equilibrium, 0.614% of the short-run imbalance of the exchange rate is adjusted to reach long-run equilibrium in each period. After analyzing the relationship between

the exchange rate and the trade balance, short-term and long-term effects were evaluated to examine the existence of the J-curve. This is one of as an increase in the exchange rate improves the trade balance both in the long- and short-run, the existence of the J-curve is not confirmed in the trade relationship between Iran and Iraq, which was the second question examined. This result is in line with previous research on the J-curve in agricultural products' trade such as the study by Yazici (2006) on Turkish agricultural trade balance, the analyses by Baek et al. (2009) and Gong and Kinnucan (2015) of the J-curve effect in the US agricultural trade, Yazgan and Ozturk (2019) in Turkey, and Trofimov (2020) of testing the J-curve hypothesis in Agricultural trade of four South East Asian economies (Indonesia, Malaysia, Philippines, and Thailand).

Conclusion

Sharing approximately 1600 kilometers of land and water border with Iran, Iraq is an excellent marketplace for Iranian products in terms of cultural, religious, and ethnic affinity, especially because the aftermath of several major wars in Iraq in recent years has brought about the destruction of this country's productive and economic infrastructure and accelerated call for imported items. The study on the effect of the exchange rate and its fluctuations in the trade balance of Iran's agriculture sector with Iraq revealed that the exchange rate has an asymmetric effect on the trade balance, and each of the positive and negative exchange rate fluctuations in the trade balance is different and significant. The effect of positive changes in the bilateral exchange rate is greater than its negative effect; thus, the non-linear relationship between the exchange rate and the trade balance is confirmed. The Wald test was used to examine the accuracy of the asymmetric effects in more detail, which indicated that the effect of the exchange rate on the trade balance is asymmetric.

The estimates from the non-linear ARDL model showed that Iran's GDP, Iraq's GDP, oil prices, and economic sanctions could justify some parts of the fluctuations in the trade balance of Iran's agriculture sector. The GDPs of Iran and Iraq have significant effects on the trade balance. The increase in GDP in Iraq has increased the tendency of this country to import from Iran, leading to the improvement of the trade balance between Iran and Iraq. The results indicated that the trade balance will decrease by more than 35% when the economic growth rate of Iran increases by one percent. This negative effect is aligned with economic theories so that the increase in income increases imports and reduces the trade balance. In recent years, Iran, as an oil-exporting country, has experienced fluctuations in oil prices and consequent shocks. As a result, Iran is more vulnerable, as a large part of its revenues depends on oil benefits. Hence, the present study examined the effect of oil price fluctuations. According to the results, oil price fluctuations have a positive and significant effect on the trade balance. The trade balance of Iran's agriculture sector with Iraq will improve as the price fluctuations increase.

The unconfirmed J-curve between Iran and its trading partner, Iraq, in this period, shows that in this situation, with the devaluation of the national currency, the trade balance does not undergo a downward trend in the short run, and the exchange rate policy can improve the trade balance from the very beginning. Iran can improve its trade balance by utilizing Iraq as a key trading partner, applying proper exchange rate policies, and enhancing foreign trade relations. The findings indicated that the effect of the exchange rate and its fluctuations on the trade balance using the asymmetric ARDL method provides more comprehensive results than the symmetric ARDL. Given the effects of positive and negative exchange rate fluctuations on the trade balance, the symmetric ARDL cannot provide comprehensive information, so the asymmetric ARDL is more appropriate for imposing appropriate policy to enhance the trade balance. Given the asymmetric effects of the exchange rate on the trade balance in Iran, it is suggested that the government take measures to control exchange rate fluctuations in Iran by implementing an appropriate exchange rate policy in cooperation with the Central Bank of the Islamic Republic of Iran. These methods include monitoring and tracking currency transactions to identify offenders. It is also important to know the tricks of currency appreciation and make a plan to manage their disruptive actions in the country's currency market. In addition, the import of unnecessary foreign goods that are similar to those produced in the country should be prohibited to protect foreign exchange reserves and increase domestic production. Iran and Iraq have been increasing their trade relations. By implementing the right policies, the Iranian government can facilitate regional trade agreements and improve the agricultural

trade balance by removing trade barriers. This will lay the foundation for future trade partnerships and tariff agreements. The results confirm that the economic sanctions imposed by the U.S. have a negative effect on the trade balance. Therefore, it is recommended to adopt a policy that, despite the sanctions, could improve Iran's trade relations with Iraq in other ways or to make the necessary efforts to remove the economic sanctions and improve the agricultural trade.

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Practical use of Agriculture 4.0 digital technologies to meet the EU's strategic goals in Czech agriculture

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Abstract

The implementation of precision technology procedures is declared in EU documents, including the implementation of these technologies in all areas of production, production, trade, including all areas of everyday life of the population. The article deals with the use of IT technologies in activities dealing with land management: i.e. crop production including landscape maintenance. In this context, precision technologies are used in agriculture, crop and livestock production, horticulture, forestry and comprehensive maintenance of the agricultural landscape. With remote sensing, all land areas are monitored, data is stored, and the whole process takes place continuously. The data is displayed in information maps that perfectly map the properties of the monitored area. Today, the development of the information society and specialized internet services of the state administration would not be possible without precise technologies and information portals. These are portals for the public needs of citizens or a specific professional community, and these must be user-friendly, clear, intuitive, visually interesting, trustworthy and complete in content. The article deals with a detailed analysis of the Czech Farmer's Portal from multiple angles, including state-of-the-art tools such as the AMS system (AMS, 2023). This is a new way of monitoring agricultural areas using a satellite system. On the basis of the analysed services, deficiencies are identified and suggestions for improvement are presented. .

Keywords

Information society, precision agriculture technology, eGovernment, Farmer's Portal, farmer, agriculture, SZIF, LPIS, single application, web application optimization, AMS system.

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Introduction

The implementation of precision technology procedures is declared in EU documents: e.g., 'Path to the Digital Decade Policy Programme (Decker and Okano-Heijmans, 2020), 'in all areas of production, production, trade, finance, management and will affect all areas of people's daily lives. The article discusses the use of IT technologies in activities dealing with land management: i.e. crop and commodity production, landscape maintenance, maintenance of forests and natural protected areas and reserves. According to the European Commission, this is the only way to guarantee the sustainable and harmonious development of natural capital in the common European space of the 'Digital Twin Transfer 2030' (Faraji, 2024). In this context, precision technologies are used in agriculture, crop and livestock production on farms, in horticulture, in forestry, and in comprehensive maintenance of the agricultural landscape. With the help of remote sensing (Sentinell, Copernicus, ...) the land areas are monitored, data on each m^2 of the land is constantly taken in layers (corresponding to different areas of the spectrum), the data is stored, the process takes place continuously throughout the growing season and dormancy. Other data is collected from sensors located at the border or directly on the property. Other volumes of data are processed using the so-called Big Data methods into information maps, which perfectly map the properties of the monitored area: moisture, presence of weeds, amount of fertilizers, etc. The information maps are then used by autonomous and robotic machines for precise interventions in the performance of operations: fertilization, harvesting, soil

amendment, soil quality, etc. Drones also monitor the soil and carry out some cultivation operations. It is expected that within 10-15 years, most of the operations will be provided and monitored by Artificial Intelligence (Sedláček, 2024).

Following the previous description of the development of the information society, it would not be possible without information portals and specialized internet services of the state administration. Any portal that is to serve the public needs of citizens or a specific professional community must be user-friendly, clear, intuitive, visually interesting, trustworthy and complete in content. The article deals with the analysis of the Czech Farmer's Portal from multiple perspectives of user activity. (analysis of graphic design, user experience, clarity, functionality) and the usability of the portal demonstrated on the example of electronic submission of a single application for a subsidy using the tools of the Farmer's Portal. One of the new features in 2024 is the AMS system (AMS, 2023). In 2023, for the first time ever, the State Agricultural Intervention Fund is introducing a new method of monitoring agricultural areas using a satellite system. From the English area monitoring system, we adopt the abbreviation AMS. This is a new way of checking whether agricultural activities have taken place on the monitored land in accordance with the legislation and have been met. conditions for the provision of the subsidy. Monitoring is carried out by the Sentinel 1 and Sentinel 2 satellites. Based on the results of the analyses, a description of specific problems was created with a recommended solution for further steps to improve them.

Materials and methods

The methodology of the article is based on the analysis of professional publications and information sources on the use of IT technologies in activities dealing with landscape management, land management, including business informatics. Subsequently, the article is elaborated on the basis of research in agricultural practice from the point of view of deploying portals, especially from the technological, functional and user point of view, using the following analyses:

- Serviceability Analysis (SUS)
- Qualitative research – focus groups and standardized interviews
- User Design Analysis (UXD)
- User Experience (UX) Analysis
- SWOT analysis

Farmer's Portal It is a single environment for submitting all applications and for accessing the registers of the Ministry of Agriculture published on the internet, which makes it a key tool for every farmer to carry out their activities (eAGRI, 2022). The portal is accessible through the website of the Ministry of Agriculture at: https://eagri.cz/public/web/mze/farmar/.

The basic core of the application consists of 3 registers: - Land Register – LPIS - Animal Register – IZR - Records of Preparations and Fertilizers – EPH These applications form the basis covering most of the farmer's user needs and also enable all legally required records to be carried out in electronic form. In addition to these applications, the Farmer's Portal also allows you to work in less frequent applications (eAGRI, 2022; Kubata, 2017): Portal applications are divided into public and non-public parts. All applications on the farmer portal should be fully compatible with most of the commonly available browsers. Apps for registered users are validated for compatibility with Microsoft Edge, Firefox, and Google Chrome (eAGRI, 2022). The SZIF Farmer's Portal is part of the SZIF paying agency (Havránek et al., 2013), which is responsible for the administration and payment of direct payments to farmers in the Czech Republic. The SZIF Farmer's Portal is closely integrated with the eAGRI Farmer's Portal (SZIF, 2023).

Usability Analysis – System Usability Scale (SUS)

Usability Analysis, also known as System Usability Scale (SUS), is a fast and reliable tool for measuring a wide range of systems, including applications, hardware, mobile devices, software, and websites. The system usability scale was invented by John Brooke in 1986 (Dunn, 2021; Hartson, 2012). The method is very useful as a basis for improving user experience and minimizing product development and maintenance costs (Nagar et al., 2022; Bruckner et al., 2012). It can also be used to compare the usability of different versions of a product or to compare the usability of products from different manufacturers (Špinar, 2004; Albert 2008) As part of the deployment of this method\ it is necessary to calculate the score of the evaluated product. The SUS score can then be used to compare the user-friendliness of products or services (Albert 2008).

The SUS score can be interpreted as follows:

- 90 and above: Excellent
- 80 – 89: Very good
- 70 – 79: Good
- 68 – 69: Above average
- 50 – 67: Average
- 49 and under: Bad

According to John Brooke, the average score of a compliant system is 68, and any lower value of the SUS score should be an impetus for product improvement (Brooke, 2013).

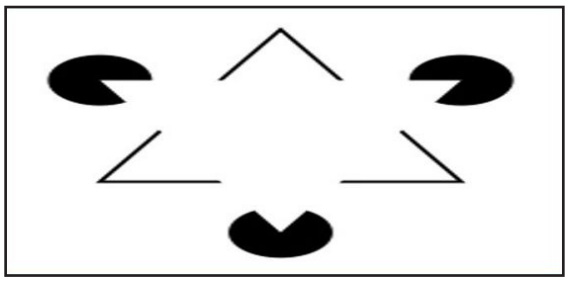
Qualitative Research – Focus Group

Thematic analysis is referred to as Focus Groups (Krueger, 2014).

A focus group is a research method that brings together a small group of people who answer questions in a moderated environment (Braun and Clarke, 2013). Focus groups are particularly suitable for collecting qualitative data (Tahal, 2022). Focus group analysis works with open-ended questions that examine users' attitudes, feelings, and beliefs, but also uses a series of questions designed to explore specific cognitive tasks related to information visualization systems (Krueger, 2014; Morgan, 1997; Walden, 2015). The premise of the method is that focusing the discussion on cognitive tasks allows to generate user comments that are more effective than informal and unstructured conversations

User Experience Design (UX design)

User Experience Design (also known as UX design, UXD, UED, or XD) is the process of defining the experience a user should experience when interacting with a digital product, website, product, or service (Marcus, 2014). The decision on a particular design within the design process should be guided primarily by research, data analysis, and user testing results rather than aesthetic preferences and opinions. Unlike UI design, which focuses primarily on the technical and graphic aspects of product design, UX design focuses on aspects of user perception of a product, such as its usability and usefulness (Marcus, 2014). The purpose of graphic design is to use visual elements such as colors, images, symbols, etc., to convey a message to the people who perceive them. Graphic design follows the laws of gestalt psychology and visual perception in order to create usable visual communication (Colascione, 2012) Shape psychology (also known as Gestalt psychology, Gestalt principles or Gestaltism) promotes the principle of wholeness. An example is the Kanizs triangle. This optical illusion vividly explains how the human eye and mind subjectively create or complete shapes where there are none. The constellation of objects in the image below leads our attention to the perception of a white triangle, which thus logically fills the missing space; however, no triangle is actually found in the Figure 1 (Cohen and Giangola, 2004).



The Kanizs triangle is a model used in the field of design and ergonomics to determine the ideal position of user interface elements. A triangle, figuratively speaking, consists of three elements: usability, aesthetics, and technical constraints (Cohen and Giangola, 2004).

Usability refers to the functionality of the user interface and how well users can interact with a website or app. It also includes making navigation easier and improving the user experience (Colascione, 2012; Cohen and Giangola, 2004; King, 2008).

Since web design is a broad term that encompasses all aspects of the human experience with a system, UXD also has elements that contribute to creating a positive user experience (Cohen and Giangola, 2004). In this evaluation context, we use the following elements (Spolsky 2001).

- Visual Design
- Information Architecture
- Interaction Design
- Usability
- Accessibility
- Human-Computer Interaction (HCI).

User Experience (UX)

User Experience (abbreviated UX) is the user experience or user experience that a website user has when using a website, portal or application (Nielsen, 2002) According to Albert Bill, UX is the process of measuring a user's interactions with the user interface and trying to evaluate them for future use. It also includes establishing policies

and guidelines that aid in the use of the digital product and its user flow (Albert 2008).

In their book The UX Book, Rex Hartson and Pardha Pyla cite the importance of UX as a crucial analysis for two main reasons. First, UX analysis helps identify existing flaws in a website or app. Second, UX analysis helps to better understand the terms that users are searching for, the parts of the site they spend the most time on, and the issues that need to be addressed as a priority (Hartson, 2012). Understanding user experience should be a top priority when designing and developing new applications, as it directly affects the success of the product through satisfaction (Albert 2008).

SWOT analysis

SWOT analysis (SWOT analysis) Strengths, Weaknesses, Opportunities and Threats) is a tool for identifying and analysing the strengths, weaknesses, opportunities and threats of an organization (Sedláčková, 2006). However, it can generally be applied to the analysis of anything, including web applications. The main objective of the SWOT analysis is to identify factors from both the internal and external environment that are involved in making key decisions (Tahal, 2022).

Information and digital literacy

Both concepts are intertwined and complement each other, but digital literacy is more specific and focused only on digital technologies. In today's digital world, digital literacy is very important and significant for many people to function successfully in both their personal and professional lives (Lauren and Lenna, 2021; Rivoltella, 2008; Samolienko, 2022) From the point of view of agriculture, Demet Soylu (2016) cites information need as satisfying the information needs of farmers, which results in an improvement in their efficiency and motivation A neutral definition was provided by UNESCO in 2018: "Digital literacy is the ability to access, manage, understand, integrate, communicate, evaluate and create information through digital technologies for employment purposes in a secure and appropriate way, decent jobs and entrepreneurship. It includes competences that are variously referred to as computer literacy, ICT literacy, information literacy and media literacy, including digital proficiency and digital awareness" (UNESCO, 2018; McFadden, 2022; Schallmo, 2021).

User interface

User Interface (UI) User Interface) is a place of interaction and communication between a person and a computer through a device. It can include display screens, keyboard, mouse, and desktop appearance. It is also the way the user interacts with the application or website (Spolsky, 2001; Cohen, 2004)

Information behaviour and information behaviour of farmers

Farmers need information about many factors influencing their activities, such as weather, soil quality, soil fertilization, soil preparation, seeds, pesticides and herbicides, crop growth, harvests, agricultural markets and many other areas (Narsh, 2017). Farmers also need to know about new technologies and practices that can help improve their yields and reduce costs. This may include, for example, information on new agricultural machinery, artificial fertilisers, new varieties of plants, and new methods of cultivation and harvesting (Wilson, 2000). As agriculture is very sensitive to changes in the environment and climate, farmers must be able to monitor and interpret information about climatic conditions in order to plan their activities and minimize risks. They need information about precipitation, temperatures, humidity, amount of sunlight, and other factors that may affect their crops (Sping, 2010). Nowadays, farmers are able to obtain information from various sources such as the Internet, educational courses, conferences, seminars and professional publications (Salampasis and Theodoridis, 2013). There are also specialized information systems that provide information on soil, weather, and other relevant areas of agriculture.

Farmers must have the ability to selectively search for information in order to acquire the necessary knowledge for their activities. They must be critical of the information they receive and assess it carefully to ensure that it is relevant and reliable (Narsh, 2017; Ostřížek, 2007).

Nowadays, it is important for farmers to be able to use modern technologies to obtain and process information. It is also important for farmers to communicate with other farmers, experts and institutions in the field who can provide useful information and advice. There are also various associations and organisations that provide advice, training and support for farmers (Fisher et al., 2006)

Optimization is the process of finding the best solution or the best possible result within certain constraints (King, 2023)

In the context of agriculture, it is important for farmers to optimize costs and increase the profitability of their crops. To do this, they can

use a variety of strategies such as selecting suitable crops, optimizing fertilization and irrigation, timely treatment of crops against pests and diseases, and effectively managing the storage and sale of products. There are many technologies that can assist farmers in optimizing their strategies and processes (Li et al., 2016). These include precision agriculture, which uses modern sensors, drones, and artificial intelligence to collect data on crops and soil quality, and then uses that data to enable more precise management of irrigation, fertilization, and pest and disease control (Pavlik et al., 2019; Stafford, 2005). Other technologies include, for example, applications for managing the storage and sale of products, automated machines for harvesting and processing crops, systems for monitoring the market and purchase prices of commodities, etc.

To optimize agriculture, the state-established agricultural Farmer's Portal provides services for the payment of subsidies, registration of land, animals, fertilizers and many others. With this platform, farmers can better plan their farming operations and optimize their practices to achieve maximum performance and minimize their costs. Portals for the disbursement of subsidies and land and animal records can also help farmers with administrative matters, allowing them to devote more time to the farming process itself. Overall, these portals can help farmers manage their farming operations effectively and improve the performance of their business. The main applications of the farmer portal are: Land Register – LPIS, Animal Register – IZR, Register of Preparations and Fertilizers – EPH, SZIF Farmer's Portal, Register of Hop Gardens, Vineyards and Orchards and others (eAGRI, 2023)

AMS system

One of the main tasks of the European Commission is the implementation of modern technologies in the field of agriculture. One of the typical examples is the novelty of 2023: the control of compliance with the rules of the single application using the AMS monitoring system. This system is more efficient and flexible than its predecessors. The European Commission is changing its overall position and, according to the new motto "prevention and communication", will first inform the applicant for inspections carried out when misconduct is discovered, before being penalized, and will create space for remedy without financial penalties (AMS, 2023).

AMS is working to evaluate remote sensing data using the Sentinel 1 and 2 satellites. On the basis of this data, it is possible to continuously monitor that the required agricultural activities are taking place according to the schedule. At that point, it has been proven that monitoring will provide the following identification (AMS, 2023):

- Agricultural Cultures
- Crop groups
- Mows
- Harvesting crops

For the future, new algorithms are envisaged to monitor additional conditions for uniform applications. Logging in to the AMS portal can be done in three ways:

Direct entry of the URL address A link on the SZIF website and a link to the Farmer's Portal

The AMS system, which remotely monitors the condition of the land, allows for a reduction in the number of time-consuming inspections for applicants of single applications and thus the obligation of their participation in the inspection. The evaluation by the AMS system can be continuously monitored for the applicant using an overview table of information on the status of compliance with the monitored conditions, on the progress of the administration of applications and on any requirements for the applicant's cooperation (e.g., taking a geotagged photograph). The table provides information about unmet conditions, undecided conditions, met conditions, and unevaluated conditions. For each of the conditions sections, we can click through to the list of relevant DPBs. The status of the monitored condition is interpreted using the traffic light, which is located on the left side of the screen. According to the colour of the traffic light, the applicant is informed whether the condition of compliance with the measures on one DPB has been met, in which case it is green, it has not been met, this is indicated by the red colour, in case a decision has not been made, it is orange in colour, or has not yet been evaluated and in this case it has a grey colour on the traffic light (AMS, 2023) (SZIF, 2024).

GTFoto

GTFoto, as stated (SZIF, 2023), is a web and mobile application for taking, sending, managing and evaluating geotagged photos for the needs of the AMS portal within the assigned tasks. The mobile app is available for users on two major mobile platforms – Android and iOS. It is used to perform tasks assigned by the SAIF

or to take separate photographs. These photos are then synchronized with the web application. Completed tasks and individual photos can be sent directly to the AMS portal from the mobile application. The GTFoto web application is used to register and manage mobile devices that will be able to take geotagged photos. Here you can delegate tasks to registered mobile devices, view photos and send completed tasks as well as individual photos to the AMS portal.

The data from the above research form the basis for proposals to improve the operation and better use of the Farmer's Portal.

Results and discussion

Research results to identify farmers' information needs

According to Pekařová (2023), the information needs of farmers differ for each of the farmers, depending on various factors such as age, education, experience in the field and also experience with information technology. Several interesting facts were found during the research. The most requested types of information that farmers most often seek are information concerning the income or expenditure side of their business and thus directly affecting their existence. The case study found that farmers mostly choose the Internet (i.e. they try to obtain information themselves) and discussions with other farmers known to them as the main source of information search – these two options were mentioned by 92% of respondents. The surveyed Farmer's Portal is only in 11th place (only a third of respondents mentioned it).

Results of the Serviceability Analysis (SUS)

Based on SUS analysis questions on 10 respondents, the SUS Farmer's Portal achieved a score of 60.75. This value indicates the Farmer's Portal as a system with an average level of usability. This means that it is in the range found in products that have a decent level of usability, but at the same time a lot of room for improvement. The result suggests that users were not entirely satisfied with its user interface, interaction, and overall user experience. The system certainly needs to be more user-friendly, intuitive and efficient.

Results of the qualitative research of focus groups

The conclusions of the survey in the form of a focus group (consisting of 10 farmers) relate mainly to impressions of the Farmer's Portal, its functionality, appearance and negative or positive experiences when working with it. The findings show the following findings. Farmers use PF for their work on average 3 to 4 times a month. Most of the users commented on PF as a very counterintuitive system that is hardly used without technical support. They rate working with PF as lengthy and even after years of use, their work with the application is not automatic. Eight out of ten respondents agreed that PF makes their work easier. Not one in 10 farmers works completely independently at PF. Suggestions for improvement: From the free discussion of the focus group, the most frequent suggestions for improving the PF were the personalization of the content or the interconnection of the PF with the Czech Statistical Office for the purposes of data collection and submission of mandatory statistical reports. Respondents would welcome it if, based on the stored user ID, after logging into the system, they could only see applications and activities that they normally use or that result from the nature of their agricultural production (animal vs. plant). For example, farmers who do not do business in the field of viticulture or orchards would not be able to see the Vineyard Register and the Orchard Register.

Results of the User Design (UXD) Study and User Experience of the Farmer Portal Homepage

Key comments about the PF UI:

- It doesn't have its own established logo
- Inconspicuous placement of a tile to click through to the SZIF portal
- The news section is not visible on the home page, but you need to scroll down the page
- News for each application separately (and not one central section)
- The graphic design and layout do not correspond with individual sub-applications (e.g., with the Farmer's Portal LPIS, PF IZR, etc.)
- The main page is filled with a wide range of confusing information
- The left navigation menu, as the main navigation menu of the site, is in small font and has items too densely packed on top of each other, in addition to having 23 items
- The pop-up signpost does not comply with the principles of creating a website, because it unexpectedly pops up and covers the navigation menu

- Small font size for headings and subheadings
- All headings and subheadings the same size
- Non-separating main headings from subheadings
- Ambiguous bookmark names
- Lacks contextual help for bookmarks and app features

Suggestions for improvement: Create a distinctive logo specifically for PF; unify the graphic design of all parts of the website; cancel the pop-up signpost (or at least prevent it from popping); condense the left navigation menu by grouping similar items; introduce context-sensitive help for menu items, icons, functions, bookmarks and subtabs; put the news in a visible place; replace the auto-expanding signpost with click-to-click expanding; separate parent and child items with an adequate font size and indent items from each other; call menu items, functions, and buttons concise and unmistakably with other menu items; provide context-sensitive help for all clickable options; Place the SZIF click-through tile at the top of the home page so that it is quickly available and provide the tile with a label, e.g. switch to PF – SZIF.

Results of the analysis of the design and user experience with the LPIS Land Register

- Absence of contextual help (especially for light bulbs)
- Important buttons for back-and-forth confirmation and switching are missing - Soil Register Application - LPIS)
- Missing navigation to next steps
- Non-contrasting color differentiation of buttons and menu items
- Unclear controls such as light bulbs, drawing tools, and map field controls and elements
- The button to invoke the action P = PREPRINTS is too small
- Insufficient size of tables, forms, and information fields relative to the size of the monitor resolution (too many tabs are not visible)
- Map field tools are fixed in the map, the panel cannot be moved and thus covers the part of the map field that the user needs to see for his work
- Tables, windows, and information boxes don't appear with all tabs, some of them remain hidden
- The navigation arrows for scrolling between tab names blend with the bookmark names
- Tables and windows within the dataset editing have only a magnifying glass icon available to return to the map field

Suggestions for improvement: Choose a more appropriate color contrast; provide the bulbs in the application with clear contextual help (e.g., a speech bubble); use uniform drawing tools; Adjust the size of the user interface to the size and capabilities of conventional monitors. highlight important buttons in color, preferably with red text or red outline of the button (or at least important buttons); Buttons and radio buttons could blink if this is the only or last step to complete the window, application, or form. for the map field control ribbon, allow the drawing tools panel to move to a different location on the map. highlight navigation arrows used to move between menu tabs (e.g. in deep yellow); label the item Soil preprints with the name Preprints, not just the letter P; the magnifying glass icon is too small due to its importance (it takes the user to the map drawings necessary for the submission of the JŽ), it is recommended to leave the magnifying glass, but with the addition of the "Map field" label and the use of context-sensitive help again.

Results of the study of user design and user experience with the Integrated Agricultural Register of the IRR

- At first glance, it is not clear that this is a register designed to register animals
- The IZR notice board has an unsatisfactory font size, the selected colors are not very contrasting and individual items disappear
- The icon to start the registry itself is drowned in the number of windows
- The navigation menu is also lacking in contrast and clutter
- Headings and subheadings are not differentiated
- The field of the animal registration record extends far beyond the display capabilities of monitors in terms of width and height
- A large number of inappropriately placed functions
- The IZR notice board and the selected colours have little contrast and individual items disappear
- The underlined inscription Register is not clickable
- Menu items are packed close together

Suggestions for improvement: Add the word "animal" to the name of the Integrated Agricultural Register to make the purpose of the IRR clear; create a more modern and user-friendly menu, which will have a clearly set and noticeable hierarchy of items and tabs (change of font, font size); Adjust the size of the user interface to the capabilities of commonly used monitors to ensure that all the items offered by the system are displayed; Combine functions for working with the animal registry into sections, e.g. animal numbers, animal movement reporting, ear tags, green diesel, etc. These sections would include other more detailed options; choose a more suitable color contrast, more saturated green colors and larger spacing between items in the left menu will add clarity; highlight the registry launcher, enlarge it and name it "Start Registry"; Create an overview of recordings that does not extend beyond the edges of the monitor and allows users to see all attributes of the recording.

Results of SWOT analysis

The positive aspects of the Farmer's Portal are its individual applications. The portal offers farmers a number of useful features, such as access to the system from anywhere and at any time, the ability to use the system without the need to install hardware or software. However, the high password requirements and password recovery process are difficult and inconvenient for farmers. A proposal to improve the situation with the password is that the Farmer's Portal offers the possibility of automatic generation of forgotten

passwords and identity verification via email and mobile phone (double identity verification).

This suggestion will surely help improve the user experience of farmers.

Another strength of PF is the high level of technical support and quick resolution of any problems, but only during working hours. The manual is also very detailed and well done, but its large scope can be challenging for some farmers. However, instructional videos are a faster and more effective option to learn how to control PF. The efficiency of PF control is a weakness of the system, which is largely due to the complexity and large number of functions. However, most farmers are satisfied with the technical support and added value that PF brings.

Farmers see the emergence of a community of virtual users as a possible opportunity. A key threat is the lack of computer literacy of users. This prevents the efficient use of technology and digital data processing, which are important aspects for the successful operation of modern farms today. It is important to remember that increasing computer literacy and technological knowledge is not an easy process, especially for people who do not have much experience with digital technologies. It is therefore necessary to ensure that farmers have access to quality training programmes that will enable them to acquire the necessary skills.

Finally, psychological obstacles, such as fear of technology and lack of confidence in one's own abilities, should also be mentioned. These factors can hinder the effective use of technology and the acquisition of computer literacy. Therefore, training programs should be aimed not only at acquiring technical skills, but also at providing psychological support to farmers and increasing their self-confidence in this area.

Evaluation of the AMS system

According to Sedlacek (Sedlacek, 2024), the analysis of the AMS case study and the first user experiences, as well as the evaluation of the SWOT analysis, shows a comprehensive view of the functionality, advantages and challenges of the Automatic Monitoring System (AMS). The research was carried out in 5 companies

Summary of results:

- All companies have demonstrated a high degree of compliance with the conditions of JŽ according to the AMS assessment.
- The results show that the AMS is an effective tool for monitoring and evaluating compliance with agricultural conditions.
- None of the companies surveyed had any red or orange alerts at the end of the reporting period, indicating that they had successfully responded to any issues identified by the AMS.

AMS SWOT analysis

Strengths: Automation and increased efficiency, accurate data for better decision-making, effective tracking and analysis, easier JS management.

Opportunities: Technological advancements, regulatory compliance, reduced inspection burdens, improved user experience.

Weaknesses: Need for training and adaptation, dependence on technology, ensuring security and data protection, technological equipment.

Threats: Problems of interconnection of information systems, social and ethical issues, risk of poor decision-making processes.

Suggestions for AMS improvements

Suggestions for improving the Automatic Monitoring System (AMS) may include the following aspects. Implementing advanced technologies to better detect and analyze data, e.g. using AI and machine learning to improve the interpretation of satellite imagery and other inputs. Ensuring that data is regularly validated and updated to ensure that it is as accurate and up-to-date as possible.

Another suggestion is to work on an interface that is as intuitive and user-friendly as possible, which will be easy to understand for all users, regardless of their technical expertise. Simplifying the process of filing additional evidence and change requests. Possibility of adapting the system to the specific needs and requirements of different types of farms. Introduction of additional features, such as predictive analytics, or automatic notification of potential issues. Enabling better integration with other agricultural and government information systems for data and information sharing. Establishment of a mechanism for collecting feedback from users and using it for continuous improvement of the system. Regular evaluation of the use and impact of the system on agricultural practices and conditions. These improvements could lead to a more efficient and user-friendly system that better meets the needs of farmers and regulators, while ensuring a high level of data accuracy, security, and reliability.

Conclusion

The analysis of the Farmer's Portal was carried out from two main points of view – the visual aspect (i.e. design) and the user experience of a selected group of farmers who have been doing business in the field of agriculture for many years. The output of the detailed analysis of the Portal are specific optimization proposals for improving and making the application more transparent, which can be found in Chapter 6 of the thesis. Several relevant methods of quantitative and qualitative analysis were used for the analysis – questionnaire survey, usability analysis (SUS), focus group research, design analysis (UED) and user experience (UX) and SWOT analysis. A case study conducted on a group of 85 farmers revealed that farmers most often search for information about the purchase prices of their products and the weather, the main source of information for them is the Internet and they most often search for information using their mobile phones as an information medium.

The quantitative analysis of the usability of SUS showed only an average usability score of the Farmer's Portal, which points to a lot of room for improvement in the usability of the system towards simplification, clarification and greater intuitiveness. Specific suggestions for improvement are outlined in Chapter 6. The analysis of the design and user experience (UX) then made it possible to obtain qualitative data on the preferences and needs of the users and helped to identify the key elements for creating a user-friendly, visually appealing and effective website, which can be found again in Chapter 6 The conclusions made from the focus group's research were very helpful in this regard. All respondents agreed that the Farmer's Portal is a very confusing, confusing and counterintuitive application, which they hardly use without technical support or the use of the services of one of the consultants. Work in it is tedious, slow. The graphic design is bland (each sub-application has its own design), the layout of the individual menu items and tabs is cluttered and gives a feeling of being lost, which is partly due to the small size of fonts, headings and the absence of accent elements. This was confirmed when determining the strengths and weaknesses of the Farmer's Portal based on a SWOT analysis, which also contributed to a comprehensive picture of this website. All specific findings, suggestions for improving the application can be found on the pages in Chapter 6. Based on the collected data and information, a number of optimization changes to the Portal were proposed in order to increase user comfort and experience. These changes included improvements to navigation, the overall layout of elements on the page, improvements to the content structure, greater personalization of content, unification of the graphic designs of the main page and its individual subsections, and the addition of other useful features. The latest AMS application was evaluated in detail with the following commentary on the evaluations. The main benefits of the website include increased efficiency and productivity, better data analysis, decision support, and improved coordination and communication. Furthermore, these conclusions in Chapter 6 point out that, despite some weaknesses and threats, such as lack of training, reliance on technology, cybersecurity and data leakage, IS integration and AMS overall contribute to better management and management of the farms under review. Designed to monitor and evaluate compliance with agricultural conditions, the AMS system has proven to be an effective tool.

Its colorful traffic light system and alert response capabilities allow for efficient management and quick response to potential issues. The results of the monitoring showed a high degree of compliance and efficiency of the use of AMS.

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Product Differentiation in Food-Product Markets: Evidence from the Asian Instant Noodles Industry

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Abstract

This study investigates product differentiation, both in vertical and horizontal dimensions, in the instant noodles industry. It first presents theoretical models that predict firms' product differentiation behaviour before testing the theories using the case of instant noodles industries in three Asian countries: Indonesia, India, and Japan. The vertical differentiation behaviour is examined using the ANOVA test followed by the Bonferroni correction to investigate which brands exhibit the most evident vertical differentiation behaviour. The horizontal differentiation strategy is explored using a descriptive analysis method. Using information on the selling prices and product variants of instant noodles leading brands in each country, the empirical findings confirm the models' predictions. The study claims that companies apply the principles of 'minimum differentiation' as their vertical differentiation strategy and 'maximum differentiation' when differentiating horizontally. These strategies are implemented by choosing prices close to each other and producing distinguishable variants from competitors. These findings bring the theories of product differentiation into a real-life application and provide insights into how firms in the food products industry behave in differentiating their products.

Keywords

Firm behaviour, food-product industry, horizontal differentiation, instant noodles market, product differentiation, quality differentiation.

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Introduction

Throughout its nearly 4000 years of history, noodles have experienced many changes in quality and variety. Noodles have undergone a long history in Asian civilisation, dating back as far as the Chinese Han dynasty, all the way to the mass production using machinery during the Industrial Revolution, to the invention of instant noodles as fast food by Taiwanese–Japanese Momofuku Ando in 1958 (Zhang and Ma, 2016). The last discovery has since created a revolution in the world's eating habits, such that people worldwide accept instant noodles as an economical energy food. The popularity of instant noodles can be attributed to their characteristics such as flavour, nutritional value, convenience, safety, extended shelf life, and affordability (Gulia et al., 2014). Not only in Asia, but instant noodles are also widely consumed in countries in which noodles were not part of their traditional diet, such as the United States, Russia, Brazil, Nigeria, and Mexico, proving that the wheat-based product continues to stimulate international trade beyond Asia (Hou, 2010). The globalisation of noodle products and other wheat-based foods continues to drive international trade in the world's most cultivated grains, measured by harvested acreage (McKee, 2009).

In its continent of origin, instant noodles play a significant importance in the Asian diet as the product is consumed massively and considered part of the staple food. Noodles make up a significant portion of their wheat flour consumption, ranging from 20% to 50% (Hou, 2010). The industry is considered a fascinating business in Asia due to its ubiquitous presence and high demand. According to the World Instant Noodle Association (WINA), Asian countries are the primary consumers of instant noodles. The data from WINA (2023) suggests that in 2022, China has the highest instant noodles consumption,

with a total demand of 45,070 million servings (MS), followed by Indonesia (14,260 MS), Vietnam (8,480 MS), India (7,580 MS), and Japan (5,980 MS).

Given the importance of instant noodles in society, comprehending the industry's market landscape is arguably essential for various stakeholders. It aids market participants within the instant noodles industry in devising optimal competitive strategies and assists prospective entrants in gaining insights into the market dynamics before making entry decisions. Most importantly, understanding the issue provides policymakers with valuable information for implementing suitable measures within an oligopolistic market setting.

Like other products with a significant presence in the market, instant noodle producers behave strategically to secure a market share, one of which is by differentiating their products. Various kinds of instant noodles can be observed with different flavours, packaging, and prices. This study explores the product differentiation behaviour of instant noodles companies, focusing on three Asian countries with substantial instant noodles consumption: Indonesia, India, and Japan.

This study uses economic theoretical models to predict the empirical outcomes with a particular application in the processed food industry. Theoretically, the primary purpose is to predict how firms behave in their product differentiation strategy to maximise their profits and strengthen their market positions. The theoretical part presents the models of the principles of minimum and maximum differentiation. The former shows how firms produce products that are as similar as possible and compete aggressively, while the latter claims the opposite, that firms ease competition by producing goods that are distinct from each other. The theoretical analysis is then tested empirically by exploring the product differentiation behaviour of instant noodle leading firms in the three Asian countries using survey data of their selling prices and product variants.

Product differentiation can be implemented along two dimensions: vertical and horizontal differentiation (Mérel and Sexton, 2012). Vertical differentiation aims to create products that differ from competitors' brands in terms of quality, while horizontal differentiation refers to attempts to create or add unique features to a product. Differentiation can be achieved through Research and Development (R&D). Vertical and horizontal differentiation are elaborated theoretically by the models in this paper and related to its application in the Asian instant noodle industry using both empirical and descriptive methods.

Imperfect competition is formed by the type of market model, which subsequently affects product price and profit margin (Severová et al., 2011; Choi, 2019). Typically dominated by only a few big firms owning significant market shares, the instant noodles industry can be classified as oligopolistic (e.g., Ueda and Watanabe, 2023; Dewi, 2016; and Kesavayuth, 2001). Nevertheless, the industry exhibits some features of a monopolistic competition market, characterised by high product differentiation (e.g., Chen and Zhen, 2022; Shim et al., 2019; and Wareewiboon, 2004).

Firms conduct product differentiation to soften competition and gain a larger market share by making their products distinguishable from and preferred to other similar products. Differentiation strategies play a crucial role in monopolistic competition markets, as firms attempt to attract consumers to purchase their products instead of other similar products available in the same industry. Product differentiation benefits consumers by providing more available options through the increased variety and producers by increasing their competitiveness and easing competition in the market. This paper discusses the underlying theories of product differentiation using the Hotelling model and applies the model to the context of the processed food products industry, taking the specific case of the instant noodles industry in Asia.

The central proposition of our study suggests that businesses tend to follow a particular strategy when making choices regarding the quality and features of their products. Specifically, it hypothesises that companies often opt for minimal differentiation in quality while pursuing maximum differentiation in product features. The minimum differentiation principle in quality implies that companies aim to offer a certain level of quality that is competitive with other products in the market but does not go significantly beyond that level. The maximum differentiation principle for features suggests that companies focus on differentiating their products through unique and distinctive features. This hypothesis primarily draws its support from the research findings of Economides (1989), which will be discussed in the next section.

While many economic models have been developed, few have considered their applicability in the food-product industry. Among the limited

number of studies, Kostovčík et al. (2020) applied the oligopoly model with a dominant company in the viticulture industry to explain market dominance and price leadership in the sparkling wine market in the Czech Republic. Also using the model of oligopoly with a dominant company featuring competitive fringe firms, Šrédl and Mikhalkina (2014) used the model to explain the role of changes in consumer preferences in the context of the oligopolistic multinational chains of fast-food restaurants in the country, particularly when a new company enters the market. They also examined further the presence of market dominance in the industry. In contrast to those papers that focus on the nature of the market structure of the relevant food products, this paper highlights the role of product differentiation in a food product market.

Another study by Severová et al. (2011) briefly discussed the oligopoly model with differentiated products characterised by competition in price and non-price dimensions. They empirically studied the food product market in the Czech Republic and claimed that competition among chain stores is rather intense so that there is no market dominance by an individual chain store. However, product heterogeneity in oligopoly was not the focus of the analysis, so product differentiation was not discussed extensively in the paper. Yet on the empirical side, similar to the method used in this paper, Prášilová et al. (2011) used the ANOVA method to analyse the price behaviour of several agricultural products in the Czech Republic and showed that duopolistic reactions are apparent among leading chain stores. Svoboda and Kopecká (2017) applied the Sweezy model to explain the price rigidity of private labels, particularly pork meat, among chain stores in the Czech Republic. They provided evidence of some chain stores that reciprocated the price decreases of their competitors while keeping their prices unchanged when the competitors increased their prices. In contrast to the above papers, this present study looks at the innovative side of processed food production and focuses on the instant noodles industry.

In the context of international trade, Soukup et al. (2014) applied the framework of monopolistic competition to show how entry by firms through international trade of agricultural products leads to the expansion of the market, an increase in the variety of available products, and a decrease in farmers' cost as the government subsidises more for farming.

Saitone and Sexton (2010) gathered recent studies on food product quality and differentiation and reviewed modelling approaches for studying competition in the agricultural-product markets. They then investigated the role of collective action and self-regulation in influencing product quality and differentiation. Dong et al. (2023) have also associated the differentiated nature of food products with the unusual relationship between market concentration, market power, and market prices in the industry. In particular, using the Dixit-Stiglitz model of monopolistic competition, they provided a theoretical explanation of a rising market concentration without being followed by greater market power and higher prices, which is against the common assumption. This finding was confirmed by empirical evidence in the food retail industry in the US. Market concentration and competition in the food industry have also been discussed by, among others, Bredahl (2019), Cotterill (2019), Clapp (2021), Wood et al. (2021), and Distanont and Khongmalai (2020).

Turning to the purely empirical stream, Jati and Premaratne (2017) used the Multivariate BEKK-GARCH Model to examine the volatility behaviour of the global price of several kinds of staple food. The study shows that a staple food's own-volatility spillover is relatively significant for all food prices, with sugar exhibiting the largest own-volatility spillover effect. It also investigates the price behaviour of those groups of staple foods around the food crisis. In the context of the Israeli food industry, Reiss (2014) explores the possible channels and explanations behind the decreasing profitability of the food industry in the country.

The economic literature on staple food is admittedly underexplored. Moreover, existing research appears outdated and drawn to the African context. For example, Tschirley et al. (1996) explore the various factors that influence the impact of providing yellow maize food assistance on the cultivation of maize as the primary crop in Mozambique; Jayne and Jones (1997) discuss grain marketing and pricing policy in Eastern and Southern Africa; and Haggblade and Dewina (2010) focus on staple food prices in Uganda. Yet, in the African setting, more recent studies relate the staple foods market and trade policy, such as Badiane and Odjo (2016) and Fabinin (2022). Among the few in the Asian context include Ellis (1993) with the case of rice in Indonesia, Huang and Bouis (2001) with the Taiwanese food case, and Dawe (2002) in a broader context of the world rice market. None of the above studies discusses staple

food in relation to the oligopolistic market structure and product differentiation behaviour, giving an avenue to this paper to fill in the sparse gap.

Several studies have investigated the presence of instant noodles and their roles in present-day societies. For example, Errington et al. (2013) conducted a thorough study on the social aspects of noodles and the industry in Japan, the United States, and Papua New Guinea. As a food product with a significant role in society due to their practicability and affordable prices, instant noodles have also been debated whether they are good for health. Like other ultra-processed foods, instant noodles usually contain artificial food colours, flavourings, and certain preservatives (Sikander et al., 2017), high calories, added sugar, sodium, and unhealthy fats, while being poor in fibre, protein, and micronutrients (Popkin et al., 2021), all of which may have adverse effects on health in the long term. Much innovation has been conducted in the industry, especially in improving product quality and nutrition levels. Researchers are currently making diligent endeavours to enhance the composition, prolong the storage capability, and advocate for the widespread fortification of instant noodles (Gulia et al., 2014). As discussed later in this paper, instant noodle companies, both incumbents and new entrants, have also attempted to optimise the potential of instant noodles by enhancing their nutritional attributes. While substantial attention has been devoted to studying instant noodles' social and health aspects, there appears to be limited attention on the economic side of the industry. This study fills in the gap in the literature by exploring the behaviour of instant noodle companies in managing the market competition by differentiating their products strategically.

Material and methods

The research question of this study is how firms in the food industry behave strategically in managing market competition by differentiating their products. This section first provides the theoretical models based on which the hypotheses on the empirical approach are formulated. Then, it elaborates on the method used in testing the hypotheses.

Product differentiation models in an oligopoly

We mainly use the Hotelling model to explain product differentiation in this study. The Hotelling model is developed in the framework of a physical spatial model but is well adjustable to fit a non-spatial framework of product differentiation. The model derives a claim that duopolistic firms agglomerate at the centre of a line market segment. In the non-spatial framework, this result is interpreted as firms producing homogeneous goods. In other words, according to the Hotelling model, under certain assumptions, competing firms produce goods that are as similar as possible, which is known as 'the principle of minimum differentiation.' This claim was challenged by d'Aspremont et al. (1979), who use a quadratic transportation cost and show a contrasting result that firms locate as far away from each other as possible, which implies the prevalence of 'the principle of maximum differentiation.' We show the relevance of both results to the specified food product industry in the next section.

Hotelling's model of product differentiation is summarised as follows. Two firms, A and B, are located separately somewhere at a line market segment of unit length, along which consumers are uniformly distributed. Firm A is located at a distance of a from the line starting point, and Firm B is at a distance of b from the endpoint. Firms' locations represent the type of products they produce, and consumers' locations represent their product preferences. Consumers incur a disutility cost for every purchase from any firm, which, in the spatial framework, is referred to as a transportation cost. A marginal consumer $\hat{x}$, who is located between the two firms, is indifferent between purchasing from either firms A or B, such that:

$$p_A + t(\hat{x} - a) = p_B + t(1 - b - \hat{x}) \quad (1)$$

where p_A and p_B are prices offered by firms A and B, respectively, and t denotes the disutility cost. The marginal consumer is, hence, defined by:

$$\hat{x} = \frac{1}{2}\left[\frac{p_B - p_A}{t} + 1 + a - b\right] \quad (2)$$

Since consumers are uniformly distributed along the line segment, $\hat{x}$ represents the demand for firm A's product, and 1-$\hat{x}$ for firm B's. We assume that the marginal production costs for both firms are zero. The profit functions of the firms are, thus, as follows:

$$\pi_A = p_A \hat{x} \quad (3.1)$$

$$\pi_B = p_B(1 - \hat{x}) \quad (3.2)$$

The game structure consists of firms choosing locations in the first stage and competing on price in the second stage, which is solved using

backward induction. In the second stage, solving the profit maximisation problems simultaneously with respect to prices gives the equilibrium prices as follows:

$$p_A^*(a,b) = t\left(1 + \frac{a-b}{3}\right) \quad (4.1)$$

$$p_B^*(a,b) = t\left(1 + \frac{b-a}{3}\right) \quad (4.2)$$

Turning to the first stage, substituting the equilibrium prices in (4) into the profit functions in (3), we obtain the reduced profit functions as follows:

$$\pi_A^*(a, b) = p_A^*(a, b)\, \hat{x}(p_A^*(a, b), p_B^*(a,b), a, b) \quad (5.1)$$

$$\pi_B^*(a, b) = p_B^*(a, b)(1 - \hat{x}(p_A^*(a,b), p_B^*(a, b), a, b)) \quad (5.2)$$

It is easy to show that the first derivatives of the reduced profit functions with respect to their location are greater than zero, that is, $\frac{\partial \pi_A^*(a,b)}{\partial a} > 0$, $\frac{\partial \pi_B^*(a,b)}{\partial b} > 0$. It implies that firms benefit by moving closer towards the center of the line market segment. There are two countervailing effects in the firms' location decisions: the hinterland effect and the competition effect. The hinterland effect pulls the firms toward the centre of the line market segment to increase their market shares, whereas the competition effect pushes them to move far away from each other to reduce competition. The hinterland effect is stronger than the competition effect, so the firms move toward the centre of the line to increase their hinterland and eventually agglomerate at the middle-of-the-line market segment. In the product differentiation framework, this result is interpreted as the firms producing products that are as similar as possible and capturing the consumers whose preferences fall within their own hinterlands. This agglomeration equilibrium is known as the 'principle of minimum differentiation.' This theory becomes the basis for the formulation of one of the hypotheses of the empirical analysis, that is, that firms choose product qualities that are as close to their rival as possible.

D'Aspremont et al. (1979) challenge Hotelling's finding and claim that agglomeration cannot be sustained in equilibrium as firms undercut each other. Instead, using a quadratic disutility (transportation) cost, they find the opposite result, that firms locate as far away from their rival as possible to reduce the intensity of competition. When the disutility cost is quadratic in the distance, the marginal consumer is characterised by:

$$p_A + t(\hat{x} - a)^2 = p_B + t(1 - b - \hat{x})^2 \quad (6)$$

$$\hat{x} = \frac{1}{2(1-a-b)}\left[\frac{p_B - p_A}{t} - a^2 + (1-b)^2\right] \quad (7)$$

Following the same procedure as in the Hotelling model, we find that the equilibrium prices under quadratic disutility cost are as follows:

$$p_A^*(a,b) = \frac{t}{3}[(2-b)^2 - (1+a)^2] \quad (8.1)$$

$$p_B^*(a,b) = \frac{t}{3}[(2-a)^2 - (1+b)^2] \quad (8.2)$$

We substitute these equilibrium prices into the firms' profit functions to obtain the reduced profit functions as before. Deriving the reduced profit functions with respect to each firm's location, we find that a firm's profit is decreasing in its location, that is, $\frac{\partial \pi_A^*(a,b)}{\partial a} < 0$ and $\frac{\partial \pi_B^*(a,b)}{\partial b} < 0$. Therefore, an increase in a is not beneficial to firm A, nor is an increase in *b* to firm B. At optimum, firms A and B choose $a = 0$ and $b = 0$, respectively, so that firm A is located at the starting point and firm B at the endpoint of the line segment. The use of quadratic transportation cost generates the so-called 'principle of maximum differentiation', under which firms produce products that are as distinguishable as possible to reduce the competition in the market. This theory is the ground for the second null hypothesis of the empirical approach, that firms differentiate their products to be as distinguishable from their rivals' products as possible in terms of product characteristics.

Economides (1989) combines horizontal and vertical differentiation in a model by integrating quality dimension into Hotelling's model to analyse the impact of quality variations on the choices of the varieties produced. The result shows that the principles of minimum differentiation prevail for quality choice and maximum differentiation for features. We adopt this proposition as the hypothesis of our study, that is, competing firms produce products that are similar in quality but differ in characteristics. As confirmed by the following empirical analysis in this study, both the principles of minimum and maximum differentiation are valid in the context of the Asian instant noodles industry, depending on the measures used to define product differentiation.

Soukup and Šrédl (2011) is related to this paper in the use of the Space Model. However, we employ the model for a completely different purpose. Although they mentioned how the model could be used to analyse product differentiation, their discussion contexts were mainly in the physical space. In contrast, we apply the model to a non-spatial framework to explain product differentiation, especially horizontal differentiation, as reflected by the product variety in the instant noodles industry.

Research method and data collection

We analyse the cases of product differentiation of instant noodles in three Asian countries: Indonesia, India, and Japan. Apart from data availability reasons, these three countries are chosen to be the subject of this study due to their positions as among the countries with the highest production and consumption of instant noodles in Asia. Recalling the data from WINA (2023) in 2022, Indonesia is placed as the second country with the highest instant noodles consumption with a total demand of 14,260 million servings (MS), India is the third with a demand totalling 7,580 MS, and Japan in the fourth position with a total demand of 5,980 MS. Not to mention, these countries are also among the leading exporters of noodles with a significant presence in the global market: Indonesia with its Indomie and Mie Sedaap, India with its Maggi, and Japan with its Nissin noodles. According to Volza's Instant Noodles Exporters and Suppliers directory in 2023, as of June 6, 2023, 181 active instant noodles exporters in Indonesia were exporting to 528 Buyers. As of August 9, 2023, India has 307 active instant noodle exporters supplying their products to 826 buyers. In the same year, there were 502 active instant noodles exporters in Japan, exporting to 650 Buyers.

The data is obtained mainly through the official website of each brand, leading e-commerce platforms in each country, statistic agencies, research papers and newspaper articles. Data for variants and net weights are readily available on each brand's official website. We consider five market leaders in terms of market share in each of the three countries, making a total of fifteen brands. In Indonesia, the brands include Indomie, Mie Sedaap, Sarimi, Supermi, and Mie Gaga. In India, the considered brands are Maggi, Sunfeast Yippee, Wai Wai, Patanjali, and Top Ramen. In Japan, we have Nissin, Toyo Suisan, Sanyo Foods, Myojo, and Acecook. Each company owning the brand mentioned has official websites on which detailed information on the company profile and their products can be learned.

Nearly all these companies classify their instant noodle products, list all available variants, and provide details of each variant. The information available typically includes the net weight, main features, ingredients, nutritional and allergen information, and sometimes, the recommended retail price of each variant. The information on variants is then used to do an online search on the average retail price of every variant during the survey period of this study, between January 2021 and July 2022, on leading online marketplaces in each country. At least one marketplace typically provides a reference for the retail price of each variant. When more than one marketplace provides different price references, we take the average of the prices. The data for market shares of each brand in each country is obtained from various sources, such as research papers, newspapers, websites, and local statistics agencies, which are stated explicitly in the corresponding parts. Obtained from various sources, the market share data projects each brand's approximate market dominance in each country with relative accuracy.

We narrowly define instant noodles as pre-cooked or dried noodles characterised by flavouring powder and/or seasoning oil included in the package. We use the hierarchy of instant noodles in this study to classify the products. First, at the country level, we select five leading brands that dominate the instant noodles market in each country based on their market shares. Those brands may belong to the same or different companies. Each brand has several variants, which we also call products or flavours. We then perform the analysis at both the country and brand levels. Two dimensions of product differentiation are explored: vertical and horizontal differentiation. Vertical differentiation refers to product quality, and horizontal differentiation refers to product characteristics or features other than quality. The measure for each variable will be explained in more detail below.

The main claim is that both the principles of minimum and maximum differentiation discussed in the theoretical models above are valid, depending on the dimension used to measure differentiation. The primary hypothesis of the empirical analysis is that companies implement the principles of minimum differentiation for quality choice and maximum differentiation

for feature choice. This hypothesis is mainly based on the findings of Economides (1989), discussed in the previous section.

One of the challenges of measuring vertical differentiation is that product quality can be subjective. Key quality aspects for instant noodles typically include their colour, taste, texture, cooking performance, rehydration rates during final preparation, and whether they develop a rancid taste after prolonged storage (Gulia et al., 2014). These characteristics, however, are hard to measure. Price is readily available information and can be a good proxy for quality as they tend to go proportionally. Companies need a higher marginal cost to produce a better-quality product, leading to a higher product price in the market. The use of price as a signal of quality has also been advocated by several studies in the literature, both theoretically (e.g., Wolinsky, 1983; Bagwell and Riordan, 1991; and Chen et al., 2020) and empirically (e.g., Verma and Gupta, 2004; and Hwang et al., 2006). In this study, we use net price and price-weight ratio measures to quantify the degree of vertical differentiation. Net price is the average net price of products belonging to each brand in each country. This information is obtained by gathering the prevailing retail price of each variant within a specific brand, and the total retail prices of variants of the brand are then averaged over the number of variants in that brand within the observation period. Meanwhile, the price-weight ratio is the average net price per gram of products belonging to each brand in each country. Accordingly, this information is presented by dividing the prevailing retail price of a variant by its net weight, totalled with variants of the same brands, and averaged over the number of variants within the specific brand during the observation period.

The null hypothesis for the vertical differentiation analysis is that companies produce instant noodles with similar quality; that is, the average prices and prices per gram across brands of instant noodles in a country are equal. In other words, the price differences across instant noodles are insignificant. We expect this result to hold especially for the two leading brands in each country in its relevance to the duopolistic model we use in the theoretical analysis. For this purpose, we apply the one-way Analysis of Variance (ANOVA) test to compare the means of prices and prices per gram across brands.

ANOVA is a statistical technique used to compare the means of more than two groups under the same underlying assumption as the *t-test*. ANOVA examines how much variation exists between the means of different groups (referred to as between-group variance) compared to the average variation within each group (within-group variance). ANOVA focuses on the positions of the distributions represented by these means. Rather than directly comparing many groups' means when dealing with a large number of means, ANOVA analyses the variance among these group means, making it a more convenient way to assess their relative positions (Kim, 2014).

After the ANOVA test, we perform the *Bonferroni correction* to investigate price differences between brands to examine which brands exhibit the largest price difference. We only provide the *Bonferroni correction* results for prices per gram, which drives most of our findings. The Bonferroni correction is employed to adjust probability (p) values in response to the increased risk of having a type I error when conducting multiple statistical tests. This correction finds common usage in various scenarios, with its primary applications being the adjustment of experiment-wide error rates in the case of multiple *t-tests* or as a *post-hoc* procedure to rectify the family-wise error rate after conducting an analysis of variance (ANOVA). The Bonferroni correction should be considered when: (1) one needs to assess a single test for the 'universal null hypothesis' (H_0) that all tests are not significant, (2) it is crucial to minimise the risk of a type I error, and (3) one is dealing with a substantial number of tests without pre-established hypotheses (Armstrong, 2014).

We use *Stata* in conducting the statistical analysis. For the groups to be comparable, we focus on 'pack' instant noodles as the most common type in the market in the vertical differentiation analysis. Hence, in the meantime, we eliminate 'cup' (bowl) noodles from the analysis, which have different characteristics and may result in unparalleled comparison.

For horizontal differentiation measures, we use various features, including flavours (varieties), nutrition facts, and ingredients. Flavours refer to the variants produced by each brand listed on their website within the observation period. Nutrition facts correspond to how healthy and nutritious a variant is labelled by the producing brand, usually indicated by its main ingredients. Ingredients refer to the inputs used in producing a particular variant, often associated with whether it contains substances that could adversely affect health, such as MSG and preservatives.

In this case, size (weight) is not considered a form of differentiation, as it does not change substantially a brand's features. Hence, a brand's products with the same flavour but different sizes (weight) are considered one variety. Due to the complex nature of firms' behaviour when differentiating horizontally in the instant noodles' context, the problem associated with horizontal differentiation is explored descriptively using a qualitative method for each of the three countries. The qualitative method is proven useful in exploring the aspects of the problem that cannot be captured by econometrics and economics theory, which are often insufficient to provide a plausible explanation behind certain social phenomena. Economists generally understand qualitative research methods to refer to data gathering, which subsequently takes not a numerical but a verbal form and cannot be analysed econometrically but only with the help of other techniques (Starr, 2014).

Results and discussion

This section explores product differentiation in the instant noodle industry in vertical and horizontal dimensions. As will be presented next, the instant noodles market appears to be highly concentrated, with only a few firms holding significant market shares in each country, resembling oligopoly characteristics. Other than the top five brands mentioned in each country, some smaller firms form a competitive fringe, typically holding insignificant market shares. Due to data unavailability, however, these competitive fringe will not be discussed here. The analysis results for each of the three countries are discussed separately for vertical differentiation and combined for horizontal differentiation.

Vertical differentiation

Indonesia

Generally, Indonesian instant noodles have a moderate aroma and a mouthfeel of salty, umami and spicy taste. The favourite spices include curry flavours, white pepper, garlic, and onion, while vegetable, chicken, seafood, beef, and shrimp flavours with chilli condiments or sweet soy sauce are in favour. Regardless of the brand, fried noodles called "Mie Goreng" are the most popular among Indonesian consumers. Since the majority of the population is Muslim, most products are halal (Guo, 2020).

According to Top Brand Award, as cited in Roisah et al. (2021), based on the share of sales, the instant noodles industry in Indonesia in 2020 was dominated by Indomie with a market share of 72%, Mie Sedaap (18%), Sarimi (4%), Supermi (3%), and Mie Gaga (3%), rounded into integers. Indomie, Supermi, and Sarimi belong to the same company, Indofood Sukses Makmur; Mie Sedaap is a brand of Wings Food; and Mie Gaga is owned by Jakarana Tama. Although Indomie is the market leader in the Indonesian instant noodles market in terms of market share, the first mover in the country's instant noodles industry is Supermi. According to Anggraeni (2023), Supermi was first introduced in 1968, followed by Indomie two years later, which instantly captivated consumers with its chicken broth soup flavour. Sarimi entered the industry as a new player in 1982, and the three companies established a joint venture under the name PT Indofood Interna Corporation in 1984, which later became PT Indofood Sukses Makmur in 1994. Mie Sedaap, which comes second in market leadership in market share, was introduced twenty years ago by WingsFood, a subsidiary of Wings Group (Oswaldo, 2022). In the same year, Mie Gaga started its market penetration under PT Jakarana Tama by Djajadi Djaja, the inventor of Indomie, but no longer owned the company share (Sabandar, 2023).

On the vertical dimension, since their establishments, these brands have competed fiercely to protect their market segments by choosing their product prices strategically. Table 1 compares product prices across instant noodles brands in Indonesia using the ANOVA test and Bonferroni correction. According to the ANOVA test, using net price as a quality measure, the differences in the means of product prices across brands are insignificant. This result implies that the firms set their average prices close to their rivals, so the principle of minimum differentiation prevails.

Using the price-weight ratio measure, however, the analysis shows that the means of prices per gram across brands are not equal at the 5% significance level. Performing the Bonferroni correction reveals that a significant price difference arises between Indomie and Sarimi. Sarimi targets a different market segment by enlarging its product sizes, resulting in a lower average price per gram than its rivals. The brand managed to secure around 4% market share using this strategy. Focusing on the two market leaders, Indomie and Mie Sedaap, we show that the difference in the means of prices per gram is insignificant. Therefore, we can conclude that the principle of minimum differentiation is valid for vertical differentiation in the Indonesian instant noodles industry, especially for the two largest market leaders.

Analysis of Variance (ANOVA)				
Source			***F***	***Prob > F***
Between groups (Net Price)			1.00	0.416
Between groups (Price per Gram)			2.97	0.025**
Bonferroni correction (Price per Gram)				
Row Mean-Col Mean	*Indomie*	*Mie Gaga*	*Mie Sedaap*	*Sarimi*
Mie Gaga	-1.281 (1.000)			
Mie Sedaap	-2.661 (1.000)	-1.380 (1.000)		
Sarimi	-6.262** (0.027)	-4.981 (0.446)	-3.601 (1.000)	
Supermi	-5.790 (0.444)	-4.509 (1.000)	-3.129 (1.000)	0.471 (1.000)

Notes: *** denotes significance at the 1% levels, ** at the 5% levels, and * at the 10% levels
Source: Analysis output based on Instant Noodles Prices Survey in Indonesia conducted by authors

Table 1: ANOVA test and Bonferroni correction for the Indonesian Instant Noodles Industry.

India

According to Guo (2020), India's most popular instant noodle flavours include curry (masala) and chicken tikka. Approximately 60% of the Indian population adheres to a vegetarian diet for religious purposes. As a result, Indians have a preference for vegetable and tomato-based soups as their most commonly consumed soup noodles.

Various reports consistently place Maggi and Sunfeast Yippee noodles as the market leaders in the Indian instant noodles market. According to Nielsen data, as cited by Anand (2017), the Indian instant noodles market was led by Nestle with its Maggi product, accounting for around 60% of the market. The leading competitor was ITC, with its Sunfeast Yippee noodles commanding a 22% market share (Malviya, 2018). More recent reports, such as by Gill (2021) and Buildd (2022), also appear to support the market leadership of these two brands. The market shares of smaller competitors were rather inconclusive; however, Statista (2020) suggests that other brands that managed to catch up include CG's Wai Wai noodles, Patanjali by Patanjali Ayurved, and Top Ramen by Nissin. Other sources, such as Madhukalya (2017), Dsouza (2021) and George (2023), also report that Wai Wai noodle has grown to above 20%, overtaking Sunfeast Yippee. However, for the analysis, we will assume that the former holds.

Maggi is the first mover in the Indian instant noodles market, introduced in 1983 by Nestlé, the renowned Swiss multinational. With some repositioning after its launch, Maggi dominated India's instant noodles market with over 90% market share, which persisted for 25 years (Buildd, 2023). The ban on the product due to alleged lead content and labelling issues in 2015 changed the monopoly power, paving the way for new entrants and market share growth for existing players. The clear standout in this scenario appears to be ITC's Sunfeast Yippee (Anand, 2017), which entered the market in 2010, creating a notable disruption in the country's instant noodles industry. Wai Wai, introduced in India in 2003 and jointly owned by the Thai Preserved Food Factory and Nepal's Chaudhary Group, also appeared as a formidable rival to Maggi (Market Feed, 2021). Another significant player in the Indian instant noodles market is Patanjali's Atta Noodles, introduced after the ban and achieved a remarkable growth of 1.3% in just under two years (Anand, 2017). Indo Nissin Foods made its foray into the Indian market in 1991 by introducing its instant noodle brand, Top Ramen, which initially struggled to establish a significant presence in the industry and went on a nearly eight-year hiatus in 2002 and later embarked again on a fresh attempt to compete in the expanding instant noodles sector (Bhattacharyya, 2011).

Over the years, these brands have also used various strategies to secure a market share in the highly concentrated industry. Price comparison of the products under these brands is presented by the results of the ANOVA test and Bonferroni correction for the Indian instant noodles industry illustrated in Table 2.

Similar to the result for the Indonesian case, using net price as a measure of quality shows the prevalence of the principle of minimum differentiation

Analysis of Variance (ANOVA)				
Source			***F***	***Prob > F***
Between groups (Net Price)			0.27	0.893
Between groups (Price per Gram)			5.42	0.001***
Bonferroni correction (Price per Gram)				
Row Mean-Col Mean	*Maggi*	*Patanjali*	*Top Ramen*	*Wai Wai*
Patanjali	-0.100*** (0.003)			
Top Ramen	-0.034 (1.000)	0.066 (0.207)		
Wai Wai	-0.078*** (0.007)	0.022 (1.000)	-0.044 (0.727)	
Yippee	-0.035 (1.000)	0.065 (0.152)	-0.001 (1.000)	0.043 (0.558)

Notes: *** denotes significance at the 1% levels, ** at the 5% levels, and * at the 10% levels
Source: Analysis output based on Instant Noodles Prices Survey in India conducted by authors

Table 2: ANOVA test and Bonferroni correction for the Indian Instant Noodles Industry.

in the quality choice of instant noodles companies in India. When using the price-weight ratio, it also replicates Indonesia's result, significant differences in the means of prices per gram across brands at the significance level of 1%. The Bonferroni correction suggests that the differences do not come from the two biggest companies but rather from Patanjali and Wai Wai. In particular, Patanjali and Wai Wai differentiate their qualities from Maggi by lowering their average prices to target the lower market segment. This finding confirms that the two most prominent companies adopt the principle of minimum differentiation in their quality choices, while the smaller competitors implement the opposite strategy to secure market positions.

Japan

Citing Guo (2020), Japanese instant noodles are renowned for their subtle, natural scent and delicate flavour. Emphasis is often placed on the quality of the soup base, frequently featuring a white broth. Pork bone soup, chicken stock soup, seafood soup, and other varieties commonly incorporate soy sauce and flavour enhancers. Traditional Japanese noodle types include Udon, Soba, and Miso. Japan boasts diverse noodles, including those crafted in partnership with local ramen establishments and renowned dining venues, and health-conscious options low in calories, salt, and fat for discerning consumers.

Data from Piece of Japan in 2021 indicates that among the market leaders in the Japanese instant noodles market are Nissin, which took around 44% of the market and made a revenue of 3.13 billion USD, and Toyo Suisan, with its Maruchan noodles, commanding a quarter of the market share and making a revenue of 2.56 billion USD. The list is followed by Sanyo Foods with its Sapporo Ichiban Noodles (15%), Myojo (8%), and Acecook (8%).

Being the first world's instant noodles, instant ramen by Nissin is both the first mover noodle brand globally and the market leader in terms of market share in the Japanese instant noodles industry. The invention by Momofuku Ando in 1958 was motivated by the food shortage after the Second World War, urging the need for nutritious, inexpensive, and easy-to-prepare ramen dishes (Zelazko, 2023). Surprisingly, despite being the pioneer of instant noodles, Nissin did not appear to monopolise the country's instant noodles market as other players swiftly followed suit with the innovation. Maruchan expanded from its fish storage and distribution venture and ventured into the instant ramen noodle industry three years later, debuting its Toyo Suisan noodles (Maruchan, 2023). According to Sanyo Foods' official website, Sanyo Foods was established in the same year, manufacturing instant noodles and dried noodles at the same time, and the first original Sapporo Ichiban noodles were introduced in 1966. The early 1960s appeared to be a period in which the Japanese instant noodles industry germinated as the industry was deemed lucrative to new and existing business players. According to the company's website, the release of Myojo Flavored Ramen in 1960 by Myojo Foods marked its entry into the instant noodles industry, expanding from dried noodles production that it started ten years earlier. Acecook Japan began its instant

noodles production and introduced 'Beijing Ramen' one year earlier, initially under the company name of Umeshin Seika, focusing on selling soft biscuits.

The Japanese instant noodles industry analysis is not as simple as that for the previous two countries due to the complexity of instant noodles differentiation in the country. Being the origin of instant noodles, the noodles market in Japan is characterised by a distinctively wide variety of instant noodles, which differ not only in the standard dimensions, such as flavour, nutrition, packaging, and price, but also in nature. Several unavailable variants in other countries, such as chilled/frozen ramen and rice noodles combinations, are relatively common in Japan. Moreover, there is substantially more variety of cup instant noodles than pack ones. Consequently, focusing the analysis on the family of pack instant noodles alone may not suffice to explain firms' product differentiation behaviour in the instant noodles industry in the country. Hence, for the Japanese case, we consider both pack and cup noodles and analyse them separately, but we focus on price per gram as the measure of vertical differentiation.

In comparing the price strategies, for the ANOVA test on the family of pack noodles, we include chilled/refrigerated pack instant noodles but exclude frozen ones. While adding to the observation number, this inclusion inevitably leads to less accurate analysis, as chilled instant noodles also seem to exhibit features that are rather different from the regular ones. Moreover, there are very few observations for the Acecook brand since the company mainly produces cup noodles.

The ANOVA test reveals significant differences across the prices per gram of instant noodles in Japan. According to the Bonferroni correction, Toyo Suisan differentiates itself from competitors. Additionally, there is weak evidence that Acecook differentiates from Myojo and Toyo Suisan. The results of the ANOVA test and the Bonferroni correction for the pack noodles category in Japan are not presented here but can be provided on request. Given how imprecisely the products are defined, we turn to cup instant noodles.

Analysis of the family of cup noodles in Japan shows more reasonable results, similar to those of the Indonesian and Indian cases. Table 3 provides the results of the ANOVA test and Bonferroni correction for the Japanese instant noodles industry, with cup noodles as the category of interest. Overall, the ANOVA test shows significant differences in the means of prices per gram across brands. The Bonferroni correction suggests that Sanyo Foods and Acecook differentiate against Toyo Suisan and Nissin, which indicates maximum differentiation. Interestingly, in contrast to the cases of Indonesia and India, the smaller competitors in Japan produce instant noodles of higher quality and aim to attract consumers in the upper market segment, as indicated by their higher average prices per gram. However, the two leading brands, Nissin and Toyo Suisan, appear to implement the principle of minimum differentiation against each other in determining their product qualities, supporting our findings for the Indonesian and Indian cases.

In summary, using prices as the quality measure, we find consistent results regarding firms' vertical

Analysis of Variance (ANOVA)				
Source			***F***	***Prob > F***
Between groups (Net Price)			3.39	0.010***
Between groups (Price per Gram)			14.42	0.000***
Bonferroni correction (Price per Gram)				
Row Mean-Col Mean	*Acecook*	*Myojo*	*Nissin*	*Sanyo*
Myojo	-0.224 (0.122)			
Nissin	-0.453*** (0.000)	-0.229** (0.045)		
Sanyo	0.035 (1.000)	0.259 (0.318)	0.488*** (0.000)	
Toyo Suisan	-0.441*** (0.000)	-0.217 (0.111)	0.012 (1.000)	-0.475*** (0.000)

Notes: *** denotes significance at the 1% levels, ** at the 5% levels, and * at the 10% levels
Source: Analysis output based on Instant Noodles Prices Survey in Japan conducted by authors

Table 3: ANOVA test and Bonferroni correction for the Japanese Instant Noodles Industry.

differentiation strategy for the three countries. In particular, the principle of minimum differentiation prevails in the vertical differentiation of instant noodles, especially for the two leading brands in each country. Brands with smaller market shares appear to strategically discriminate their qualities reflected in product prices to enter and gain a position in the market.

Horizontal differentiation

In the remainder of this section, we discuss descriptively the behaviour of instant noodle companies in horizontally differentiating their products. Most of the information in this section is obtained from each brand's official website. We claim that the principle of maximum differentiation prevails for horizontal differentiation, such that instant noodle companies tend to produce instant noodles with features that are as distinguishable from those of their rivals as possible. Several pieces of evidence support this claim. First, very few to no instant noodle companies produce precisely the same flavour in each country. Second, each brand has at least one unique variant which the brand is famous for, that is completely distinguishable from the products of other brands. Third, many companies attempt to introduce new variants featuring healthier ingredients and higher nutritional content. We discuss this evidence for each of the countries considered above. A table for the summary of the result of horizontal differentiation analysis and the list of the evaluated features for each market is provided in Table 4.

We start with the Indonesian case. Around the execution of this study for this particular part of horizontal differentiation analysis, between January and June 2022, the number of variants listed on the website of each of the brands considered in the Indonesian case is as follows. Indomie, as the market leader in terms of market share, produced 43 flavours consisting of 28 pack variants and 15 cup variants. Mie Sedaap, as the main competitor, had 21 flavours, seven variants of which are cup noodles. Sarimi and Supermi specialised in pack noodles, with Sarimi producing 15 and Supermi 6 variants. Mie Gaga owned 14 flavours, two of which are cup noodles.

These incumbents strive to maintain their market positions by continually introducing new variants to meet consumers' preferences. Many variants imitate the ingredients of local cuisines, such as Indomie Soto Medan, Indomie Empal Gentong, Mie Sedaap Salero Padang, Mie Sedaap Tasty Ayam Geprek, etc. Meanwhile, some embrace famous international flavours, such as Mie Sedaap Korean Spicy Soup, Indomie Taste of Asia Mi Goreng Bulgogi ala Korea, Indomie Mi Kuah Tom Yum ala Thailand, and Indomie Laksa ala Singapura. Meanwhile, new entrants such as Lemonilo and Fitmee attempt to promote healthier options, often featuring non-MSG, low-caloric, and organic instant noodles as an entry strategy. Clearly, both incumbents and new entrants innovate their variants to be as distant from their rivals as possible.

In India, firms appear to horizontally differentiate relatively less aggressively than those in the Indonesian case, at least for the incumbents. According to each company website during the study analysis, Maggi, even with the largest market share, only had 13 flavours, three of which were cup noodles, while Sunfeast Yippee produced 11 variants, including two cup noodles. Nissin seemed to produce the most variants, totalling

Country/Brand	Differentiation Strategy	Features	Highlighted products
Indonesia Incumbents: 1. *Indomie*	Imitate the ingredients of local cuisines and/or adopt famous international flavours.	Local and international flavours	Indomie Soto Medan, Indomie Empal Gentong, Indomie Taste of Asia Mi Goreng Bulgogi ala Korea, Indomie Mi Kuah Tom Yum ala Thailand, Indomie Laksa ala Singapura.
2. *Mie Sedaap*		Local and international flavours	Mie Sedaap Salero Padang, Mie Sedaap Tasty Ayam Geprek, Mie Sedaap Korean Spicy Soup,
3. *Supermi*		Local-cuisine flavours	Supermi Extra Soto Daging, Supermi Opor Ayam, Supermi Sop Buntut
4. *Sarimi*		Local-cuisine flavours	Sarimi Goreng Ikan Teri Pedas, Sarimi Instan Gulai Ayam
5. *Mie Gaga*		Local-cuisine flavours	Gaga Bakmi, Gaga 1000 Soto Mi, Gaga 100 Extra Pedas Kuah Soto
Selected New Entrants: 6. Lemonilo	Promote healthier options.	Made without frying, contains vegetable essences; no additives, preservatives, or artificial food colouring.	Lemonilo Mie Instan Goreng Konjak, Lemonilo Mie Instan Rasa Rendang, Lemonilo Mie Instan Kuah Soto Koya
7. Fitmee		Low-caloric, cholesterol-free, low in sugar, and high in fibre.	Instant Korean Fried Shirataki, Instant Shirataki Soto Flavour, Instant Spinach Noodles Soto Flavour, Instant Shirataki Garlic Chicken

Source: Companies' websites analysed by authors

Table 4: Summary of the Horizontal Differentiation Analysis in each country. (To be continued).

Country/Brand	Differentiation Strategy	Features	Highlighted products
India Incumbents: 1. *Maggi*	Produce several variants resembling local and international cuisines with similar flavours but observable distinguishing features.	Local and international flavours, preparation practicability (served in 3 minutes)	Special Masala Noodles, Maggi Nutrilicious Atta Masala, Maggi Fusian Singaporean Tangy Pepper, Fusian Hongkong Spicy Garlic
2. *Sunfeast Yippee*		Local flavours and vegan options	Yippee Noodles – Classic/ Magic/Mood/ Saucy/ Masala, Power Up Atta Noodles, My Crazy Chow Noodles Vegetarian, Quik Mealz Veggie Delight
3. *Wai Wai*		Local and international flavours, vegetarian options	Atta Noodle Masala Flavor, 1-2-3 Noodles - Veg Masala Flavour, X-PRESS Noodle Masala Delight, Wai Wai Chinese Hakka Veg Noodles
4. *Top Ramen*		Local and international flavours, vegetarian options	Top Ramen Noodles - Curry Veg, Top Ramen Noodles – Atta, Vegetarian Masala Noodles, Cup Noodles Italiano, Scoopies Mad Masala
5. *Patanjali*		Local-cuisine flavours	Patanjali Atta Chatpataa Instant Noodles, Atta Classic Instant Noodles, Atta Noodles Chatpata, Atta Noodles Yummy Masala, Green Chilli Atta Noodles, Veggie Atta Noodles, Atta Noodles Dal Tadka
Selected New Entrants: 6. Marico	Introduce healthier options.	Wholegrain oats and wheat ingredients; no maida; not containing preservatives	Saffola Oodles Ring Noodles Yummy Masala
7. Naturally Yours		High in protein, dietary fibre, and calcium; no maida and chemicals; made with 100% whole grains; suitable for vegans; jain friendly (no onion and garlic); no preservatives, artificial flavours, colours, and MSG; Gluten-free variants	Multi millet noodles, Red rice noodles, Gluten Free Spinach Noodles, Gluten Free Grain Noodles, Gluten Free Multigrain Pasta, Quinoa Noodles, Soya Noodles
8. Slurrp Farm		Made from natural ingredients (millets); maida-free, no refined sugar, palm oil, preservatives, saturated and trans fat, artificial colours and flavours; not fried.	Instant Millet Noodles: Yummy Masala, Mild Masala, Curry Masala; Foxtail Millet Noodles, Little Millet Noodles
Japan Incumbents: 1. *Nissin*	Produce massive numbers of variants, promote healthier options, and introduce lesser-known flavours.	Massive numbers of variants; low calorie and reduced sugar content	Vegetable-rich Tanmen Soy Sauce, Nissin Ramen Shop Flavored Vegetables Shio, Nissin RAOH Tanmen soy sauce with plenty of vegetables
2. *Toyo Suisan*		Massive numbers of variants	Maruchan Noodle Making Chicken Gala Soy Sauce, Vegetables are so good!, Wild vegetable random cut soba,
3. *Myojo*		Lesser known flavours, unique and colourful vegan noodles	Low Carbo Noodles Vegetable Tanmen, Myojo Rocabo Noodles Tanmen with plenty of vegetables, Myojo Delicious Marutto Onion Ramen filled with the flavour of vegetables
4. *Sanyo*		Shorter shelf life and preparation practicability (served in 3 minutes)	Salt Ramen Topped with Vegetable Dashi
5. *Acecook*		Noodle-less ramen using seaweed; "mochichi" type of Ramen and Yakisoba	Dense Vegetables (Salt Tanmen), Ramen Mottich Vegetable Tanmen Shio
Selected New Entrants: 6. Momotaro Shokuhin	Strategise on other dimensions.	Production of halal noodles; fresh, safe-to-consume, delicious and additive-free noodles; Gluten-free options	Healthy Ramen, Healthy Inaniwa Style Udon, Healthy Zaru Soba, Halal Nama Ramen With Shoyu Soup, Halal Zaru Chasoba, Gluten Free Ramen
7. Kibun Healthy Noodles		Sugar-free; only 25 calories per portion; made of tofu lees (soybean fibres), plant-derived cellulose, sodium algenate, konjac yam powder; fat & cholesterol free, gluten-free, dairy-free; free from preservatives; diabetic and vegan friendly; neutral flavour and smell, and smooth mouth feeling	Kibun's Sugar-Free Noodles, Kibun's Tofu-somen—healthy noodles, Isokobachi

Source: Companies' websites analysed by authors

Table 4: Summary of the Horizontal Differentiation Analysis in each country. (Continuation).

29 flavours with only 7 Top Ramen pack noodles. Wai Wai had 18 variants, two of which are cup noodles. Patanjali focused on pack noodles production, owning eight flavours.

Although the market leaders appear to produce several variants with similar flavours, such as masala, horizontal differentiation is still clearly observable. For example, Maggi has Special Masala Noodles, Top Ramen has Vegetarian Masala Noodles, and Sunfeast Yippee has Power Up Masala. The horizontal differentiation behaviour of new entrants in the Indian instant noodles industry exhibits a similar pattern to those in the Indonesian case. Marico, India's market leader in edible oils, launched its Saffola Oodles in early 2021, pitching it as a healthier option among the existing brands for being made of wholegrain oats and wheat and not containing artificial preservatives. Another new brand, Naturally Yours, promoted several variants of gluten-free noodles, incorporating three

main criteria of their products: no maida (white flour), no chemicals, no junk, and the use of whole grains as the main ingredients. Slurrp Farm, a brand started in 2016, offers similar features.

The Japanese instant noodles industry exhibits a slightly different pattern. Being the origin of instant noodles, massively diverse instant noodle varieties are produced in the country. During the analysis, the two market leaders, Nissin and Toyo Suisan, had 262 and 292 variants, respectively; half of Nissin's listed variants were pack noodles, whereas Toyo Suisan had 171 pack variants. These two companies also produce not a small number of frozen noodles. Sanyo Foods had 50 flavours with only 13 pack variants; Myojo had 98, out of which 24 were pack noodles; and Acecook had 48 with only five pack noodles.

The market is also characterised by the strong market power of a few large companies, which continually innovate and diversify their products. Unsurprisingly, new variants are introduced mainly by the competing incumbents instead of new entrants. Apparently, healthy instant noodles are narrowly defined in the country as those with low calorie and reduced sugar content. While nearly all brands produce varieties featuring such quality, they are evidently presented in different flavours. For example, Nissin RAOH has Vegetable-rich Tanmen Soy Sauce, Myojo has Low Carbo Noodles Vegetable Tanmen, Acecook produces Dense Vegetables (Salt Tanmen), Toyo Suisan produces Maruchan Noodle Making Chicken Gala Soy Sauce, and Sanyo Foods has Salt Ramen Topped with Vegetable Dashi. New entrants, realising the market demand, strategise on another dimension instead. For example, Momotaro Shokuhin, established in 2004, started its production of halal noodles in 2015. Kibun went as far as initiating Sugar-Free Noodles, containing only 25 calories per portion in 2013.

Based on the analysis of horizontal differentiation in the instant noodles industries in the three countries above, we conclude that companies indeed produce variants that are distinguishable from their rivals' products. New entrants typically perform market penetration by introducing healthier alternatives to existing instant noodles in the market, while incumbents often promote variants that embrace the tastes of local cuisines. While, in some cases, incumbents produce variants with similar features, there are always apparent differences among the products, such that horizontal differentiation is always exercised. Thus, the principle of maximum differentiation indeed prevails along the horizontal differentiation dimension in the Asian instant noodles industry.

Summarising the findings of this study, firms are shown to apply the principle of minimum differentiation when differentiating products vertically by choosing quality levels, as measured by prices, that are similar to one another. They may focus on providing a baseline level of quality to meet customer expectations without overinvesting in quality features that might not provide a significant competitive advantage. When differentiating horizontally, they apply the principle of maximum differentiation by offering features that set their products apart from competitors. Companies seek to create a competitive advantage and attract customers based on these unique attributes. The possible intuition behind these findings is that it may be more cost-effective for companies to compete on features (maximum differentiation) rather than quality (minimum differentiation) because consumers often have various preferences regarding product features. Additionally, achieving significantly higher quality levels may be more challenging and expensive than creating or adding new product features.

Adopting a minimum differentiation strategy in quality choice might be associated with what Shim et al. (2019) discovered by studying how consumers perceive premium and low-priced food items, with particular representations of premium instant noodles and premium yogurt. They show that adding premium to food items increased negative emotions, such as suspicions about quality and price. This notion might discourage firms from competing using price and quality strategy and focus on a variety strategy instead.

Our finding that minimum differentiation strategy in quality choice is especially valid for the two leading brands in each country, however, is different from what Ueda and Watanabe (2023) show. Their evidence on the Japanese data indicates that firms with larger market shares exhibit more frequent and larger price changes than those with smaller market shares. This discrepancy could be attributed to the fact that our study observes prices and, hence, draws an inference on firms' quality strategy only at a particular time, whereas Ueda and Watanabe (2023) made a multiple-period observation.

Our result on the application of maximum differentiation in the horizontal dimension also aligns with Kesavayuth (2001), who studies

the marketing strategies of MAMA as a leading brand in Thailand's instant noodles market in maintaining its leadership position. In Kesavayuth's (2001) study, it is demonstrated that MAMA places relatively less emphasis on pricing due to the stability of its pricing. Instead, the company primarily relies on promotional tactics to compete with rivals by highlighting its brand awareness through social activities. Within the marketing mix, MAMA prioritises product strategies as the most crucial element, as taste holds the utmost significance. Thus, the company ensures consistent taste quality in each production to sustain consumer loyalty.

Conclusion

This study explores the product differentiation behaviour of instant noodles companies in Asian countries. Based on a research question of how firms in the food industry behave strategically in differentiating their products, the analysis produces several novel findings that bring economic theories into real-life applications. Both theoretical predictions, the principles of minimum and maximum differentiation, are proven true depending on the differentiation dimension. In particular, firms apply the principles of minimum differentiation when differentiating products vertically and maximum differentiation when differentiating horizontally. This result is based on the evidence showing that instant noodle companies choose quality levels, as measured by prices, that are close to one another, especially for the two leading brands in each country. It further reveals that brands with smaller market shares in each country tend to exhibit more evident vertical differentiation behaviour. Meanwhile, when determining the variants to produce, companies tend to introduce variants that are distinguishable from their competitors' products. In addition to bringing the product differentiation theories into a real-life application, this study helps explain how firms in the food products industry behave strategically in differentiating their products.

Understanding such behaviour is arguably necessary for different parties, such as for existing market players in the instant noodles industry in determining the best strategy to deal with their competitors, for potential entrants in learning the market landscapes before deciding on whether or not to enter, and for policymakers in imposing relevant intervention in an oligopolistic market environment. The findings also highlight the importance of the existing theories in the literature as they are proven true in the context of the processed food industry, a barely explored topic in the Economic literature. While providing a rich insight into the industry and the literature, this paper is also subject to some limitations, especially in the limited data used. For future research, it is recommended that a larger and more complete dataset is employed, ideally covering at least the top ten countries with the highest instant noodles consumption worldwide. Moreover, it admittedly uses the information on market share readily available in the respective source instead of processing raw data of each brand's sales in each country and calculating the market share accordingly. A more accurate market size could be redefined, more specifically, using a better-quality dataset. Finally, the reference to Economides (1989) suggests that the hypothesis is grounded in economic theory and previous research, providing theoretical support for these principles of differentiation in the context of business strategy or industrial organisation. However, it is important to note that this hypothesis should also be tested through empirical analysis in other contexts to determine whether it holds across different industries and markets.

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Analysing Household Food Consumption in Turkey Using Machine Learning Techniques

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Abstract

The fluctuations in food prices have highlighted the significance of analysing the factors influencing household food consumption. Recent advancements in data analysis have opened new avenues for investigating this subject. While studies have employed novel data analysis methods to examine the factors impacting household food consumption, the effect of the chosen analysis method on the research outcome remains unexplored. In this study, we aimed to investigate household food consumption in Turkey between 2012-2019 using various data analysis techniques (Linear Regression, Support Vector Machine, Random Forest, eXtreme Gradient Boosting, and Multi-Layer Perception). Our findings reveal that income emerged as the most influential factor in household food consumption across all methods. However, the impact of other factors varied depending on the method employed. This suggests that the method chosen to analyse factors other than income in studies of this nature can significantly impact the results. Researchers should exercise caution when selecting their analysis method..

Keywords

Machine learning, data analysis, food consumption, income.

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Introduction

Investigating household food consumption behaviours has been a long-standing area of scientific research. The pioneering studies in this field include those of David Davies and Frederick Eden in the 18th century and the work of Frederick Le Play and Edouard Ducpetiaux. Ernst Engel's contributions in the late 19th century, particularly in economics, were seminal, resulting in the formulation of Engel's law (Engel, 1857). Subsequently, numerous scientists have researched household food consumption behaviours, building upon the foundations laid by Engel.

Research on this topic has often focused on the effects of household income on food consumption. The impact of income on household food consumption has been examined by Staudigel and Schröck (2015) for Russia, Tiffin and Tiffin (1999) for England, Balli and Tiezzi (2010) for Italy, Holcomb, Park, and Capps (1995) for the USA. For worldwide, Clements and Si (2018) examined how the food composition of households is formed and what factors are affected.

The focus of these studies has generally been the impact of household incomes. However, studies in the literature examine the effects of other factors on household food consumption. For example, on issues such as food subsidies and the effects of income and price policies, Unnevehr et al. (2010); household size, Baragani et al. (2009); household location and housing tenure, Lund and Derry (1985); education level of women, Rae (1999); age, gender and etc., Göktolga et al. (2006) have been researched.

While these researches on the food consumption of households are being carried out worldwide, similar studies have been carried out in Turkey. Because it can be predicted that the food prices index, which has increased in recent years, affects the food consumption of households in Turkey. On the other hand, econometric analysis methods and multivariate statistical analysis have usually been used in these studies up to now. These studies generally used econometric analysis methods such as AIDS, the Working-Leser model, etc. However, depending on the changes in data analysis methods, it is possible to deal with the issue with new

methods, such as Machine Learning (ML).

Studies using these new analysis methods, such as ML, are quite new in the literature. ML is frequently used for some estimation problems. Moreover, ML methods are also becoming widespread in food consumption research. Martini et al. (2022), Deléglise et al. (2022) are a few of the current studies using these techniques in food consumption research. The use of ML to analyze the relationship between household food consumption and other household characteristics is one of the important aspects of this study.

This study aims to investigate the factors influencing food consumption in households in Turkey using various analytical methods. By doing so, we aim to understand the impact of different analysis techniques in this field. Furthermore, our study seeks to take into account the latest global and national developments in the field and provide valuable insights and recommendations for researchers working in this area of study.

Materials and methods

Data

The data used in the research was created from the Household Budget Survey cross-section micro data set collected for 2012-2019 by the Turkish Statistical Institute (TURKSTAT). The data set contains information on 89.135 households. Household Budget Surveys is a comprehensive data set used to determine households' monthly consumption expenditures, especially in creating the consumer price index. Households are visited 8 times a year on average by TURKSTAT officers, and data are collected. Households are selected to represent Turkey. This survey includes consumption, income, and various household characteristics. This survey details the economic status of a Household, including demographic status etc. The survey also accounts for household members' age, gender, education, and employment status. Descriptive statistics of the variables used in the study are given in Table 1.

Problem formulation

Within the scope of the research, the prices of the products consumed by the households will not be dealt with. For this reason, econometric demand models such as AIDS or QUAIDS, frequently used in this type of research, are unsuitable. Working-Leser (Working, 1943; Leser, 1963), a model that does not include price data, was used to measure the effect of household income on food demand.

$$W_F = B_0 + B_1 LN_{INCOME} + E_F \quad (1)$$

where: W_F represents the average monthly food expenditure ratio in total monthly household income (Average Monthly Food Expenditure/Total Monthly Household Income), LN_{INCOME} represents the natural logarithm of total monthly household income, and E_F represents the error term.

When other variables that are predicted to affect the food consumption of the households are added to the model, the model is established as follows:

$$W_F = B_0 + B_1 LN_{INCOME} + B_2 A + B_3 HS + B_4 SG + B_5 HO + E_F \quad (2)$$

where: A represents the age of the head of the household, HS represents the number of people living in the household, SG represents the educational institution where the household head last graduated, HO represents whether the family owns a home.

Methods

Linear Regression (LR)

Regression is a statistical method to determine the linear and nonlinear relations between a dependent variable and one or more independent variables. The regression approach can be

Variables	Description	Mean	Std. Dev.
Household food expenditure share	Share of food expenditures in total household expenditures (%)	25.71	13.82
Income	Household total monthly income (TL)	3667.32	3575.71
Age	Age of the head of the household	50.17	14.65
School Graduation	The educational institution where the household head last graduated (1: not graduated from school; 2: primary school; 3: secondary school; 4: high school; 5: university)	2.80	1.29
Household Size	Number of people living in the household	3.53	1.83
Home Ownership	1 if the residence is property, 0 otherwise	1.24	0.42

Note: Household Budget Survey is calculated using 2012-2019 data.
Source: Author´s work

Table 1: Descriptive statistics.

named single or multiple regression according to the number of independent variables. A simple linear regression model is illustrated in Figure 1 where the lines between the regression line and data points indicate the prediction errors. The regression line here can be determined by minimizing the sum of squares of the prediction errors.

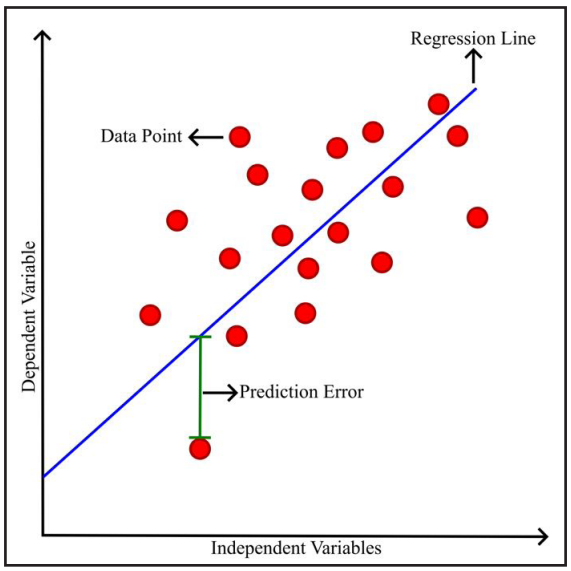

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Figure 1: Linear regression model.

Multiple linear regression extends simple linear regression to include more than one independent variable. The basic multiple linear regression model is defined as follows

$$Y = B_x + c \quad (3)$$

where: Y is the dependent variable, $X = (1, x_1, x_2,\ldots, x_n)$ represents the independent variable, $B = (B_0, B_1,\ldots, B_n)$ represents the predicted coefficients of the independent variable, and c represents the constant. The coefficients of the independent variables can be estimated by the least square method (Grégoire, 2014).

Support Vector Machine (SVM)

The support vector machine (SVM) algorithm originated by (Boser et al., 1992) is a supervised machine learning method that is based on the statistical learning theory, and it can be applied to both linear and non-linear datasets for classification and regression purposes (Trafalis and Gilbert, 2007; Xu et al., 2009). Assuming that the number of features in the dataset is n, the SVM algorithm maps each item in the dataset into an n-dimensional feature space. Then it selects a hyperplane to divide items in the dataset into two separate classes. This hyperplane is selected to maximize the marginal distance, which is the distance between the selected hyperplane and the nearest data item of a class (Vapnik, 2000; Xu et al., 2009). A simplified version of an SVM classifier is illustrated in Figure 2 where the hyperplane is defined to differentiate two classes by the maximum marginal distance. By defining the hyperplane that results in possible prediction errors, the SVM algorithm can be used for regression tasks to make accurate predictions.

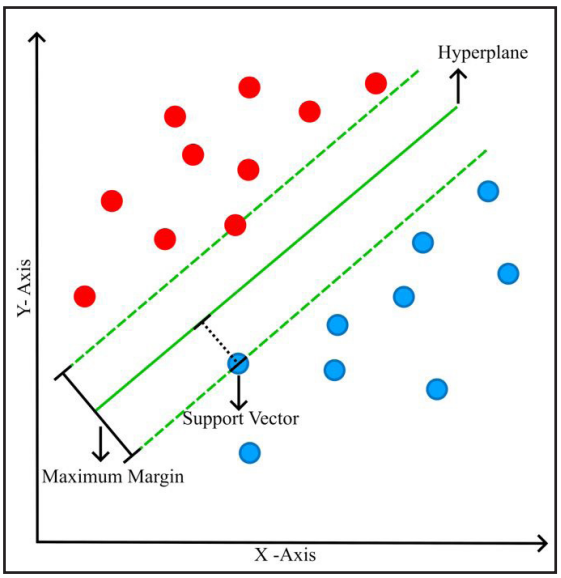

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Figure 2: A simplified illustration of the support vector machine model.

Random Forest (RF)

The decision tree method, which models the data items in a dataset into a tree-like structure for classifying them, can be considered one of the earliest machine learning approaches (Breiman, 1998). In this approach, the nodes on the tree-like structure have three major categories. The top-level node is called the root node; every node with at least one child node is called an internal node, and nodes with no child nodes are called a leaf node or a terminal node. All internal nodes in a decision tree represent tests on attributes of input, based on the results of these tests, the algorithm moves to the appropriate child node, and this process repeats until reaching a terminal node which represents a decision as shown in Figure 3.

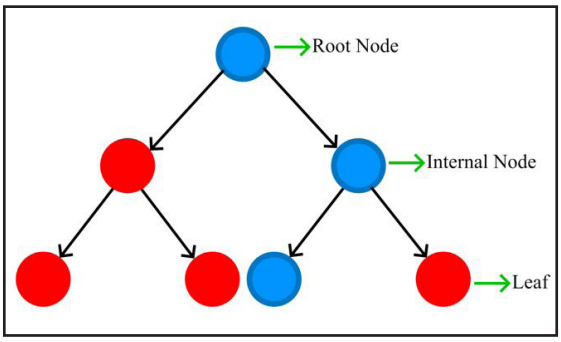

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Figure 3: Decision tree.

The random forest approach can be considered as a collection of many decision trees, and it can be used for both classification and regression tasks (Breiman, 2001). Decision trees are quite sensitive in their training; this can make them error-prone to test data and lead to overfitting on training data. To prevent these drawbacks, different decision trees can be trained using random parts of the training data on the random forest approach, as shown in Figure 4. Each decision tree dives into a decision, and the RF algorithm takes the mean of these individual predictions to solve regression tasks.

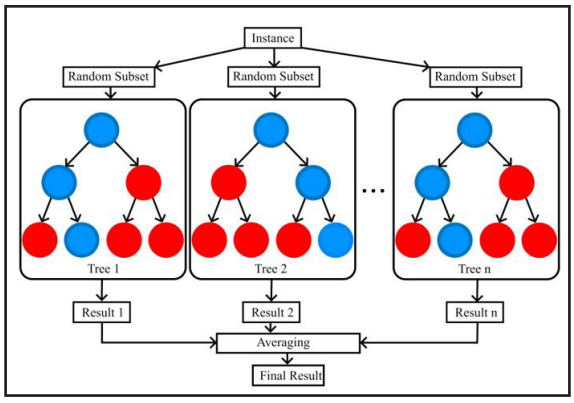

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Figure 4: Simplified structure of Random Forest.

eXtreme Gradient Boosting (XGBoost)

XGBoost stands for extreme gradient boosting, which is a very efficient ML method based on a gradient boosting algorithm proposed by (Chen and Guestrin, 2016). Basically, the XGBoost approach employs multiple DTs as in the RF algorithm. However, unlike the RF algorithm, the boosting algorithms' trees are connected sequentially. XGBoost is an iterative DT algorithm where it adds a new tree each time by learning a new function to fit the residual of the last prediction, as shown in Figure 5. When a predefined number of trees are obtained after training, XGBoost combines the predictions of each individual tree by weighting them according to their relative importance as the predicted value instead of voting.

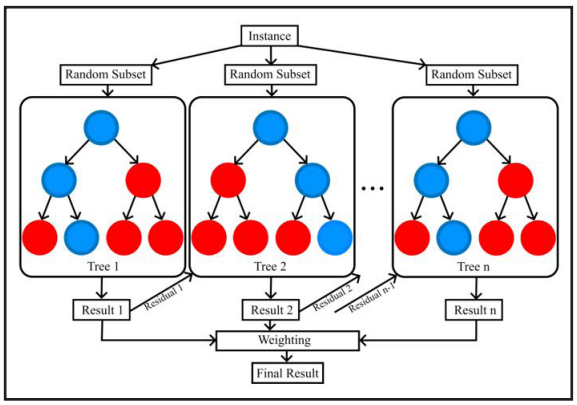

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Figure 5: Simplified structure of XGBoost.

Multi-Layer Perception (MLP)

Artificial Neural Network (ANN) models are inspired by the ability of human neurons to generate new logical results based on previous experiences (Rumelhart et al., 1986; Hill et al., 1994). Neurons in the human brain are connected to each other through axons. Similar to that graph-like architecture, the ANNs can be modelled as interconnected groups of different groups of neural networks. These types of ANNs are called as Multi-Layer Perceptron (MLP) neural networks. MLP architecture includes at least one hidden layer apart from an input layer, one or more hidden layers, and an output layer. Every layer consists of one or more nodes, and the output of one node goes as input of another node. Edges have weights, so input values are multiplied by weights while transmitting to the next layer. In the end, the output layer produces the final output by the values computed in the hidden layers. The MLP neural network updates randomly selected weight values based on the training data and can make a prediction for the test data. The general structure of an MLP neural network is illustrated in Figure 6.

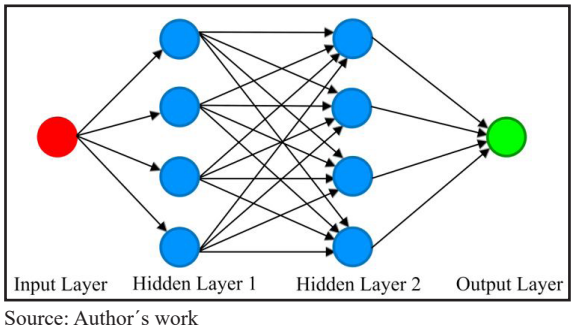

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Figure 4: Simplified structure of Random Forest.

Experimental Setup

In this study, a series of experiments were conducted using LR, SVM, and MLP models, along with RF and XGBOOST models. The LR model was trained using default parameters from the scikit-learn library (Pedregosa et al., 2011), while a linear kernel was employed for the SVM model. The MLP model was configured with two hidden layers, each containing 50 neurons. Additionally, an early stopping criterion enabled to prevent overfitting.

On the other hand, RF and XGBOOST models fine-tuned using the Fast Library for Automated Machine Learning & Tuning (FLAML) developed by Microsoft (Wang et al.,2021). FLAML is a Python library that automates machine learning model selection and hyperparameter tuning. Instead of employing a grid search, FLAML takes the available computing time as a parameter and attempt to identify optimal hyperparameters within the allotted time.

For this study, the RF and XGBOOST models were optimized for 1 hour on a Windows workstation featuring an Intel Core i7 3.5 GHz CPU and NVIDIA GeForce GTX 1070 (8 GB) GPU. This methodology facilitated the identification of the most suitable hyperparameters such as number of trees and number of tree levels, to achieve optimal performance of the RF and XGBOOST models.

Evaluation Metrics

To assess the overall performance of the models, three widely used evaluation metrics are used, namely, Root Squared (R2), Root Mean Squared Error (RMSE), and Mean Absolute Error (MAE). Equations of the metrics are given below.

$$R2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2} \quad (4)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \quad (5)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n} | y_i - \hat{y}_i |^2 \quad (6)$$

where: y_i and $\hat{y}_i$, are the ith actual value and the ith predicted value among n samples, and $\bar{y}$ is the mean of the y values. The smallest RMSE, MAE values indicate the highest prediction accuracy.

Results and discussions

Experiments have been performed with the five ML models. Since the correlation between food consumption and household income can be directly evaluated through the coefficients acquired by the LR model, in this study, the LR model was considered as the baseline. According to these coefficients, it is possible to calculate the ratio of change in food consumption depending on the change in each household income parameter. The coefficients acquired by the LR algorithm are given in Table 2.

To evaluate the performance of the models, R2, RMSE, and MAE scores of the prediction processes carried out with both the LR algorithm and other ML algorithms are given in Table 3. The models were evaluated by performing a five-fold cross-validation. Results show that the SVM model gives almost the same results as LR, while the RF, XGBoost, and MLP models give better results.

Although it is possible to make better predictions with RF, XGBoost, and MLP algorithms, these algorithms do not provide information about how much each household income parameter directly affects the ratio of food consumption. On the other hand, it is possible to find out how much each feature affects the ML models' prediction performance. Accordingly, the magnitude of the LR coefficients

BIAS	A	SG	HO	HS	LN_{INCOME}
63.73	0.20	-0.99	-3.04	1.52	-6.75

Note: *A* - age of the head of the household; HS - the number of people living in the household; SG - the educational institution where the household head last graduated; HO - whether the family owns a home.
Source: Author´s work

Table 2: Acquired coefficients of the LR models on the food consumption dataset.

	LR	SVM	RF	XGBOOST	MLP
R2	0.25	0.24	0.28	0.29	0.29
RMSE	11.89	11.99	11.69	11.63	11.62
MAE	9.04	8.92	8.89	8.83	8.80

Source: Author´s work

Table 3: R2, RMSE, and MAE scores of the LR, SVM, RF, XGBOOST, and MLP models.

(the correlation between food consumption and household income) can be discussed depending on the feature importance scores of the LR and other ML models. In this study, the permutation importance (PI) algorithm was used to calculate the effects (importance) of the features on the prediction performance of the models. The acquired feature importance values are given in Figure 7.

With the given figure, it is seen that there is a consistency in the feature importance values; that is, all models give similar importance values to similar features. On the other hand, if the table features are examined in detail, it is clearly seen that the LNINCOME feature contributes the most to the prediction process. However, LN_{INCOME} is less important in ML models with a relatively high success rate, such as LR. Considering these values, it can be stated that LN_{INCOME} should affect the food consumption ratio less than the value given in Table 3. Furthermore, the second most important feature, *HS*, is more important in better models. Therefore, it can be concluded that *HS* affects food consumption more than the value given in Table 3. Similarly, according to the feature importance values, it can be concluded that *HO* and the *SG* features should affect food consumption more than the coefficient values given in Table 3. On the other hand, it is seen that the LR and SVM models with a low success rate and the MLP model with a high success rate give almost the same importance value to the *A* feature. Therefore, it is impossible to say anything definite about feature *A*, only considering its importance scores.

Previous studies on the factors influencing household food consumption have primarily focused on product-specific calculations, particularly those related to calorie content, making it difficult to compare their findings. However, our findings on the values of factors affecting food expenditure in Turkey are similar to those found in previous studies. Akbay et al. (2007) identified income as the most significant factor affecting household food expenditure. However, they reached varying conclusions about the impact of other factors. Our study demonstrates that the importance of factors varies depending on the analysis method used, with income being the most crucial factor. Overall, the literature suggests that income is the primary factor influencing food expenditure, but the effectiveness of other factors may vary depending on the analysis method employed.

Conclusion

In this study, the factors affecting food consumption were examined using the consumption data obtained from approximately 89 thousand households in Turkey between the years 2012-19. Consistent with Engel's Law, it was found that as the income of the households increased, their share of food expenditure decreased. It has been observed that this result is in parallel with other studies in the literature. However, the level of importance of the effects of factors other than income varies according to the analysis method. In this research, five different models, including Linear Regression (LR), Support Vector Machine (SVM), Random Forest (RF), XGBoost, and Multi-Layer Perceptron (MLP).

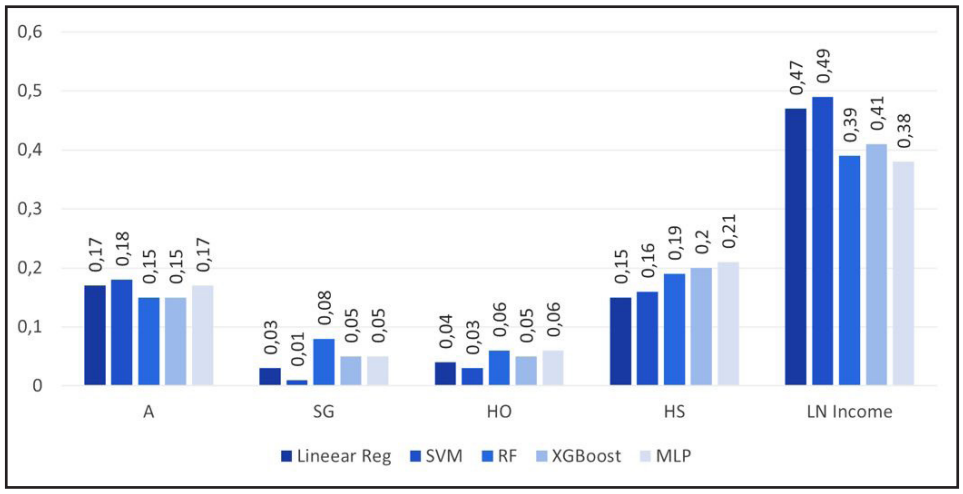

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Figure 7: Feature importance scores of the food consumption features according to the PI algorithm on the ML models

When these different analysis methods developed in the literature in recent years are compared, it is seen that XGBOOST and MLP models have higher R2 values and lower RMSE and MAE values compared to other methods. The LN_{INCOME} variable was calculated to be the variable with the highest significance level, consistent with previous studies. However, it was determined that the order of importance and values of other variables changed according to the analysis method. According to the LR, SVM, and MLP methods, the least effective variable on the food expenditure ratios of the households was *SG*; According to the RF method, it is the *HO* variable. According to the XGBoost method, *SG* and *HO* variables are equally important and least effective.

In conclusion, our research demonstrates that the choice of analysis method significantly impacts the results when examining household food consumption rates in Turkey. Future studies should consider utilizing new analysis methods to investigate the distribution of food consumption and the factors influencing it. Additionally, evaluating the effects of economic and food crises in the 2000s on food consumption through these novel methods could yield valuable insights for policymakers when formulating social policies. Furthermore, determining the impact of various household characteristics on food consumption using different analysis methods can assist in identifying key policy focus groups.

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The Role of Social Media on Green Food Consumption Intention in Hanoi, Vietnam

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Abstract

This study aims to discuss the role of social media in shaping consumer attitudes in the Vietnamese context. The research examines the impact of green attitude, green customer value, and social media on environmental concerns, subjective norms, and perceived green value concerning green consumers' food purchase intention. The study utilizes data from a survey conducted among 483 consumers in Hanoi, Vietnam, and adopts the Theory of Planned Behavior (TPB) as the initial framework for studying green food purchase intention. We modify and extend the TPB model by incorporating cultural, social, and personal psychological factors relevant to green food consumption. The findings of this study contribute to the understanding of the factors influencing consumer purchase intention in Hanoi, Vietnam. The results demonstrated the influence of social media on subjective norms, environmental concerns, and perceived green value, which in turn affect green food purchase intention among Vietnamese consumers. These results imply that to increase green food preferences among consumers, governments should also consider social media-based education programs to build an understanding of green food and sustainable consumption and emphasize the outstanding benefits of green products for the environment and society. In addition, marketers should pay attention to providing complete information and advertisements about green food products on social media.

Keywords

Green consumption, green food, green food purchase intention, social media, TPB.

Phuong, N. V., Mai, N. T. N., Mergenthaler, M., Cuc, L. T. and Quynh, P. N. H. (2024) "The Role of Social Media on Green Food Consumption Intention in Hanoi, Vietnam", *AGRIS on-line Papers in Economics and Informatics*, Vol. 16, No. 2, pp. 107-120. ISSN 1804-1930. DOI 10.7160/aol.2024.160208.

Introduction

In recent decades, due to global warming and climate change, governments, enterprises, researchers, and consumers have paid great attention to reducing environmental pollution and obtaining sustainable development (ElHaffar, Durif and Dubé, 2020). To achieve sustainable development, efforts should link cleaner production with sustainable consumption (Ali et al., 2023). “Green foods refer to foods that are safe for consumption, fine in quality, and nutritious in meeting the principle of sustainable development” (Rezai, Kit Teng, Mohamed and Nasir Shamsudin, 2012, Golnaz, 2012). Therefore, green food consumption has been recognized as an environmentally significant behavior contributing to preventing non-environmental practices of manufacturers (Mohd Suki and Mohd Suki, 2015). Many studies concentrate on green food consumption in worldwide countries to emphasize that consumers can contribute to sustainable development through their sustainable consumption (Yang, Tang, Cheung and Zhang, 2021, Bryant et al., 2019, Suhartanto et al., 2022).

In the recent literature, various studies have determined factors and mechanisms that motivate consumers to change their behavior toward green food consumption. Some studies have paid attention to analyzing the relationship between psychological, sociodemographic, and socioeconomic factors with green food purchase behavior (Wang and Wang, 2016, Witek and Kuźniar, 2021). For example, Rustam, Wang and Zameer (2020) investigated the influence

of consumers' perceptions and relational quality on their environmentally responsible behaviors, consumers' attitude towards green purchases, social trust and consumers' subjective norms can also affect their purchase intention (Nguyen et al., 2019, Nuttavuthisit and Thøgersen, 2017). Besides, Allen and Spialek (2017) determined gender inequality that affects a household's decision to adopt green consumption. Several studies suggest that environmental knowledge has a significant effect on consumer's intention to purchase green products (Dong, Jiang, Zeng and Kassoh, 2022, Wang, Nguyen and Bu, 2020). Previous studies also have provided substantial evidence on the factors influence of media including print media, electronic media, and social media on green purchases and green food consumption. Especially, social media has transformed the way of customers and businesses in selling green products, communicate, engaging shopping experiences (Chen and Lin, 2019). The impact of social media on consumer behavior and purchase intentions including the green food market has been extensively studied in several countries (Sun and Xing, 2022, Zorell, 2022).

In emerging countries such as Vietnam, the concept of green food is relatively novel, and a significant portion of consumers remains hesitant to embrace it (Nguyen and Dekhili, 2019, Anh et al., 2022). The primary factors contributing to this reluctance are economic challenges and a lack of established green purchasing habits, so manufacturers often prioritize price considerations over quality and food safety (de Koning et al., 2016, My, Rutsaert, Van Loo and Verbeke, 2017). Consequently, a shift in consumer attitudes towards green food could potentially prompt producers to modify their production methods to align with changing consumer preferences (Anh et al., 2022, Quynh et al., 2023). Given this context, the identification of factors influencing green food purchase intentions in Vietnam becomes imperative, assisting green food producers in understanding and adapting their practices to meet consumer needs and gradually fostering greater acceptance of green food. While a substantial body of research on Vietnamese consumers' purchase intentions of green food has utilized theoretical frameworks from Western developed countries, the Theory of Planned Behaviour (TPB) emerges as one of the most widely employed psychological theories (Boobalan, Nawaz, Harindranath and Gajenderan, 2021, Xie and Rasool, 2023, Nekmahmud, Naz, Ramkissoon and Fekete-Farkas, 2022). However, there exists a noteworthy research gap, with limited studies specifically measuring consumers' purchase intentions in Vietnam with a focused emphasis on social media influences, utilizing the TPB framework. Specifically, the mediation role of social media in influencing green food consumption intentions through variables such as green product knowledge, subjective norms, environmental concerns, and perceived green value remains insufficiently explored. Addressing this gap in the literature is crucial for obtaining a nuanced understanding of the socio-cultural dynamics in Vietnam and offers valuable insights for both academic and practical applications in the realm of green food adoption

This research aims to address an existing research void by investigating the role of social media in shaping consumer perceptions within the Vietnamese context. To achieve this aim, we use data from a survey including 483 consumers in Hanoi – the capital of Vietnam. Findings from this study can help understand consumer behavior to propose the government's policy and enterprise's marketing strategies to encourage green food purchases in Vietnam. The Theory of Planned Behavior (TPB) has been chosen as the initial framework to study green food purchase intention. We modify and extend the TPB model by introducing cultural, social, and personal psychological factors toward green food consumption. Consequently, this study try to answer the questions of how social media influences green product knowledge, subjective norms, environmental concerns, and perceived green value toward green food purchase intention. This led to the outline of the antecedents of green food purchase intentions among Hanoi consumers.

Firstly, green product knowledge can have a significant impact on consumer purchasing intentions. The positive impact occurs when consumers know that a product is good for them, they will buy more. Conversely, if a product is not good for consumers, they will buy less (Dong, Jiang, Zeng and Kassoh, 2022). With knowledge about the product, consumers will have more confidence in it, thereby promoting them to make a purchase(Lam, Heales and Hartley, 2020). According to Ghali (2020), Tunisian consumers purchase organic food because they believe that using organic products is good for their health. From the findings above, the Hypothesis 1 is developed: *Green product knowledge has a positive impact on green food purchase intention*.

Secondly, the environmental concerns of consumers

have become increasingly important in sustainable development. When consumers are concerned about the environment, they will have a better understanding of it, and therefore take actions that cause less harm to the environment (Suhartanto et al., 2022). A previous study sampled consumers in Hong Kong, China and showed that environmental concerns strongly influence consumer attitudes (Sh. Ahmad, Rosli and Quoquab, 2022). It is also recognized that environmental concern has a positive impact on the intention to buy organic food among young Chinese consumers (Joo, Seok and Nam, 2020). Environmental concern is the main motivation for the intention to purchase organic food (Santhoshkumar and Kousalyadevi, 2022). Therefore, the Hypothesis 2 is: *Environmental concerns have a positive impact on green food purchase intention.*

Thirdly, subjective norms can have a positive influence on customers' eco-product purchase intention. Subjective norms not only reflect the individual's concern but also the societal acceptance or rejection of certain behaviors and attitudes (Ali et al., 2023). In general, it can be understood that consumers often purchase products not only to satisfy their own needs but also to impact social needs, establish and maintain social relationships, as well as achieve other social functions such as social status (Zorell, 2022). From the perspective of buying green products, subjective norms may be considered as a suggestion for individuals to act and contribute to pro-environmental intentions towards sustainable products. Subjective norms have a significant impact on consumers' intention to purchase green food products (Qi and Ploeger, 2019). In other words, subjective norms had a positive influence on customers' eco-product purchase intention. Thus, the Hypothesis 3 is developed: *Subjective norms are positively related to green food purchase intention.*

Fourthly, perceived green value can be reflected as one of the important contributors to assessing the effectiveness of pro-environmental behavior. Perceived green value can be understood as the overall evaluation of consumers about what they give and receive from a product or service, based on their desire for environmental friendliness, expectations of sustainability, and green needs (Kennedy and Adhikari, 2022). Perceived green value is an attribute related to the perceived value of a product, so it can establish positive word-of-mouth effects and increase green purchase intention. When consumers perceive the green value for themselves and the environment from buying a green product, they will be more willing to purchase it (Zinoubi, 2020). Perceived green value has a significantly positive impact on green purchasing intention. The higher the perceived green value of green products, the stronger the purchase intention of consumers (Zhuang, Luo and Riaz, 2021). From the findings above, the Hypothesis 4 is developed: *Perceived green value has a positive impact on green food purchase intention*.

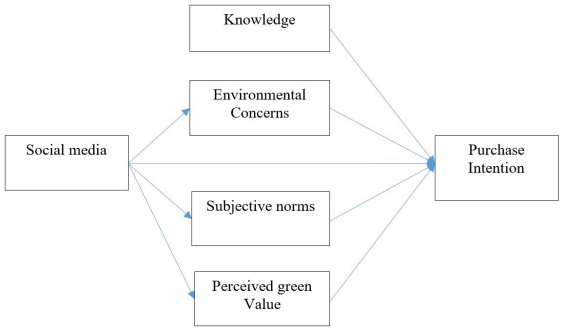
Furthermore, we analyzed the influence of social media on perceived green value and green purchase intention. The social media environment is popular and allows users to be influenced by interactions on social media and shared information content during their browsing and they can interact to take sustainable development actions (Joo, Seok and Nam, 2020). For example, people sharing photos of their use of green products and their experiences with them on social media will encourage others to be more practical and promote awareness of sustainable consumption through tangible actions and promote awareness of sustainable consumption among others (Van Boven, Kane, McGraw and Dale, 2010). At the same time, many retailers of green products post positive messages about the environment and related green product information on social media platforms, thereby stimulating readers' green value perception and positively influencing individuals' purchasing behavior towards green products (Zorell, 2022). It can be seen that social media messages information about the environment also stimulate the perceived green value of consumers, and the higher the perceived green value, the stronger the intention to purchase green products (Sun and Xing, 2022). Hence, the following hypotheses are developed. Hypothesis 5: *Social media has a positive impact on green food purchase intention.* Hypothesis 6: *Social media has a positive impact on perceived green value.* Hypothesis 7: *Perceived green value mediates between social media and green food purchase intention.*

Moreover, the influence of social media on environmental concerns and green purchase intention is analyzed in this research. Social media sharing channels play an important role in environmental communication (Severo et al., 2019). Social media outlets share environmental information, including messages promoting green environmental protection, which is a positive message that benefits people (Tlebere, Scholtz and Calitz, 2016). Some companies share information on social media to encourage green consumer behavior to address environmental

protection issues (Idowu, Capaldi, Zu and Gupta, 2013). For example, Starbucks focuses on green marketing, promoting green ideas about the environment to develop green consumption habits among consumers (Tsai et al., 2020). Exactly, when consumers pay attention to information on social media, they increase their awareness of using environmentally friendly products, which will increase their intention to buy green products (Kang and Kim, 2017). Hence, the following hypotheses are developed: Hypothesis 8: Social media has a positive impact on environmental concerns. Hypothesis 9: *Environmental concerns mediate between social media and green food purchase intention.*

In addition, the influence of social media on subject norms and green purchase intention is described. The interaction and sharing of information on social media allow consumers to feel social pressure, which can influence or be influenced by subjective norms. In a comparative study of Chinese and Korean consumers, it is evident that Chinese consumers' green consumption behavior is positively influenced by external social factors such as collective values and the behavior of their community, family, and friends (Lee, 2017). Moreover, well-known people in sharing information on social media can transmit messages about green lifestyles on social media platforms, e.g., sharing information about green products on social media can increase their fans' environmental awareness (Chwialkowska, 2019). In this way, social factors are important to trigger the Chinese consumer's intention to purchase green products (Podoshen, Li and Zhang, 2011). Hence, the following hypotheses are developed. Hypothesis 10: Social media has a positive impact on subject norms. Hypothesis 11: *Subject norms mediate between social media and green food purchase intention.*

Based on the above hypotheses, a theoretical model (Figure 1) was developed:



Source: Author's proposed model

Figure 1: Conceptual model

Materials and methods

To test the hypotheses depicted in Figure 1, a questionnaire-based survey with face-to-face interviews was implemented among consumers in Hanoi, Vietnam.

Questionnaire development

The data was used in this study collected from the consumer survey through a questionnaire. All items have been widely used and have been validated in previous studies. The questions in the questionnaire were discussed and tested within one group discussion with 7 researchers and lecturers from universities and two groups of consumers in Hanoi with 7-8 people for each group to clarify the meaning of the questions in Vietnamese. However, to avoid misunderstanding, the authors conducted a primary survey with face-to-face interviews 20 consumers and revised the questionnaire before distributing officially the questionnaires to a large number of respondents. The items are measured by five-point-Likert's scales that ranged from 1 (strongly disagree) to 5 (strongly agree). The items and sources used in the questionnaire are described in Table 1.

Data collection method

In this study, the total study population was covered the total number of customers working and living in Hanoi, the capital of Vietnam. In these populations, the samples were selected through convenience sampling technique. The research team has taken a sample size of 501 respondents by interviewing "face to face" in 3 local markets, 5 convenience stores and 2 supermarkets around Hanoi city. The survey was conducted by a group of students from Dec. 2022 to Mar. 2023. The students have been trained to understand the concepts of the items in the questionnaire. The interview time was around 30 minutes on average. Concepts used the questionnaire were explained directly to the respondents such as green food, environmental benefits.

Data analysis method

The data collected from 501 respondents was entered into the Excel template. However, some observations contain missing information or have not been completed. So, the authors have dropped 18 observations. The data set with 483 respondents was used for this study's purposes. Descriptive statistics were used to describe the demographic characteristics of the survey samples. An exploratory factor analysis was conducted, and Cronbach's alpha was used to check

Variables	Items	Explanation	Reference
Knowledge	KNO1	I know the relationship of green consumption and the environment.	Cheah and Aigbogun (2022); (Ghali, 2020); Zameer and Yasmeen (2022)
	KNO2	Human usage of equipment and transportation causes pollution.	
	KNO3	Use of non-recyclable material causes severe effects for the environment.	
	KNO4	Energy usage in production process is also the cause of environmental problem.	
Subjective norms	SNO1	My acquaintances are very responsible for the environment.	Qi and Ploeger (2019); Sun and Xing (2022); Kumar, Manrai and Manrai (2017)
	SNO2	My acquaintances think green purchase behavior is essential for the environment.	
	SNO3	My acquaintances advised me to implement green purchase behavior.	
	SNO4	My acquaintances introduce me to green food.	
	SNO5	My acquaintances support my green food purchase behavior.	
	SNO6	My acquaintances' viewpoints influenced my decision to purchase green food.	
Perceived green Value	PGV1	I buy green food because of the better environmental benefits.	Sun and Xing (2022); (Zinoubi, 2020)
	PGV2	The eco-friendly features of the green food are value for the money for me.	
	PGV3	The environmental performance of the green food meets my expectations.	
Purchase intention	INT1	I will consider purchasing green food.	Zafar, Shen, Shahzad and Islam (2021); (Zameer and Yasmeen, 2022)
	INT2	I want to purchase green food.	
	INT3	I will purchase green food in my next shopping.	
	INT4	I would recommend other people to purchase green food.	
Environmental Concerns	ENC1	I am really worried about the current environmental situation of the world.	Cheung and Services (2019); Zameer and Yasmeen (2022); Ghali (2020)
	ENC2	People at planet should live in harmony to protect nature	
	ENC3	I think humans are creating disastrous consequences for the environment.	
Social media	SOM1	I can use social media information sharing to interact with others about green consumption.	Sun and Xing (2022); Severo et al. (2019)
	SOM2	My engagement with environmental topics on social media sharing has influenced my green food purchases.	
	SOM3	The eco-friendly information shared in social media messages was able to give me easier access to information or feedback on green food.	
	SOM4	On social media, information sharing content about green food is worthwhile and trusted.	

Source: Own, 2023

Table 1: Variables, items, and explanations used in the PLS-SEM.

the internal consistency of the variables.

This study used Microsoft Excel (2010) for descriptive statistical analysis of the sample. Smart PLS (version 3.2.8) software was used for factor analysis. The partial least squares structural equation modeling (PLS-SEM) was used to examine the proposed hypotheses. The PLS-SEM is widely used in green consumer behavior research for several reasons. It handles complex models with multiple independent and dependent variables and does not require normally distributed data. PLS-SEM allows simultaneous analysis of measurement and structural models, providing insights into the latent factors influencing behavior. It also facilitates multi-group comparisons and evaluates the validity and reliability of measurement scales. This method is crucial for examining nonlinear relationships and interactions, making it a powerful tool for understanding the drivers of green consumer behavior and developing effective marketing strategies. To test hypotheses using PLS-SEM, the total sample must be more than 5 times items (Hair, Risher, Sarstedt and Ringle, 2019). In this study, we have 33 items; the total sample must be more than 165 observations, so 483 respondents used for analysis is enough. In addition, this study used a multiple regression method and a Bootstrap method to test hypotheses.

Results and discussion

Profiles of the respondents: The Table 2 shows the characteristics of the respondents. The sample covers all age groups. Around 60% of them are female. Regarding the educational level, almost all respondents have a college and vocational education level or higher. The highest percentages

Variable	Category	Frequency	Percent (%)
Age (years)	< 24	95	19.67
	25 to 34	94	19.46
	35 to 44	95	19.67
	45 to 54	73	15.11
	55 to 64	62	12.84
	> 64	64	13.25
Gender	Male	190	39.34
	Female	293	60.66
Education	Under high school	34	7.04
	High school	48	9.94
	College and vocational	184	38.1
	University & higher	217	44.92
Occupation	Worker	68	14.08
	Farmer	13	2.69
	Officer and staff	202	41.82
	Businessman/woman	91	18.84
	Others	109	22.57
Family annual income (million VN Dong)	< 100	62	12.84
	100 to 199	128	26.5
	200 to 299	152	31.47
	300 to 399	93	19.25
	400	48	9.94
Total		483	100

Source: survey, 2023

Table 2: Demographic characteristics of the respondents (N = 483).

of jobs are officer and staff (40.7%). Most family incomes were 200 to 299 million Vietnam Dong per year.

To assess the reliability of the factors and items, the study used indices such as outer loading, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) (Table 3). Specifically, the single-factor loading coefficient of all items was greater than 0.7 (Hair, Risher, Sarstedt and Ringle, 2019). The outer loading factor value less than 0.7 will be removed from the model and the loading factor value greater than 0.7 means that it has good validity. So, some Items INT4, SNO3, and SNO4 have been removed from the model. The analysis results show that all other factors have an outer loading coefficient greater than 0.7.

All factors have Cronbach's alpha greater than 0.7, indicating that the measurement scales are reliable and can be used in the model (Hair, Risher, Sarstedt and Ringle, 2019, Sarstedt, Ringle and Hair, 2021). AVE and CR are measures of the quality of the items, with AVE being an indicator of convergent validity. The values of AVE and CR range from 0 to 1, with higher values indicating higher reliability. An AVE greater than or equal to 0.5 confirms convergent validity (Hair et al., 2019). Thus, the test results of AVE and CR indicate that the construct is reliable.

The results in Table 4 shows that the diagonal elements of the matrix, which correspond to the square root of the AVE, consistently exceed the diagonal elements of their corresponding rows and columns. This finding provides evidence for the discriminant validity of the scales used in the study (Fornell and Larcker, 1981). Additionally, the items exhibit a stronger correlation with their respective constructs than with other constructs, as most entries in the matrix load above or close to the threshold of 0.50. These results suggest that all constructs can be considered reliable and warrant further investigation into the relationship between the dependent and independent variables (Hair, Risher, Sarstedt and Ringle, 2019).

To find out whether hypotheses can be accepted or rejected based on the value of the path coefficients, t-statistics and p-values were

Items	Outer loading	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Environmental Concerns		**0.85**	**0.907**	**0.766**
ENC1	0.881			
ENC2	0.873			
ENC3	0.872			
Purchase Intention		0.856	0.912	0.776
INT1	0.886			
INT2	0.888			
INT3	0.868			
Knowledge		**0.776**	**0.856**	**0.599**
KNO 1	0.785			
KNO 2	0.771			
KNO 3	0.808			
KNO 4	0.729			
Perceived green Value		**0.758**	**0.859**	**0.671**
PGV1	0.769			
PGV2	0.889			
PGV3	0.795			
Subjective norms		**0.842**	**0.894**	**0.678**
SNO1	0.82			
SNO2	0.807			
SNO5	0.793			
SNO6	0.871			
Social media		**0.862**	**0.906**	**0.707**
SOM2	0.842			
SOM3	0.807			
SOM4	0.824			
SOM1	0.888			

Source: survey, 2023

Table 3: Evaluation of measurement model.

	Environmental concerns	Knowledge	Perceived green Value	Purchase Intention	Social Media	Subjective Norm
Environmental concerns	0.875					
Knowledge	0.345	0.774				
Perceived green Value	0.118	0.214	0.819			
Purchase Intention	0.528	0.463	0.357	0.881		
Social Media	0.350	0.541	0.201	0.401	0.841	
Subjective Norm	0.312	0.417	0.357	0.659	0.331	0.823

Source: survey, 2023

Table 4: Discriminant validity test results.

considered. The research hypothesis testing ledge was carried out using the SmartPLS 3.2.8 software. Based on bootstrapping analysis which the results are interpreted based on the criteria for the t-statistics > 1.96 with a significance size of p-value 0.05 (5%) and the beta coefficient is positive.

From the t-test results, almost all variables are found to influence directly and indirectly

and have significance values. Only Social media does not directly influence green food purchase intention (Table 5). Thus, from the results, we can make decisions for the hypotheses as presented in Table 6.

In combination, the role of social media affected green food intention is shown in Figure 2.

One major finding in our study is the significant influence of four factors (green product knowledge, environmental concerns, and perceived green value and subjective norm) on consumers' intention to purchase green foods. That is, if consumers know that a product is good for them, has less impact on the environment, and can create value for society, they intend to purchase more. This result is consistent with the work of Zameer and Yasmeen (2022), and the study of Sun and Xing (2022), which apply the TPB for green purchase intention. Several other studies suggest that consumers in developing and emerging markets such as Vietnam, pay little attention to environmental quality when making purchasing decisions (Barbarossa and De Pelsmacker, 2016). However, the findings of this study may suggest that Vietnamese consumers increasingly express environmental concerns and perceived green values through their intended purchasing decisions regarding environmentally friendly products. This may be because the respondents

Path Coefficient	Original Sample (Beta)	Sample Mean (M)	Standard Deviation (STDEV)	t Statistics (O/STDEV)	p Values
Direct effects					
Environmental concerns -> Purchase Intention	0.315	0.313	0.044	7.167	0
Knowledge -> Purchase Intention	0.108	0.11	0.036	2.989	0.003
Perceived green Value -> Purchase Intention	0.124	0.122	0.032	3.843	0
Social Media -> Environmental concerns	0.35	0.355	0.045	7.757	0
Social Media -> Perceived green Value	0.201	0.204	0.044	4.517	0
Social Media -> Purchase Intention	0.058	0.06	0.044	1.321	0.187
Social Media -> Subjective Norm	0.331	0.334	0.052	6.403	0
Subjective Norm -> Purchase Intention	0.452	0.451	0.043	10.564	0
Specific Indirect effects					
Social Media -> Environmental concerns -> Purchase Intention	0.11	0.111	0.019	5.719	0
Social Media -> Perceived green Value -> Purchase Intention	0.025	0.025	0.009	2.712	0.007
Social Media -> Subjective Norm -> Purchase Intention	0.15	0.15	0.021	7.254	0

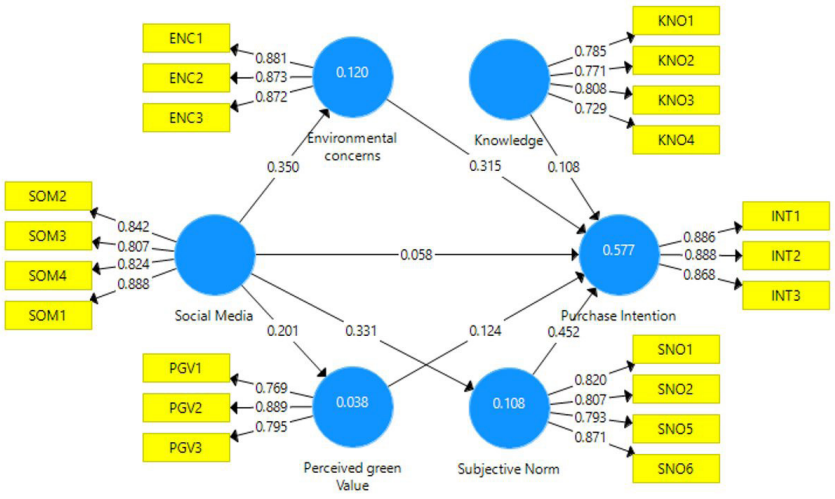
Source: survey, 2023

Table 5: Path coefficient and total indirect effect of the structural model.

	Hypotheses	Decision
H1	Green product knowledge has a positive impact on green food purchase intention	Accepted
H2	Environmental concerns have a positive impact on green food purchase intention.	Accepted
H3	Subjective norms are positively related to green food purchase intention	Accepted
H4	Perceived green value has a positive impact on green food purchase intention.	Accepted
H5	Social media has a positive impact on green food purchase intention.	Rejected
H6	Social media has a positive impact on perceived green value	Accepted
H7	Perceived green value mediates between Social media and green food purchase intention.	Accepted
H8	Social media has a positive impact on environmental concerns.	Accepted
H9	Environmental concerns mediate between Social media and green food purchase intention.	Accepted
H10	Social media has a positive impact on subject norms.	Accepted
H11	Subject norms mediate between Social media and green food purchase intention.	Accepted

Source: survey, 2023

Table 6. Decision for t-test Hypotheses.



Source: survey, 2023

Figure. 2. Structural Model.

in this study were urban consumers, and a large number of them were middle and high-income earners. These consumers are likely to care more about the environment and social values. The result shows that subjective norms also significantly impact green food purchase intention and is consistent with the results of Ali et al. (2023) and Rathnayaka and Gunawardana (2021). Consumers in Vietnam are quite influenced by social relationships such as their families, friends, professionals, or others around them to purchase green food products. This is partly because of Vietnamese culture, consumers are often concerned with other people's opinions and consider their interests when making purchase decisions (Van Tran and Nguyen, 2021).

Most importantly, the findings in this study indicate a crucial role of social media in changing consumers' environmental concerns, subjective norms, and perceived green value over the consumption of green food and these results are consistent with the results of Kang and Kim (2017) and Elahi, Khalid and Zhang (2022). Furthermore, the finding of this study is that social media does not positively impact green food purchase intention. This appraisal stands in contrast to the results of de Lenne and Vandenbosch (2017) and Zorell (2022), which show the importance of social media in changing green purchase behavior. The finding of this study provides new insights into the relationship between social media and green food purchase intention in Vietnam. Vietnamese consumers seem quite less influenced by social media when purchasing green food. However, the result indicates that social media indirectly impacts green food purchase intention through consumers' environmental concerns, subjective norms, and perceived green value. This shows the role of social media in changing consumer behavior in Vietnam.

Conclusion

Overall, this study provides insights into Hanoi consumers' perception on social media and other factors and how these factors influence their purchase intention. The results of structural equation analysis confirm the role of social media to green food consumption. The study aimed to investigate the mediating role of environmental concerns, subjective norms, and perceived green value from social media on green consumers' food purchase intention. The findings of this study contribute to understanding the determinants of consumer purchase intention in Hanoi / Vietnam and help policymakers and food enterprise managers use social media in their marketing strategies to encourage green food consumption in Vietnam. These results imply that in order to increase green food preferences among consumers, governments also should consider social media-based education programs to build an understanding of green food and sustainable consumption and emphasize the remarkable advantages of green products for both the environment and society. In addition, marketers should pay attention to providing complete information and advertisements about green food products on social media. These may help consumers to evaluate products' safety and their good effect on the environment and society to promote their consumption.

Furthermore, to increase the intention to buy green food products from individual consumers, businesses should focus on affecting the people around them. For instance, creating consumer groups and improving communication within the group, or leveraging social influence, such as utilizing celebrities, can be an effective approach to promote and provide advice on green product consumption.

The result also implies that government authorities should facilitate stronger media and improve social media quality to strengthen their influence on customers. At the same time, the government should issue regulations on information transparency and sanction manufacturers who falsely advertise their products on social media to protect the interests of consumers. Besides, businesses can use a combination of other communication channels instead of just focusing on social networks. For example, improving print and electronic media, and increasing in-store communication using brochures, fliers, signage, and staff consultation.

By extending the TPB, this study contributes novel evidence regarding the mediation effect of social media through environmental concerns, subjective norms, and perceived green value on green consumers' food purchase intention. This helps green marketers develop their marketing strategies through social media channels to target increasing green food consumption. Firstly, to influence consumers' environmental concerns and perceived green value, government agencies should make more effort to popularize the green concept on social media and convince consumers to change their consumption behavior toward green food products. Policymakers can use advertising to persuade consumers that they will greatly contribute to protecting the environment and improving society when they consume more environmentally friendly food products. Food enterprises should also engage consumers through advertisements that emphasize the long-term benefits of green food products for the environment and society. Secondly, in order to impact consumers' subjective norms, the important strategy is using social media to review and share experiences and lessons from experts, and scientists who may give advice on the benefit of eco-friendly products. The results contribute to enhancing environmental awareness and social trust to engage Vietnamese consumers in positive activities that benefit the environment and society.

However, our study is not without limitations. As our dependent variable is intention to purchase and not real purchase decisions, we can only speculate about the reasons for this obvious gap. There is extensive literature on the intention-behavior-gap related to sustainable food purchases. Future research should specifically look at this aspect concerning green food purchases in Vietnam. Also, our sampling procedure as a convenience sample does not allow us to define any specific inference population. Our recruitment strategy might have led to systematic sample selection biases. It should be the objective of future studies to generate more representative samples. This research was conducted in Hanoi, Vietnam and it would be interesting for future research to include other areas.

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Fish-NET: Advancing Aquaculture Management through AI-Enhanced Fish Monitoring and Tracking

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Abstract

This study seeks to enhance aquaculture and fishery management using artificial intelligence, focusing on Nigerian catfish farming. The methodology encompasses a sequence of steps from data collection to validation. A dataset, primarily composed of aerial imagery from catfish ponds and supplemented with additional data from the internet, formed the foundation of this research. By leveraging computer vision and deep learning techniques, the data were processed to assess the potential of the three distinct cutting-edge object detection models. Based on various evaluation metrics to gauge their effectiveness in fish detection tasks, the Faster R-CNN emerged as the optimal model, boasting a superior balance of precision and recall. This model was subsequently integrated with an object-tracking model and deployed as an application, yielding promising results in terms of fish detection and tracking. The findings in this study suggest that AI-driven tools can automate monitoring processes, significantly increasing accuracy and efficiency in resource utilization.

Keywords

Aquaculture, fish detection, AI fish tracking, Nigerian catfish farming, sustainability.

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Introduction

Agriculture, particularly aquaculture, has long been a major source of livelihood in sub-Saharan Africa, sustaining rural households and contributing significantly to the economic landscape. Even within the context of a nation such as Nigeria, where the petroleum industry has substantial economic influence, the pivotal role of agriculture in the country's gross domestic product cannot be overemphasized. Notably, over 70% of Nigeria's population finds employment and sustenance through agriculture, underscoring its enduring significance in the nation's economy (Iyang et al., 2020). Over the past few decades, aquaculture has witnessed exponential growth globally and in Nigeria. The fast-growing aquaculture production in Nigeria, as evidenced by a substantial expansion of 10.3% between 1961 to 2011, showcases the potential and role of fish farming in contributing to the nation's economy (Katampe, 2016). Despite these significant contributions, the Nigerian aquaculture industry is hampered by outdated and manual methods such as traditional fish counting and processing, and the use of underdeveloped techniques like cage, pond, and composite fish cultures (Emmanuel et al., 2014). These methods, while long-standing, are inefficient, difficult to scale, and prone to human error, necessitating innovative approaches for better management. Addressing these challenges, this research explores the integration of advanced artificial intelligence (AI) systems to automate fish detection and tracking, aiming to enhance both the economic and operational efficiency of the aquaculture sector.

Artificial intelligence, a branch of computer science focused on creating machines with human-like intelligence, has already begun transforming the aquaculture industry. The emergence of AI and computer vision technologies has spurred both startups and established businesses to develop applications that address the unique challenges of aquaculture, enhancing research and production (Kacprzyk, 2009). The integration of artificial

intelligence and computer vision in aquaculture marks a critical advancement in improving efficiency, scalability, and sustainability (Patel et al., 2022). This digital transformation is essential to meet the growing global seafood demand and enhance the livelihoods of fish farmers, particularly in Nigeria. The 'agro-vision' concept, pivotal in precision agriculture, has significantly advanced aquaculture by employing AI-driven cameras and sensors for continuous monitoring of aquatic life. This technology facilitates early detection of anomalies and diseases, informed by historical data and current environmental conditions, thereby improving the management of feeding schedules, reducing stress, and boosting overall health in aquatic life (Udeogu et al., 2023). Consequently, these insights are instrumental in refining feeding schedules, alleviating stress in aquatic life, and boosting overall health. AI improves precision aquaculture by providing a data-driven understanding of fish behavior, paving the way for resource-efficient and environmentally sustainable practices (An et al., 2021).

The introduction of AI and computer vision has opened new opportunities for enhanced environmental monitoring, community engagement, and efficient fish detection and tracking. Combined with environmental sensors, these technologies offer a robust solution for monitoring key parameters like water quality and temperature, essential for maintaining fish health and habitat (Mandal and Ghosh, 2023). The application of computer vision-based technologies has been identified as a means to enhance the performance and productivity of aquaculture industries, ease the lives of fish farmers, and improve harvest (Shreesha et al., 2020). Moreover, AI-based applications extend to optimizing water quality management, feed optimization, and enhancing environmental monitoring, community engagement, and fish welfare. These advancements not only increase production efficiency using fewer resources but also support sustainable practices essential for meeting global seafood demands and enhancing fish farmers' livelihoods in Nigeria (Lim et al., 2023; Patel et al., 2022).

While AI and computer vision hold the promise of enhancing aquaculture productivity and easing the burden on fish farmers, the success of these technologies depends on deep domain expertise in AI and aquaculture thus making it a multifaceted endeavor. This necessitates collaborative efforts to overcome data and environmental, financial, and expertise-related challenges to fully realize the potential of AI in revolutionizing aquaculture practices, including the development of image processing algorithms for fish monitoring and sizing using computer vision (Rodriguez et al., 2015).

Related Works The application of artificial intelligence in fish farming presents a plethora of opportunities to overcome the inherent limitations associated with traditional aquaculture and fishery management. Among the critical advancements is the use of deep learning, which significantly improves real-time decision-making through applications such as live fish identification, species classification, behavioral analysis, and water quality prediction. Furthermore, diverse local conditions and aquaculture practices across different regions and species require artificial intelligence models to be highly adaptable to meet specific local and species-centric requirements. Fish detection challenges are highlighted as a result of varying illumination, low contrast, and other factors, necessitating robust computer vision models for effective fish detection in unique application scenarios (Yang et al., 2021). Concurrently, the burgeoning issue of overproduction, which frequently leads to environmental imbalance and a decline in aquatic product quality, has been meticulously addressed through AI-driven solutions such as Precision Fish Farming (PFF), which aims to improve the accuracy, precision, and repeatability of farming operations, thereby fostering more sustainable aquaculture practices (Føre et al., 2018). Additionally, the integration of digital twin technology with the Artificial Intelligence Internet of Things (AIoT) has been recognized as a catalyst for intelligent fish farming, providing a nuanced understanding and management of aquaculture ecosystems (Ubina et al., 2023). Furthermore, machine learning algorithms have been extensively explored for their potential to evaluate fish biomass, identify and classify fish, and analyze behavioral patterns, which are integral to efficacious aquaculture management (Zhao et al., 2021).

In the evolving aquaculture landscape, there has been a surge in innovative techniques to improve fish tracking and monitoring. One such advancement is the radio-based fish tracking system, which allows for detailed observations of individual fish movements and behaviors, proving to be an invaluable tool for large-scale aquaculture operations (Martín et al., 2022). Underwater acoustic telemetry has also been recognized as an effective means of overseeing fish activity, especially within expansive water bodies. This modality provides a lens for the continuous nuances of fish behavior and migration trajectories

(Yang et al., 2022). Harshith et al. (2023) demonstrated in their work the implementation of remote aquaculture monitoring using image processing and AI, enabling real-time detection of parametric changes, disease identification in fish, and automated control of aquaculture systems. Moreover, machine vision technologies have been surveyed for target tracking applications in aquaculture, presenting a taxonomy of techniques and analyzing fish detection and tracking methods (Mei et al., 2022). The introduction of environmental DNA analysis offers a promising avenue for determining fish presence and decoding species-specific information within aquaculture systems. Its non-invasive nature is a cornerstone for gauging both fish populations and their genetic diversity (Shu et al., 2020). Diving deeper into individualized fish metrics, the introduction of wearable sensors and bio-logging apparatuses heralds a new era of data collection. These tools are meticulously designed to collect detailed data on fish behavior and physiology, shedding light on gender-specific activity trends and other critical aspects (Kaidarova et al., 2023). Notably, the merging of computer vision with machine learning has ushered in a transformative approach to real-time fish behavior surveillance. There is an unprecedented ability to decipher and understand fish behavior, which in turn augments insights into their holistic well-being and growth trajectories (Sung et al., 2017).

Aquaculture has also seen the development of intuitive mobile applications, granting practitioners the luxury of monitoring and tracing fish dynamics via handheld devices. These applications serve as gateways for instantaneous data retrieval and interpretation (Zhao et al., 2021). Several studies have explored the application of artificial intelligence (AI) in aquaculture, particularly in the identification and management of fish diseases. Yang et al. (2021) demonstrated how AI can analyze fish photos to detect disease indicators such as lesions, odd behavior, and discoloration. Chan et al. (2022) leveraged cameras in fish farms to monitor and identify early symptoms of disease. Early detection through this approach can help farmers mitigate the need for antibiotics and reduce the risk of disease outbreaks, thereby improving treatment outcomes and limiting the spread of infections within fish populations.

Additionally, AI has been utilized to analyze video data from salmon farms to detect behavioral changes indicative of stress or disease. Deep learning algorithms were employed to identify and interpret these behavioral patterns, achieving a high degree of accuracy in early disease detection. Wu et al. (2022) expanded this research by examining four major aspects of deep-sea aquaculture: intelligent feeding, water quality detection, biomass estimation, and underwater inspection. They highlighted the shift from traditional manual practices to mechanized and automated systems, collectively referred to as unmanned intelligent equipment. The adoption of these technologies in various aquaculture fields has been shown to reduce labor costs, mitigate threats, and enhance operational efficiency. Fish activity can be directly impacted by water quality due to their high reliance on the aquatic environment. Lu et al. (2022) introduced a low-cost AI buoy system for real-time water quality monitoring at offshore aquaculture cages, providing data on dissolved oxygen, salinity, water temperature, and velocity. Additionally, by analyzing data from sensors that measure parameters such as temperature, dissolved oxygen, pH, and ammonia levels (Dupont et al., 2018), AI algorithms can detect patterns and anomalies that may indicate problems with water quality (Zhao et al., 2021; Khurshid et al., 2022). This enables farmers to take corrective actions before any harm is done to the fish. AI-powered water quality monitoring systems can continuously monitor multiple parameters in real-time, providing more accurate and timely information than manual monitoring methods (Javaid et al., 2022). This allows for quick responses to changes in water quality, reducing the risk of fish mortality and other negative outcomes.

AI plays a pivotal role in developing predictive models that anticipate changes in water quality before they occur. By analyzing historical data on water quality and other factors such as weather patterns and feeding schedules, AI algorithms can predict the likelihood of changes in water quality and provide early warnings to farmers (Saeed et al., 2022). Gunda et al. (2019) developed an AI-based mobile application platform for monitoring water quality, specifically for bacterial contamination, using a low-cost rapid test kit. These advancements demonstrate the significant potential of AI in enhancing water quality management in aquaculture, ultimately supporting healthier and more sustainable fish farming practices. Dixit et al. (2023) highlighted how AI systems can identify genetic variations associated with specific traits by analyzing vast amounts of genomic data. This information is then used to develop predictive models of fish performance. These models can predict the performance of various fish populations

under different environmental conditions and identify the best candidates for breeding to achieve specific goals, such as enhanced disease resistance or improved growth rates. By making breeding operations more targeted and efficient, AI helps save time and resources while ensuring the attainment of desired traits. This approach significantly enhances the productivity and sustainability of fish populations, offering substantial benefits for aquaculture and fisheries management (Mandal and Ghosh, 2023).

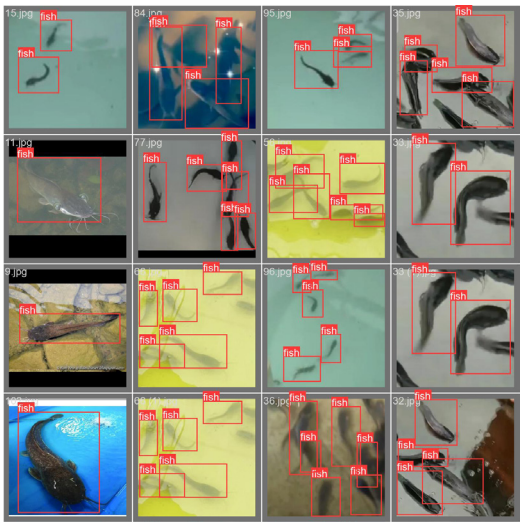
Despite these remarkable advances in harnessing artificial intelligence for aquaculture advancements, a palpable gap remains in the collective understanding of fish monitoring and tracking. To address this lacuna, the present research endeavors to pioneer the realm of aquaculture management by championing the cause of AI-Enhanced Fish Monitoring and Tracking.

Materials and methods

This section describes the methodical approach consisting of several steps that contributed to the development and validation of an AI-driven solution aimed at improving the accuracy, scalability, and efficiency of detecting and tracking fish, with a specific focus on Nigerian catfish farming.

Dataset description

The dataset comprises about 102 catfish images of different sizes, the majority of which were extracted from video footage taken above a fish pond, while the rest were obtained from the Internet. Additional files, such as code and model configurations, are made available here on GitHub.



Source: Authors

Figure 1: A compilation of images from the Nigerian Catfish Image Dataset.

Dataset creation

In this study, a mobile phone camera was used to record fish in the tarpaulin fish pond from an overhead perspective. This perspective was chosen because it is the most economical and efficient, and it minimizes reflection and other potential disturbances, ensuring clearer visibility of the fish. Efforts were made to record the video when fish clustering was minimal to aid in the accurate annotation of images extracted from the footage, given that catfish, like other fish, tend to congregate in one area of the pond to avoid sunlight. Using this method, we were able to obtain approximately 80 images of catfish. To diversify and enrich the dataset, supplementary data were procured from the internet. Figure 1 shows various sizes and orientations of catfish captured from different ponds. Each image extracted from the overhead camera footage contains bounding boxes that indicate the detected catfish for object-detection annotation. The images reflect the diverse datasets obtained from both manual recording and supplementary online sources, processed, and annotated.

Preprocessing and annotation

The dataset used in this study underwent preprocessing to enhance image quality and normalize the images, making them suitable for training. Data cleaning was performed by eliminating unsuitable images. This causes the number of images to decrease from about 150 to 102. They were resized to 320 × 320 and renamed in numerical order, ranging from "1.jpg" to “102.jpg”. Bounding boxes are essential for object-detection tasks. They are rectangular boxes that define the location of the target object (catfish in this case), with each bounding box consisting of the x and y coordinates (xmin-top left, ymin-top left, xmax-bottom right, ymax-bottom right) (Everingham et al., 2010). The annotations for each image of the dataset were created using a free graphical image labeling tool, LabelImg, in both the PASCAL VOC format and the YOLO format (Abedeen et al., 2023).

Modeling experiments and evaluation

This research was modeled as an object detection problem and three models were designed using different architectures: Faster R-CNN, YOLO, and RetinaNet. For this study, the models were trained utilizing the complimentary GPU resources offered by Google Colab. The results of the models were inspected and compared.

Evaluation Metrics Precision is the ratio of correctly classified positive samples to the total number

of samples identified as positive, whether accurately or inaccurately. The recall is the ratio of correctly classified positive samples to the total number of actual positive samples. Precision measures the accuracy of the detected objects, while recall measures a model's ability to detect all possible objects. Both precision and recall were used to understand the performance of the object detection models and tune them to achieve better results (Equation 1 and 2).

$$Precision = \frac{TP}{TP + FP} \quad (1)$$

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

Where:

TP - is the number of True Positives,

FP - is the number of False Positives,

FN - is the number of False Negatives.

Higher precision may decrease recall, and vice versa. This trade-off can be visualized and analyzed using a precision–recall curve. A Precision-Recall (PR) curve illustrates the balance between precision and recall at varying thresholds. The average precision (AP) is a single metric that summarizes the area under the precision-recall curve, providing an aggregate measure of a model's performance across a single class (in this case, the fish) and at different thresholds. Higher average precision values indicate better model performance in terms of both precision and recall (Equation 3) (Mercaldo et al., 2023).

$$\mathrm{AP} = \sum_{n} (R_n - R_{n-1}) P_n \quad (3)$$

Where:

R_n and P_n are the precision and recall at the n^{th} threshold respectively.

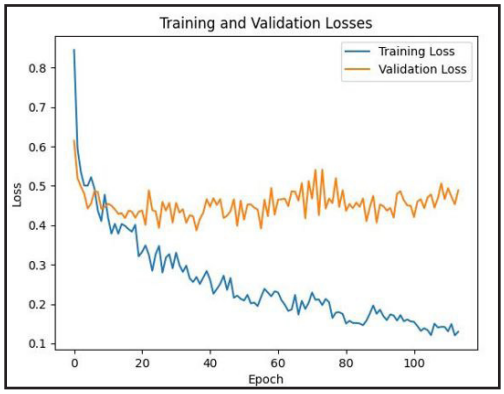
In this study, the Intersection over Union (IoU) metric was used to evaluate the accuracy of the bounding boxes predicted by the object detection models in comparison with the ground truth bounding boxes. This quantitatively measures how well the model can locate and delineate objects within images. The IoU is computed by dividing the intersection area of the two boxes (the predicted bounding box and the ground-truth bounding box) by the area of their union (Rezatofighi et al., 2019). A higher IoU score (close to 1) indicates that the predicted bounding box is very close to the ground truth. In this study, the measure of overlap was evaluated at two levels: 50% overlap (@0.5) and 95% overlap (@0.95).

Data augmentation

For object detection tasks such as this research, data augmentation plays a crucial role in enhancing the performance and generalizability of the models by artificially enlarging the training dataset with diverse variations of the input data. This is desirable because we have a small image dataset. The data augmentation techniques used were horizontal flip, vertical flip, and random rotation. Horizontal flip augmentation mirrors the fish image along its vertical axis, effectively duplicating the dataset and providing additional variations of the object orientations. Similarly, vertical flip augmentation mirrors the image along its horizontal axis, adding variability to the dataset. In the random rotation technique, the image is rotated by a random angle, exposing the model to a variety of rotational variations and assisting it in learning rotation-invariant features.

Object detection using Faster R-CNN

Faster Region-based Convolutional Neural Networks improve upon previous iterations like Fast R-CNN by introducing a Region Proposal Network (RPN) that shares full-image convolutional features with the detection network, thus enabling nearly cost-free region proposals (Ren et al., 2015). The architecture comprises three main components: a ResNet-50 backbone for feature extraction, a Region Proposal Network (RPN) for generating object proposals, and Fast R-CNN for object classification and bounding box regression. The ResNet-50 backbone leverages residual learning to extract hierarchical features from input images (Chen et al., 2021). The RPN uses these features to propose regions of interest, which are then processed by the Fast R-CNN component to classify objects and refine bounding box predictions. In this study, the model was trained for approximately 150 epochs, and its performance was evaluated on a test set. Figure 2 depicts



Source: Authors

Figure 2: Graph depicting the trend of training and validation losses over epochs during Faster R-CNN training progresses.

the trend of training and validation losses over epochs, highlighting the Faster R-CNN model's learning progression.

Object detection using YOLO

You Only Look Once (YOLO) is a state-of-the-art, real-time object detection system that processes an image in a single pass. It treats object detection as a single regression problem, predicting both class labels and bounding box coordinates directly from the image pixels (Redmon et al., 2016). We trained across 150 epochs using the YOLOv8l implementation and annotations in YOLO format. Figure 3 illustrates the training progress of the YOLOv8 model, showing the evolution of losses, precision, recall, and mean average precision (mAP) over time.

Object detection using RetinaNet

RetinaNet addresses the class imbalance problem, which is common in object detection tasks. RetinaNet combines the simplicity of single-stage detectors with a novel loss function called focal loss. Focal loss reduces the loss contribution from easy negatives (background) while focusing more on misclassified positives and hard negatives (Lin et al., 2017).

The focal loss formula (Equation 4) is given by:

$$\mathrm{FL}(p_t) = -\alpha_t (1 - p_t)^{\gamma} \log(p_t) \qquad (4)$$

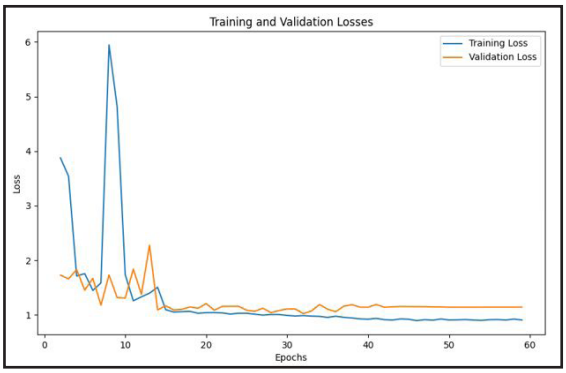
Where:

p_t - is the model's estimated probability for the true class.

α_t - is a balancing factor.

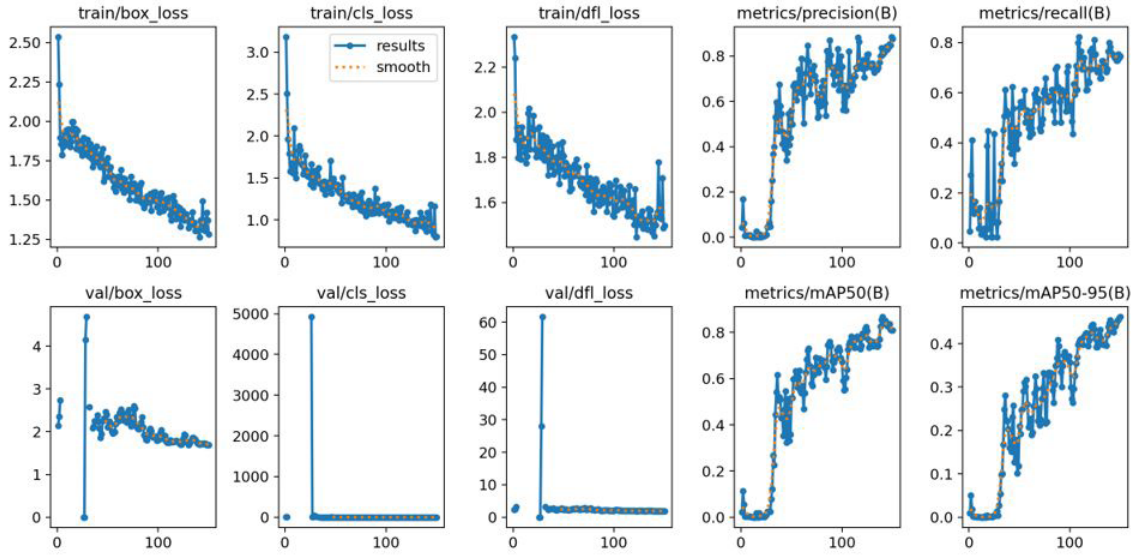
γ - is the focusing parameter (usually set to 2), which helps in reducing the contribution of easy examples to the loss and focusing more on the hard misclassified examples.

RetinaNet's architecture comprises a backbone network for feature extraction and two task-specific subnetworks for classification and bounding box regression. For this research, the backbone network used was ResNet50, The model was trained for approximately 60 epochs, and its performance was evaluated on a test set. Figure 4 illustrates the trend of training and validation losses over epochs, highlighting the RetinaNet model's learning progression.



Source: Authors

Figure 4: Graph depicting the trend of training and validation losses over epochs during RetinaNet training progresses.



Source: Authors

Figure 3: Graph of losses, precision, recall, and mAP as YOLOv8 training progresses.

Results and discussion

The table below presents the evaluation metrics of three different model architectures: Faster R-CNN, YOLO, and RetinaNet when applied to fish detection tasks in the context of Nigerian catfish farming.

Metrics	Faster R-CNN	YOLO	RetinaNet
Precision	0.8575	0.8758	0.1278
Recall	0.6358	0.7469	0.7961
AP: @0.5	0.9222	0.8095	0.2223
AP: @0.95	0.749	0.4619	0.1111

Source: Authors

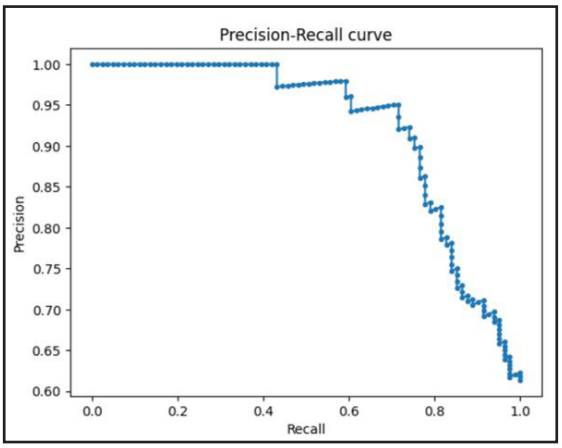
Table 1: Comparison of precision, recall, and AP across the three different models.

Precision Analysis YOLO emerged as the best-performing model as depicted in Table 1, with a precision of 0.8758, closely followed by Faster R-CNN with 0.8575. In contrast, RetinaNet had a significantly lower precision of 0.1278, suggesting a higher rate of false detections.

Recall Analysis RetinaNet outperformed its competitors in this metric, with a recall of 0.7961. YOLO followed with a commendable 0.7469, whereas Faster R-CNN lagged with a recall of 0.6358. This implies that RetinaNet may be better at identifying most fish, but at the expense of more false positives, as evidenced by its low precision.

Average Precision (AP) Analysis Faster R-CNN dominated with an AP of 0.9222 when tested at an IoU threshold of 0.5, indicating superior performance in moderately strict detection criteria. YOLO trailed with 0.8095, whereas RetinaNet's score was significantly lower at 0.2223. However, at a more stringent IoU threshold of 0.95, a Faster R-CNN still led the pack with an AP of 0.749. YOLO's performance dipped to 0.4619, and RetinaNet further lagged by 0.1111. This suggests that Faster R-CNN consistently performs well, even under stricter detection criteria.

Figure 5 displays a Precision-Recall curve, illustrating the trade-off between precision and recall for the Faster R-CNN model, with performance remaining high at the beginning and decreasing as recall increases. Given these results, Faster R-CNN emerges as a balanced model offering both high precision and decent recall, making it suitable for applications where both accuracy and comprehensiveness are paramount. Although YOLO has slightly higher precision, its recall is slightly lower. RetinaNet has a high recall but a low precision, making it less suitable for our specific use case where false positives can be harmful.



Source: Authors

Figure 5: Precision-recall curve for Faster R-CNN fish detection model.

Faster R-CNN's proficient detection capabilities can lead to more accurate and efficient monitoring of fish populations in the context of the study's goal of improving aquaculture and fishery management. Such advancements are pivotal in the automation of monitoring procedures, potentially leading to improved resource utilization and reduced operational costs.

Conclusion

In the dynamic landscape of aquaculture and fishery management, the integration of artificial intelligence represents a beacon of innovation, holding the promise to transform conventional approaches. This study delved deeply into the realm of AI, with a specific focus on Nigerian catfish farming, aiming to leverage its potential to enhance the accuracy, scalability, and efficiency of fish detection. Our robust methodology encompasses a comprehensive process of data collection, data processing, model training, and model evaluation. In our evaluation of three prominent object detection models: Faster R-CNN, YOLO, and RetinaNet, we identified Faster R-CNN as the frontrunner. It struck a balance between precision and recall, rendering it the ideal choice for fish detection in aerial imagery of catfish ponds.

The economic implications of our findings are profound. With Faster R-CNN leading the way, stakeholders in aquaculture can anticipate a future where monitoring processes are not only automated but also remarkably accurate. Such advancements have the potential to significantly

reduce manual labor, minimize errors, and optimize resource utilization. Furthermore, the integration of an application that combines fish detection with object tracking enables real-time monitoring and data-driven decision-making, previously unattainable through traditional methods. This AI-enhanced approach promises substantial improvements in operational efficiency and cost-effectiveness for fisheries management by automating fish population monitoring and optimizing resource allocation. Nonetheless, our research merely marks the initial step in a wide array of possibilities. While Faster R-CNN excelled in our dataset, the ever-evolving nature of AI suggests that newer models or techniques may emerge with even greater capabilities. Additionally, exploring data augmentation strategies, model fusion, or the incorporation of other AI paradigms could further enhance the accuracy and efficiency of fish detection.

In conclusion, this study underscores the immense potential of artificial intelligence in reshaping traditional aquaculture and fishery management. By bridging the gap between technology and aquaculture, we not only pave the way for a more sustainable and efficient future but also set the stage for countless innovations in the realm of AI-driven fishery management. The journey has just begun, and the horizon is promising.

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The Revealed Comparative Advantage of Agri-Food Industries in Selected Countries in the Central and Eastern Europe: Gross-Versus Value-Added Trade Flows

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Abstract

The aim of the article is to interrogate comparative advantage of agrarian and food processing sectors in the context of the agri-food global value chains in particular countries in the Central and Eastern Europe using gross trade and value-added trade data from TiVA database. The Normalized revealed comparative advantage index (NRCA) was applied to analyze comparative (dis)advantage of agrarian and food processing sectors from 1995 to 2020. The article contributes twofold: First, NRCA pairs of indices calculated using gross trade and value-added trade data are mostly consistent. The analysis identifies for what areas and countries there is a discrepancy; second, it reveals comparative advantage of agrarian and food processing sectors in each country separately. It indicates different trajectories of development among countries in the Central and Eastern Europe. These results are complementary to the results of studies that evaluated comparative advantages on the product basis.

Keywords

Agrarian sector, food processing, fragmentation, global value chain, value-added.

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Introduction

World trade and production are increasingly structured around global value chains (GVCs). A global value chain identifies the full range of activities that firms undertake to bring a product or a service from its conception to its end use by final consumers and takes place in numerous locations in different countries (Gereffi, 2014) and accounts for a significant share of international trade over the past decades (Lim and Kim, 2022). The agriculture and food sectors are no exceptions and are increasingly integrated into global value chains (De Backer and Miroudot, 2013; Kowalski et al., 2015; Giovannetti and Marvasi, 2016; Greenville et al., 2017; OECD, 2020; Montalbano and Nenci, 2022, Lim, 2021; Lim and Kim, 2022), however due to factors such as the perishability of raw and intermediate processed products in the food supply chain, nature of products and processes in agri-food industries, these chains differ from those in other sectors (Trienekens, 2011). Despite the slowdown in economic globalization in the last decade, the countries across Europe still remain integrated into GVCs (Antràs, 2020; Constantinescu et al., 2015; Xing et al., 2022).

International trade is traditionally analyzed by using data on gross trade (gross trade is trade that crosses national borders and is registered by customhouses). The assumption is that gross trade flows provide sufficient information to analyze the structure of international trade. Such an assumption is correct as long as the international fragmentation of the production chain is limited (Brakman and Van Marrewijk, 2017). However, the fragmentation of the production process has become a significant characteristic of the world economy (Jones and Kierzkowski, 1990; Krugman et al., 1995; Feenstra, 1998; Hummels et al, 2001; Grossman and Helpman, 2002; Grossman and Rossi-Hansberg, 2008) and international trade flows no longer (or to a lesser extent than it used to be) reflect what a country is producing and exporting (Brakman and Van Marrewijk, 2017). Analyzing characteristics of international trade flows thus becomes more challenging. Traditional trade statistics measured in gross terms, which

include both intermediate inputs and final products, double count the value of intermediate goods that cross international borders more than once and do not explicitly account for foreign value-added in final product (OECD, 2020). Ceglowski (2017) and Fertö (2018) conclude that countries' and/or industries' export competitiveness looks different through the lens of domestic value-added than on the basis of conventional measures using gross exports.

Historically, the value and importance of the data on gross trade to assess and monitor the trade performance of countries, have been illustrated in various scenarios. The gross trade data are regularly used in various types of trade analyses, e.g., to interrogate the concept of revealed comparative advantage in the agriculture and food industries in the countries of the Central and Eastern Europe (e.g. Bojnec and Fertő, 2009; Smutka et al., 2012; Jámbor, 2013; Ignjatijević et al., 2014; Carraresi and Banterle, 2015; Smutka et al., 2016; Bojnec and Fertő, 2019; Matkovski et al. 2019; Pavlak and Smutka, 2022; Vondráček et al., 2022). The agri-food gross trade data in these studies is typically structured according to products (following the methodology of e.g., Harmonized System, HS; or Standard international trade classification, SITC). Nonetheless, new datasets have recently emerged and allow studying trade performance of countries using research strategies that include value-added types of data. Also, the GVC methodology indicates ongoing specialization along the value chains and thus the necessity to identify more clearly what fragment in the production chain is internationally competitive in a particular country. There are currently several such a dataset as e.g. OECD TiVA, UNCTAD Eora, and IDE-JETRO. This new data allow to determine a country's weak and strong sectors based on value-added. Additionally, the way in which the data is structured also allows assessing the performance of individual sectoral segments in the agri-food value chain, i.e. not only the agricultural sector, but also the food processing industry separately and the mutual interaction of the development trajectories and its performance.

Against this background, the paper aims to interrogate comparative advantage and competitiveness of agrarian and food processing sectors in selected countries in the Central and Eastern Europe using gross trade and value-added trade data.

This paper contributes to several literature strands. It contributes to the literature on agricultural trade. There is a long, well established agriculture and development literature on the Countries of the Central and Eastern Europe (Bojnec and Fertő, 2009; Smutka et al., 2012; Jámbor, 2013; Ignjatijević et al., 2014; Carraresi and Banterle, 2015; Smutka et al., 2018; Bojnec and Fertő, 2019; Matkovski et al. 2019; Pavlak and Smutka, 2022; Vondráček et al., 2022). However, the majority of the literature looks at the relationship between agri-food trade and development from an angle of traditional gross trade data. Our analysis contributes to this broad literature by linking globalized agri-food chains to international trade performance. The validity of traditional method (specifically NRCA) that is used to analyze trade performance of countries and regions was assessed. Second, we contribute to the literature on agriculture development by providing evidence that show change in the comparative advantage of particular segments (industries) in the agri-good chains in the countries of Central and Eastern Europe. By highlighting the different trajectories in reveled comparative of agriculture and food sectors using value-added RCA we support policy makers to ensure supportive policies for agri-food firms.

Theoretical background

Over the last couple of decades, critical economic changes have affected the competitive position of the agri-food sector in the EU including globalization, evolution in the patterns of demand for food safety and quality, the completion of a single European Market, introduction of the Euro in some EU Member States, integration into the global value chains, impacts of new trade agreements, and the financial crisis in 2008 and currently the COVID-19 and energy crisis (Harvey et al., 2017; Čechura et al., 2017; Fertö, 2018; Bojnec and Fertő, 2019; Mizik, 2021; Pawlak et al., 2021; Hamulczuk and Pawlak, 2022; Matkovski et al., 2022; Blažková et al., 2023). These changes affected countries in Central and Eastern Europe nonetheless it was even more complex for them as the ex-socialist countries already underwent the substantial changes since the transformation and liberalization in 1990's. and became member states of the EU.

Competitiveness and the following selection process among firms are key components of the market economy regardless of the sector. The term itself has undergone significant changes however there is not a commonly accepted

definition (Mizik, 2021). The diversity of concepts and measures of competitiveness largely relates to the variety of policy analysis needs, perspectives and objectives of the research (Bojnec and Ferto, 2009). The term competitiveness is close to the term comparative advantage. Both terms refer to a firm's ability to produce goods and services and to succeed against competitors over time.

Michael Porter (Porter, 1990) studied firm competitiveness and sources of comparative advantage. Porter's Five Forces Model analyses determinants of national competitive advantage and the model specifies four broad attributes of nation that individually and as a system constitute the diamond of national comparative advantage. These attributes are factor conditions, demand conditions and firm strategy, structure and rivalry, and related and supporting industries. The model describes the prominent role of supplier industries and other related industries as well as demand conditions on the international competitive position of the industry (the model also suggests that related and supporting industries are not the only factor playing a role). Following the logic of the model, it suggests possible linkages between performance of the agrarian industry and performance of the food processing industry in the globalized business environment. The competitive food industry can enhance the competitive position of the agrarian sector because the food processing industry is able to use the raw material produced by domestic farmers and then market processed food products at domestic food markets (competing against imports) or to successfully export processed food products and market it abroad. This potential synergy also applies other way round. The ability of the agricultural sector to supply quality and cheap raw materials to the food industry is a one of the prerequisite for the food industry to be able to show high performance against its foreign competitors and thus maintain or enhance its position on the market. Contrary to Porter's model, the GVC models indicate the fragmentation of the production process and the dispersion of production as a fundamental characteristic of current world production and trade (Gereffi and Fernandez-Stark, 2011). Countries tend to specialize in specific segments of the value chain or specific business functions and tasks. There they build its comparative advantage. GVC emphasize how export competitiveness relies on sourcing of efficient inputs (not necessarily locally produced) as well as access to final producers or consumers abroad.

As suggested by theories of global value chains the possible explanation behind the discrepancies between results using gross trade and value-added trade data can be the process of the international fragmentation of production. In the case of seaside countries, the reason for discrepancies could be existence of the Rotterdam-Antwerp effect. It describes potential distortions in trade statistics occurring as a result of misreporting of commodities passing through major world ports on their way to their final destination (Lemmers and Wong, 2019).

Materials and methods

Data used in the analyses were extracted from The Trade in Value-added (TiVA) database (TiVA, 2023). TiVa is a collection of measures that can provide insights into global production networks and supply chains beyond what is possible with conventional trade statistics. The TiVA database contains a selection of principal indicators that track the origins of value-added in exports, imports and final demand for the years 1995-2020. Indicators are available for 45 industries within a hierarchy based on ISIC Rev. 4. The indicators are derived from the 2018 version of OECD's Inter-Country Input-Output Database (Martins Guilhoto et al., 2022).

The first step was to assess the comparative advantage using gross trade and value-added value-added data. The most widely used indicator of comparative advantage in empirical trade analysis is based on the concept of revealed comparative advantage (RCA) index, which was developed by Balassa (Balassa, 1965), with its variants. The theoretical foundation and empirical distribution characteristics of the Balassa index have been extensively debated and criticized in the literature (Bowen, 1983; Vollrath, 1991; Hinloopen and Van Marrewijk, 2001; De Benedictis and Tamberi, 2004). Because of the shortcomings of the Balassa index, other indices have also been proposed (i.e. Bowen, 1983; Vollrath, 1991; Lafay, 1992; Dalum et al., 1998; Proudman and Redding, 2000; Hoen and Oosterhaven, 2006; Yu et al., 2009; Leromain and Orefice, 2014). At this point, it is worth emphasizing that none of the suggested alternatives seem to be without problems. Nonetheless, Yu et al. (2009) adopted an alternative measure to assess the dynamics of comparative advantage, utilizing the normalized revealed comparative advantage index (NRCA) to improve certain aspects of the original one. The advantage is that the NRCA allows comparison over space and trends over time.

The NRCA is defined as follows:

$$NRCA_{ij} = \frac{E_{ij}}{E} - \frac{E_i}{E} \times \frac{E_j}{E} \quad (1)$$

where E denotes total world trade, E_{ij} describes country i's actual export of commodity j in the world market, E_i is country i's export of all commodities and E_j denotes export of commodity j by all countries. The NRCA index ranges from -0.25 to 0.25 and the comparative neutral point is zero. The sum (and the mean value) of scores is constant and equals to zero and a sum of positive scores equals the sum of negative scores. If NRCA is higher (lower) that 0, a country has a comparative advantage (disadvantage) in product i. The higher the value, the stronger the comparative advantage and vice versa. The scores can be rescaled by multiplying with 10,000 without affecting the results (Sanidas and Sin, 2010). Due to these desirable properties, the NRCA index was used in this study. The TiVA database provided information about the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic, Slovenia, Bulgaria, Croatia and Romania. The TiVA is based on underlying input-output tables that are organized at the industry level (not products) according to NACE code. The two agri-food value chain related industries used in this study are (i) agriculture, hunting, forestry and fishing and (ii) food, beverages and tobacco. Following Fertő (2018), we use the TiVA measures for gross exports and the domestic value-add in foreign final demand to calculate NRCA scores. Even if these databases overcome some of the problems of traditional gross trade data, resorting to the traditional data while value-added data are available, implies that value-based data is probably still far from satisfactory. For more detail see Sturgeon (2013) and the challenges of economic globalization for statistical measurement.

To identify and compare the differences between the calculation of NRCA scores based on gross flows versus value-added flows we are following Brakman and Van Marrewijk (2017) and we use four possible sector classifications. First, a sector may reveal to have a comparative advantage for both gross trade NRCA and value-added NRCA (strong-strong). Second, a sector may reveal to have a comparative disadvantage for both gross trade NRCA and value-added NRCA (weak-weak). Third, a sector may reveal to have comparative disadvantage for gross trade and simultaneously a comparative advantage for value-added trade (weak-strong). Apparently the strength and importance of these sectors for a particular country are underestimated when using gross trade flows. Fourth, a sector may reveal to have a comparative advantage for gross trade and simultaneously a comparative disadvantage for value-added trade (strong-weak). Apparently the strength and importance of these sectors for a particular country are underestimated when using gross trade flows.

In the next step, pairs of scores of NRCA were analyzed regarding its consistency. Ballance et al. (1987) suggest empirical tests to examine the extent to which various NRCA scores are consistent as a cardinal measure (the extent to which a country has a comparative advantage or comparative disadvantage in a sector) and dichotomous measure (similarity in suggesting whether the sector have comparative advantage or comparative disadvantage), and ordinal measure (consistent in ranking sectors by NRCA).

In the third step, we suggest analytical tool to interrogate mutual interaction between the revealed comparative advantage of the agrarian and food processing sectors. For a particular country, we use NRCA scores for agrarian industries and NRCA scores for food processing industries together in the Cartesian coordinate system (Table 1).

Based on the NRCA pair-scores for agrarian and food processing industries, the pair-score will belong to one of these four quadrants depending

Value added RCA or gross trade RCA of food processing industry	NRCA > 0	**B: disadvantage - advantage**	**A: advantage- advantage**
		weak agrarian sector and strong food processing sector	strong agrarian sector and strong food processing sector
	0 < NRCA	**D: disadvantage - disadvantage**	**C: advantage - disadvantage**
		weak agrarian sector and weak food processing sector	strong agrarian sector and weak food processing sector
		NRCA < 0	**0 < NRCA**
		Value added RCA or gross trade RCA of agrarian sector	

Source: authors own proposition

Table 1: Classification of the interaction between RCA of agrarian and food processing sector.

on NRCA and if it reveals comparative advantage or disadvantage. The meaning of each quadrant is following:

- Quadrant A (advantage- advantage): both agrarian sector and food processing industry reveal comparative advantage,
- Quadrant B (disadvantage - advantage): agrarian sector reveals comparative disadvantage, however the food processing industry reveals comparative advantage,
- Quadrant C (advantage - disadvantage): agrarian sector reveals comparative advantage, however the food processing industry reveals comparative disadvantage,
- Quadrant D (disadvantage - disadvantage): both agrarian sector and food processing industry reveal comparative disadvantage.

The situation of synergies derived from Porter's model (Porter, 1990) is representative for the situation in quadrants A and D as the role of supplier industries (or demand) positively or negatively effects the international competitive position of the agrarian industry resp. food processing sector. On the other hand, quadrants B and C rather represent the situation of the fragmentation of production process when countries tent to specialize in specific segments of the global value chain. However, it is necessary to point out that this tool has limitations, because the model also suggests that related and supporting industries as well as demand conditions are not the only factor playing a role. Also, part of production and trade still takes the form of classic bilateral trade, and the production chain is therefore not as fragmented as in the case of other sectors (electronics, cars). The reason could be because the specifics of agricultural and food products and production processes play a role. Thus, the mutual and complex interaction of the comparative advantages of the agrarian sector and the food sector is not clear and should be subject to further empirical assessment. Although this is a simple analysis and comparison, the results of the shifts in the pair-scores of comparative advantages of the agrarian and food industries indicate complex development trajectories in selected countries in the central and eastern Europe.

Results and discussion

The NRCA scores for the agri-food industries in selected countries of Central and Eastern Europe were calculated using gross trade and value-added data in the period 1995 to 2020. Please also figures (figure A1) in appendix. Then the consistency of NRCA scores was tested.

Agrarian industries

The first important result is that most of the Central and Eastern European countries (on average between 1995 and 2020) reveal comparative advantage in agriculture according to both gross trade and value-added data. The gross trade data suggest that about half of the agrarian industries in CEES countries have enhanced their comparative advantage in agriculture and with about half of them the comparative advantage has deteriorated. Analysis of the value-added data suggest that the comparative advantage of the agrarian industry deteriorated in almost all (except of Latvia) Central and Eastern European countries.

More in detail, based on the calculations of NRCA scores using traditional gross trade data (Table 2), the scores of NRCA suggest (on average) that 7 out of the analyzed 11 agrarian sectors in particular countries in the Central and Eastern Europe revealed comparative advantage from 1995 to 2020. To the contrary, 4 out of the analyzed 11 sectors revealed comparative disadvantage. Agrarian sectors in Bulgaria (0.568), Romania (0.393), Hungary (0.335), Lithuania (0.234), Latvia (0.144), Croatia (0.079) and Estonia (0.054) revealed a positive NRCA score. Agrarian sectors in Poland (-0.622), Czech Republic (-0.391), Slovak Republic (-0.148) and Slovenia (-0.132) revealed a negative NRCA score. The scores of NRCA also indicate that the comparative advantage of agrarian sectors in Poland, Czech Republic, Hungary, and Slovak Republic have deteriorated. On the other hand, the comparative advantage has improved in Romania, Bulgaria, Hungary, Lithuania, Latvia and Slovenia (despite revealing comparative disadvantage), and despite a certain decline in comparative advantage the last years in Estonia and Croatia. These results suggest a geographic association with changes in the comparative advantages of agrarian industries. From a geographical point of view, the Baltic and the Balkan countries show an improvement in comparative advantage. The countries of the Visegrad group in the center of Europe show a deterioration of their comparative advantage in agrarian production.

According to the results of calculations of NRCA scores using value-added data (Table 2), the scores of NRCA indicate on average that 7 out of the analyzed 11 agrarian sectors in selected countries in the Central and Eastern European

Agrarian sectors									
	Gross trade approach (index)								
	1995	2000	2003	2005	2010	2015	2020	avg. 95-20	Δ (T2 – T1)
Czech Republic	0.106	-0.164	-0.425	-0.259	-0.540	-0.360	-0.582	-0.391	-0.412
Estonia	0.074	0.046	0.033	0.036	0.055	0.067	0.068	0.054	-0.029
Hungary	0.332	0.194	0.215	0.247	0.501	0.246	0.246	0.335	-0.150
Latvia	-0.003	0.028	0.033	0.110	0.261	0.215	0.296	0.144	0.240
Lithuania	0.132	0.107	0.142	0.099	0.278	0.271	0.277	0.234	0.087
Poland	-0.485	-0.520	-0.515	-0.238	-0.665	-0.337	-1.361	-0.622	-0.446
Slovak Republic	0.076	-0.127	-0.274	-0.112	-0.098	-0.161	-0.350	-0.148	-0.250
Slovenia	-0.191	-0.128	-0.221	-0.129	-0.105	-0.079	-0.103	-0.132	0.112
Bulgaria	0.304	0.099	0.187	0.249	0.681	0.915	1.028	0.568	0.677
Croatia	0.043	0.071	0.054	0.087	0.118	0.107	0.069	0.079	0.034
Romania	0.012	-0.036	-0.097	-0.096	0.671	0.920	0.905	0.393	0.963
	Value added approach (index)								
	1995	2000	2003	2005	2010	2015	2020	avg. 95-20	Δ (T2 – T1)
Czech Republic	0.153	-0.181	-0.539	-0.413	-1.035	-0.753	-0.942	-0.593	-0.767
Estonia	0.070	0.066	0.073	0.093	0.083	0.046	0.096	0.083	-0.026
Hungary	0.976	0.499	0.309	0.206	0.323	0.231	0.362	0.442	-0.582
Latvia	0.011	0.044	0.035	0.092	0.202	0.106	0.275	0.101	0.203
Lithuania	0.235	0.175	0.146	0.085	0.027	0.066	0.092	0.157	-0.222
Poland	0.297	-0.636	-0.836	-0.567	-0.885	-1.193	-1.675	-0.737	-1.088
Slovak Republic	-0.170	-0.221	-0.352	-0.300	-0.315	-0.254	-0.412	-0.242	-0.078
Slovenia	-0.043	-0.078	-0.214	-0.154	-0.255	-0.229	-0.239	-0.178	-0.113
Bulgaria	0.429	0.232	0.309	0.370	0.379	0.504	0.580	0.468	-0.033
Croatia	0.184	0.209	0.093	0.122	0.075	-0.034	0.027	0.099	-0.203
Romania	1.049	0.227	0.444	0.165	0.254	0.266	0.294	0.426	-0.471

Note: T1 - average of 1995-2000; T2 - average of 2015-2020
Source: own calculations, data from TiVA

Table 2: RCAs indices for selected countries in Central and Eastern Europe using gross and value added approach, selected years.

countries revealed comparative advantage from 1995 to 2020. On the other hand, 4 out of the analyzed 11 sectors revealed comparative disadvantage. Agrarian sectors in Bulgaria (0.468), Hungary (0.442), Romania (0.426), Lithuania (0.157), Latvia (0.101), Croatia (0.099) and Estonia (0.083) revealed positive NRCA scores. The agrarian sectors in Poland (-0.737), Czech Republic (-0.593), Slovak Re-public (-0.242) and Slovenia (-0.178) revealed a negative NRCA score. The NRCA scores show discrepancies compared to the approach based on gross trade data. The calculation based on value-added data suggests that the comparative advantage of agrarian sectors deteriorated in Poland, Czech Republic, Hungary, Slovak Republic, and Slovenia. Croatia, Lithuania and Estonia. In the case of Bulgaria and Romania the NRCA scores fluctuates, but revealed a decline in the first decade followed by a rise of NRCA scores in the second half of the period under investigation. The only country revealing an improvement of its agrarian industry comparative advantage is Latvia. In the case of calculations using added value data, it is not possible to identify such distinct geographical connections as in the case of calculations using gross trade data.

The Brakman and Van Marrewijk (2017) classification gives the following results. In the case of Estonia, Hungary, Lithuania and Bulgaria and for most of the years Latvia, scores of NRCA revealed comparative advantage for both gross trade NRCA scores and value-added NRCA scores calculations (strong-strong). In the case of Poland, Czech Republic, Slovak Republic and Slovenia, the sector revealed to have a comparative disadvantage for both gross trade NRCA scores and value-added NRCA scores (weak-weak). Romania and Croatia revealed mixed results. Romania reveals a comparative

advantage for both gross trade NRCA scores and value-added NRCA scores calculation in most of the years, but in the years 2000-2006 (before the accession into the EU) revealed comparative disadvantage for gross trade and simultaneously a comparative advantage for value-added trade (weak-strong). Croatia also revealed a comparative advantage for both gross trade NRCA scores and value-added NRCA scores in most of the years, but in the years 2015-2019 (after the accession into the EU) revealed comparative advantage for gross trade and simultaneously a comparative disadvantage for value-added trade (strong-weak).

In the next step, NRCA scores pairs value-added were analyzed regarding their cardinal, dichotomous and ordinal consistency (using gross trade data and value-added data to calculate scores).

The consistency test of the indices as cardinal measures (the extent to which a country has a comparative advantage/comparative disadvantage in an industry) of comparative advantage was based on the correlation coefficient between paired indices in each of the 26 years (Table 3). Only 2 countries (Czech Republic and Latvia) show a high levels of correlation (≥ 0.75). Estonia, Poland, Slovak Republic and Bulgaria show moderate levels of correlation (≈ 0.5). The rest of the countries shows low levels of correlation (Hungary and Lithuania) or even show negative coefficient of correlations (Slovenia, Croatia and Romania). This suggests that the use of traditional gross trade and value-added data leads to consistent assessment in the case of Czech Republic and Latvia and partially Estonia, Poland, Slovak Republic and Bulgaria. When assessing revealed comparative advantage of agrarian sector in Hungary, Lithuania, Slovenia, Croatia and Romania we can expect inconsistencies in analysis as the gross trade data reflect what a country is producing and exporting to a lesser extent.

The test of indices as a dichotomous measure was based on assessment of the share of years in which both of the paired indices suggest comparative advantage or comparative disadvantage (Table 3). In the case of the Czech Republic, Estonia, Hungary, Lithuania, Slovenia and Bulgaria this test indicates perfect match between 1995 and 2020. Also, other countries as Latvia, Poland, Slovak Republic and Croatia are highly consistent with all shares higher than 70%. This suggest that application of NRCA indices calculated using gross trade or value-added data are consistent as dichotomous measures.

The consistency test of the indices as ordinal measures (consistent in cross-country ranking of industry by NRCA) was based on the rank correlation coefficient for each pairing of gross and value-added data (Table 4). On average,

	cardinal measure		dichotomous measure	
	No. of obs.	score	No. of obs.	score
Czech Republic	26	0.922	26	1.000
Estonia	26	0.449	26	1.000
Hungary	26	0.273	26	1.000
Latvia	26	0.910	26	0.885
Lithuania	26	0.219	26	1.000
Poland	26	0.597	26	0.923
Slovak Republic	26	0.571	26	0.923
Slovenia	26	-0.454	26	1.000
Bulgaria	26	0.545	26	1.000
Croatia	26	-0.292	26	0.808
Romania	26	-0.032	26	0.731

Source: own calculations, data from TiVA

Table 3: Tests of consistency – correlation coefficients of paired RCAs indices.

	ordinal measure						
	1995	**2000**	**2005**	**2010**	**2015**	**2020**	**avg. 95-20**
cross-country ranking	0.300	0.845	0.818	0.909	0.945	0.909	0.868

Source: own calculations, data from TiVA

Table 4: Tests of consistency – correlation coefficients of paired RCAs indices

the NRCA calculated using gross trade and value-added data shows high level of correlation (0.868) over the period.

Food processing industries

The gross trade data indicated about half of the countries revealed comparative advantage in food processing. On the other hand, the value-added data indicated that most of the analyzed Central and Eastern European countries revealed comparative advantage except of the Czech Republic, Slovak Republic and Slovenia. The gross trade data and value-added data indicated that the comparative advantage in food processing has deteriorated in most countries of Central and Eastern Europe. Therefore, the prevailing tendency is the weakening of food industries in the analyzed Central and Eastern European countries, but there are also exceptions to this tendency.

More in detail, according to the results of calculations using gross trade data (Table 5), the scores of NRCA scores indicate on average that 6 out of analyzed 11 food processing industries in particular countries in the Central and Eastern European countries revealed comparative advantage from 1995 to 2020. Contrary 5 out of analyzed 11 industries revealed comparative disadvantage. On average, the positive NRCA scores revealed food industries in Poland (2.176), Lithuania (0.386), Croatia (0.386), Bulgaria (0.136), Latvia (0.134), and Estonia (0.057). The negative NRCA scores revealed food industries in the Czech Republic (-0.737), Romania (-0.538), Slovak Republic (-0.533), Slovenia (-0.317), and Hungary (-0.039). The scores of NRCA scores also indicate that comparative advantage of food processing industries deteriorated in the Czech Republic, Slovak Republic, Slovenia, Romania, and Croatia. The NRCA scores revealed mix result for Hungary, where the scores are oscillating around the comparative neutral point during the period under interrogation. In the case of Estonia, the comparative advantage deteriorated in the first decade of the period and then stagnated near the comparative neutral point. On the other hand, the comparative advantage improved in Latvia, Lithuania and significantly in Poland.

Food processing industries									
	Gross trade approach (index)								
	1995	2000	2003	2005	2010	2015	2020	avg. 95-20	Δ (T2 – T1)
Czech Republic	-0.242	-0.479	-0.817	-0.711	-0.838	-0.787	-0.925	-0.737	-0.793
Estonia	0.189	0.008	0.004	0.025	0.084	0.017	0.022	0.057	-0.143
Hungary	0.320	0.090	-0.175	-0.260	-0.131	-0.194	-0.114	-0.039	-0.537
Latvia	0.091	0.035	0.016	0.093	0.189	0.103	0.195	0.134	0.096
Lithuania	0.071	0.137	0.192	0.307	0.552	0.534	0.780	0.386	0.519
Poland	0.210	0.174	0.346	1.288	2.674	4.429	5.600	2.176	4.788
Slovak Republic	-0.310	-0.249	-0.464	-0.322	-0.611	-0.913	-0.846	-0.533	-0.488
Slovenia	-0.261	-0.186	-0.314	-0.341	-0.348	-0.346	-0.412	-0.317	-0.139
Bulgaria	-0.024	-0.049	-0.085	-0.054	0.312	0.309	0.365	0.136	0.365
Croatia	0.477	0.495	0.578	0.721	0.384	0.133	0.041	0.386	-0.433
Romania	-0.451	-0.294	-0.460	-0.526	-0.646	-0.620	-0.845	-0.538	-0.346
	Value added approach								
	1995	2000	2003	2005	2010	2015	2020	avg. 95-20	Δ (T2 – T1)
Czech Republic	-0.050	-0.133	-0.223	-0.119	-0.185	-0.266	-0.080	-0.186	-0.158
Estonia	0.096	0.015	0.007	0.001	0.033	0.007	0.005	0.025	-0.074
Hungary	0.188	0.148	0.035	-0.042	0.134	-0.032	-0.037	0.047	-0.214
Latvia	0.085	0.062	0.003	0.023	0.090	0.024	0.073	0.064	-0.020
Lithuania	0.104	0.135	0.182	0.235	0.309	0.317	0.453	0.257	0.213
Poland	0.817	0.448	0.427	0.999	1.946	2.187	2.849	1.369	1.712
Slovak Republic	-0.062	-0.068	-0.157	-0.039	-0.135	-0.274	-0.234	-0.125	-0.140
Slovenia	-0.021	-0.001	-0.052	-0.094	-0.110	-0.128	-0.149	-0.079	-0.129
Bulgaria	-0.011	-0.003	-0.010	0.022	0.137	0.197	0.117	0.100	0.135
Croatia	0.292	0.310	0.352	0.435	0.252	0.125	0.106	0.266	-0.165
Romania	0.012	0.093	0.185	0.085	-0.055	-0.146	-0.114	0.067	-0.161

Note: T1 - average of 1995-2000; T2 - average of 2015-2020
Source: own calculations, data from TiVA

Table 5: RCAs indices for selected countries in Central and Eastern Europe using gross and value added approach, selected years.

Also, the comparative advantage of food processing industry has improved and changed from comparative disadvantage to comparative advantage in Bulgaria.

According to results of calculations using value-added data (Table 5), the scores of NRCA scores indicated that 8 out of the analyzed 11 food processing industries revealed comparative advantage from 1995 to 2020. On the other hand, 3 out of analyzed 11 industries revealed comparative disadvantage. The positive NRCA scores revealed food industries in Poland (1.369), Croatia (0.266), Lithuania (0.257), Bulgaria (0.100), Romania (0.067), Latvia (0.064), Hungary (0.047), and Estonia (0.025). The negative NRCA score revealed food industries in the Czech Republic (-0.186), Slovak Republic (-0.125), and Slovenia (-0.079).

When comparing the changes in comparative advantage of food processing industries, the results show similarities as well as differences to the results based on the gross trade data. The scores of NRCA also indicate that comparative advantage of food processing industries deteriorate in Hungary, Slovenia, Slovak Republic, Czech Republic, Croatia and Romania. In the case of Estonia, the comparative advantage deteriorated in the first decade of the period under scrutiny and then stagnated near the comparative neutral point. The NRCA scores revealed mix result for Latvia. Scores are oscillating but keep the level of the comparative advantage in the period under scrutiny. On the other hand, the comparative advantage of food processing industry has changed from comparative disadvantage to comparative advantage in Bulgaria. The comparative advantage improved in Latvia, Lithuania and significantly in Poland.

This overview of revealed comparative advantages (calculated using gross and value-added trade data) indicates differences in the values of indicators. Following the Brakman and Van Marrewijk (2017) classification, in the case of the Poland, Croatia, Latvia, Lithuania, and partially Estonia, sectors revealed to have a comparative advantage for both gross trade NRCA scores and value-added NRCA scores (strong-strong). In the case of the Czech Republic, Slovakia and Slovenia sectors revealed to have a comparative disadvantage for both gross trade NRCA scores and value-added scores NRCA scores (weak-weak). In the case of Hungary and Bulgaria, the sectors revealed to have a comparative disadvantage for gross trade NRCA scores and simultaneously a comparative advantage for value-added trade NRCA scores (weak-strong) in some of the years under scrutiny. Apparently the strength and importance of these sectors for Hungary and Bulgaria were underestimated when using gross trade data. In the case of Romania, the sector revealed to have a comparative advantage for gross exports and simultaneously a comparative disadvantage for value-added trade (strong-weak). Apparently the strength and importance of these sectors for Romania was overestimated when using gross trade data. This could be caused by the Rotterdam-Antwerp effect.

In the next step NRCA scores were analyzed according to their cardinal, dichotomous and ordinal consistency (Table 6 and 7). Most countries (9 out of 11) show high levels

	cardinal measure		dichotomous measure	
	No. of obs.	score	No. of obs.	score
Czech Republic	26	0.841	26	1.000
Estonia	26	0.956	26	0.846
Hungary	26	0.798	26	0.769
Latvia	26	0.695	26	1.000
Lithuania	26	0.950	26	1.000
Poland	26	0.943	26	0.962
Slovak Republic	26	0.900	26	1.000
Slovenia	26	0.929	26	0.923
Bulgaria	26	0.870	26	0.808
Croatia	26	0.977	26	0.923
Romania	26	0.701	26	0.269

Source: own calculations, data from TiVA

Table 6: Tests of consistency – correlation coefficients of paired RCAs indices.

	ordinal measure						
	1995	2000	2005	2010	2015	2020	avg. 95-20
cross-country ranking	0.583	0.836	0.791	0.945	0.997	0.885	0.824

Source: own calculations, data from TiVA

Table 7: Tests of consistency – correlation coefficients of paired RCAs indices.

of correlation (≥ 0.75), and the correlation for all the observations was 0.946. In the case of Latvia (0.695) and Romania (0.701) the results show rather medium levels of correlation. This suggests that usage of NRCA indices and gross trade and value-added data are mostly consistent as cardinal measures (although there are exceptions).

The test of indices as a dichotomous measure was based on assessment of the share of years in which both of the paired indices suggest comparative advantage or comparative disadvantage. In the case of the Czech Republic, Slovakia, Latvia and Lithuania this test indicated perfect matches. Also, other countries like Estonia, Hungary, Poland, Slovenia, Bulgaria, and Croatia are highly consistent with all shares higher than 70%. Only Romania show high level of inconsistency (0.269). The consistency for all the observations was 0.864 which suggests that usage NRCA indices and gross trade and value-added approach are mostly consistent as dichotomous measures.

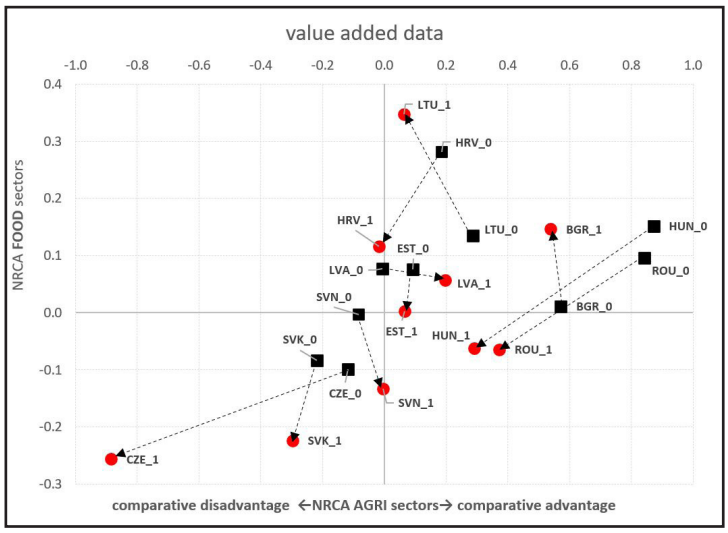
The consistency test of the indices as ordinal measures (consistent in cross-country ranking of industry by NRCA) was based on the rank correlation coefficient for each pairing of gross and value-added data. NRCA scores calculated using gross trade and value-added data show high correlations (0.934) over the period. Also, the consistency improved over the observed time period. Results show that the NRCA scores calculated using gross trade and value-added data are consistent in the cross-country ranking of industries.

Trajectories and mutual interaction between revealed comparative advantages

FFor a particular country, NRCA pair-scores for agrarian industries and food processing industries are presented in the Cartesian coordinate system. Both figures (Figure 1 and 2) compare the change in pair scores between the beginning of the period under scrutiny (average 1995-2000) and the end of the period (avg. 2015-2020).

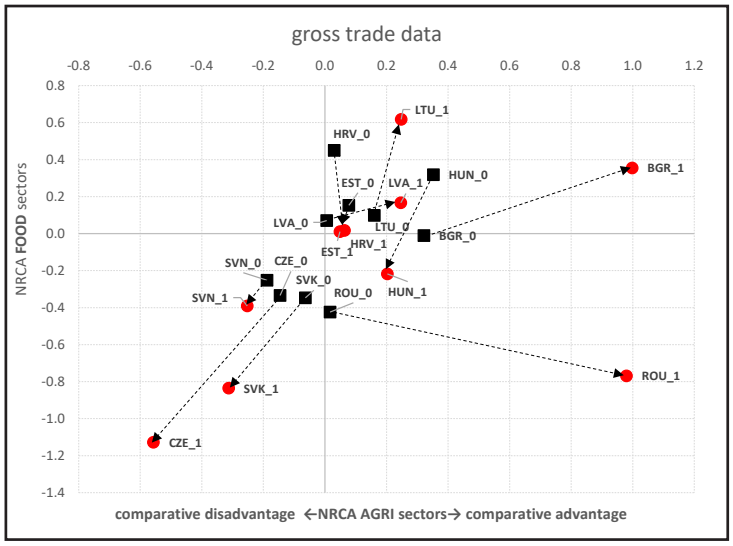
First interesting result is that pair scores indicate complex positioning and change in trajectory if we compare NRCA pair-scores of agrarian and food processing industries in specific countries of Central and Eastern Europe at the beginning and at the end of the period under scrutiny. Baltic countries show diverse trajectories when comparing each other. According to both gross trade data and value-added data, Estonia revealed comparative advantage in both agrarian and food processing industries at the beginning of the period. Gross trade as well as value-added trade data indicate a decline of the comparative advantage in both the agrarian and food processing industries (it shows dissimilarity when indicating how strong the decline is). At the end of the period, Estonia seems to have lost its comparative advantage in food processing and still (despite the decline) keeps its comparative advantage in agriculture. According to gross as well as value-added data, Lithuania revealed comparative advantage in both agrarian and food processing industries at the beginning of the period. The usage of trade or value-added trade show different tendency. The gross trade data suggest that the comparative advantage of both agrarian and food processing industries is getting stronger in Lithuania. The value-added data indicate that comparative advantage of food processing industry is getting stronger and the comparative advantage of the agrarian sector is deteriorating. Lithuania still maintains a comparative advantage in both industries, but at the end of the period, however, value-added data suggest a negative tendency in the development trajectory. According to both gross trade data and value-added trade data, Latvia revealed a comparative advantage for its food processing industry and a neutral position (close to comparative advantage neutral point) for its agrarian sector at the beginning of the period. The data suggest an improvement in the comparative advantage of the agrarian sector using both gross and value-added data. The gross trade seems to overrate the tendency in the comparative advantage of the food processing industry when compared to the value-added data. Latvia seems to maintain its comparative advantage in both industries by the end of the period.

In the case of Poland, both gross trade data and value-added data revealed a comparative disadvantage for the agrarian sector. Both types



Source: own calculations, data from TiVA

Figure 1: Classification of the interaction between RCA of agrarian and food processing sector (value added data).



Source: own calculations, data from TiVA

Figure 2: Classification of the interaction between RCA of agrarian and food processing sector (gross trade data).

of data indicate that the comparative advantage of the food industry is getting significantly stronger. (data for Poland are not in the Figure 1 and 2 because the axis scale does not allow to visualize the Polish data). On the other hand, despite the enhanced advantage in food processing, the comparative advantage of agrarian industry deteriorated in Poland. The Czech Republic and Slovak Republic revealed comparative disadvantage both in agrarian and food processing industries at the beginning of the period using gross data as well as value-added data. Both countries similarly show deterioration of the comparative advantage of agrarian and food processing industry. Hungary revealed comparative advantage in both agrarian and food processing industry at the beginning of the period using gross data as well as value-added data. There is deterioration of comparative advantage in both industries in Hungary. At the end of the period, Hungary almost lost its comparative advantage in food processing and could lose the comparative advantage of its agrarian industry if the trend continues.

In the case of Croatia, both gross trade data and value-added data revealed comparative

advantage of food processing industry and slight comparative advantage of agrarian sector at the beginning of the period. The trend shows deterioration of the comparative advantage of food processing industry, contrary to slight enhancement of the comparative advantage of agrarian sector. Croatia seems to face a risk of losing comparative advantage in food processing in upcoming years.

Slovenia revealed comparative disadvantage of both agrarian and food processing industry. Both gross and value-added data show further deterioration of the comparative advantage of food industry. In the case of the comparative advantage of agrarian sector, the gross data show slight improvement of comparative advantage. On the other hand, the value-added data indicate deterioration of the comparative advantage.

Both gross and value-added data indicate that the comparative advantage of food processing industry in Bulgarian has improved. Also, gross and value-added data are signaling mix results when used to analyze comparative advantage of agrarian sector in Bulgaria. The gross trade data indicates that comparative advantage of agrarian sector becomes stronger, the value-added data indicates opposite tendency. In the case of Romania, the calculations also show mix results. Both gross and value-added data indicate deterioration on comparative advantage of food processing industry, however revealing opposite levels of comparative advantage at the beginning of the period. The gross data indicate significant improvement of comparative advantage of agrarian industry. Value-added data show opposite tendency of deterioration of the comparative advantage of agrarian sector in Romania.

Conclusion

This article interrogates comparative advantage and competitiveness of agrarian and food processing sectors in the context of international fragmentation of production in selected countries in the Central and Eastern Europe using gross trade and value-added trade data. The international fragmentation of production could be a powerful source of increased efficiency and firm competitiveness. Despite the slowdown in economic globalization in the last decade, the countries across the Europe still remain integrated into GVCs. Analysis in this article delivers conclusion in two areas in the body of knowledge: 1) it assessed the consistency of NRCA scores calculated using gross and value-added trade data, 2) it assessed comparative advantage and competitiveness of agrarian and food processing sectors in particular Central and Eastern European countries (again using gross and value-added trade data).

The consistency test suggests that NRCA pairs of indices calculated for agrarian sectors using gross trade and value-added trade data suggests that are generally consistent as dichotomous and ordinal measures (excl. Romania). Test of NRCA pairs of indices as cardinal measures shows high discrepancies in all countries of scrutiny, except of the Czech Republic and Latvia. The analysis of NRCA scores for food processing industries suggests that these scores are generally consistent as cardinal, dichotomous and ordinal measures, except of Romania (as dichotomous measure). The possible explanation for such a discrepancy in the case of Romania could be also Rotterdam-Antwerp effect.

Ceglowski (2017) and Fertö (2018) concluded in theirs studies that countries' and/or industries' export competitiveness look different through the lens of domestic value-added exports than on the basis of conventional measures using gross exports. Fertö (2018) assessed specifically agri-food trade. Results of this analysis have found significant differences for NRCA pairs as cardinal measures in the case of agrarian sectors. On the other hand, results of this study generally do not support the conclusions of Ceglowski (2017) and Fertö (2018) because of the dichotomous and ordinal characteristics of agrarian industries and the cardinal, dichotomous and ordinal characteristics of food industries.

In the period under review (1995-2020), most of the analyzed Central and Eastern European countries (Estonia, Hungary, Latvia, Lithuania, Bulgaria, Croatia and Romania) revealed comparative advantage in agricultural production in both gross trade and value-added trade data. The Czech Republic, Poland, Slovenia, and Slovakia revealed comparative disadvantage in agrarian production. The gross trade data has indicated about half of the countries (Poland, Estonia, Latvia, Lithuania, Bulgaria and Croatia) reveal comparative advantage and the Czech Republic, Hungary, Slovakia, Slovenia, Romania revealed comparative disadvantage in food processing. However, using value-added data, the results suggest that only the Czech Republic, Slovak republic and Slovenia revealed comparative disadvantage.

Although the results of this analysis offer insight (identifying which sectors have or do not have a comparative advantage as a whole) on the state

of comparative advantage and competitiveness of the agricultural and food sectors of selected countries, it is necessary to point out that even if a country does not have a comparative advantage in the agricultural sector (or food processing), it may have a comparative advantage in specific sub-sectors of production, or with specific regions. In this sense, the results of this study should be used as complementary findings to the results of studies that evaluated the comparative advantages of individual sub-sectors using data structured according to the applied methodologies, e.g., the Harmonized System or Standard international trade classifications (e.g. Smutka et al., 2018; Bojnec and Fertő, 2019; Matkovski et al. 2019; Vondráček et al., 2022).

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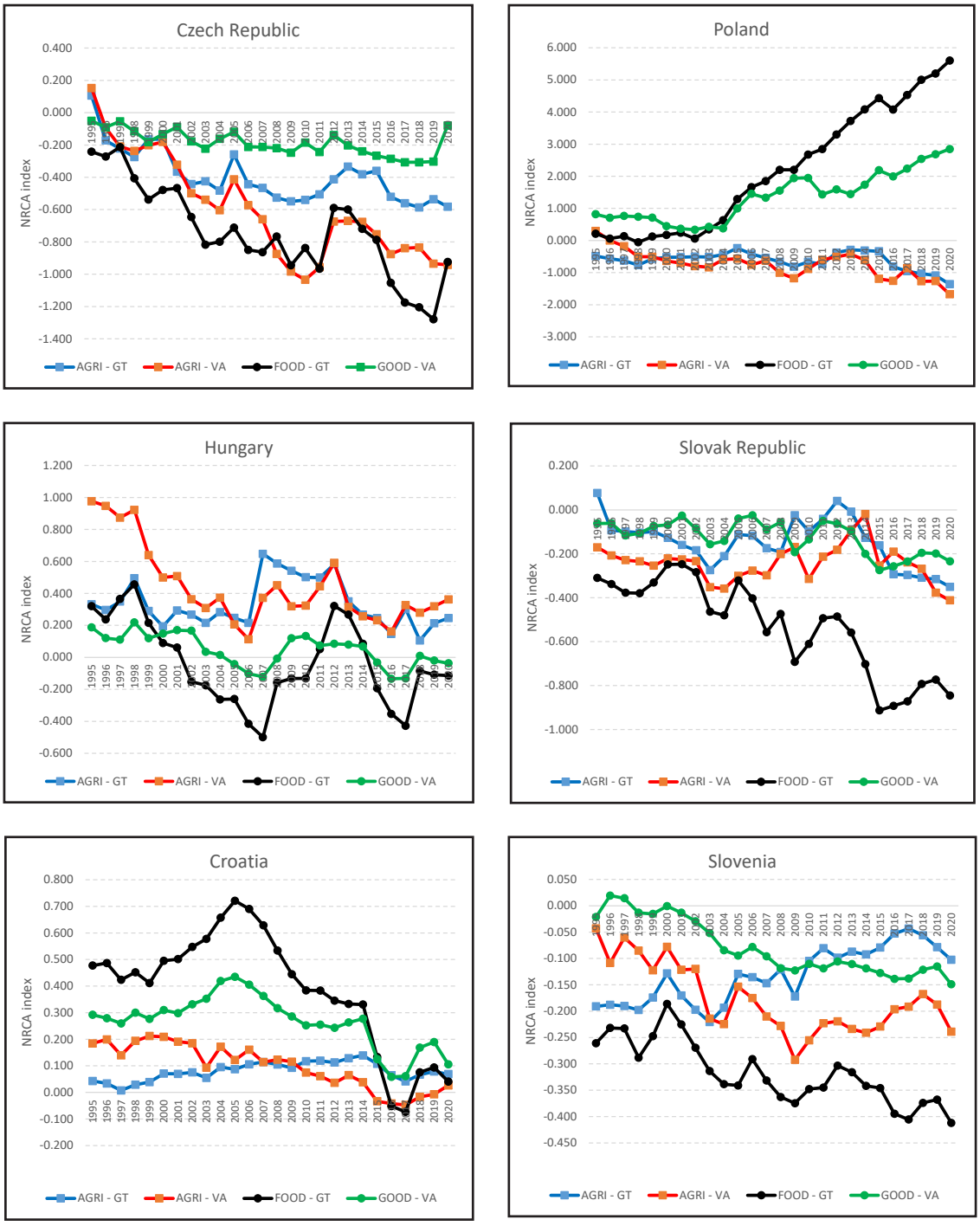
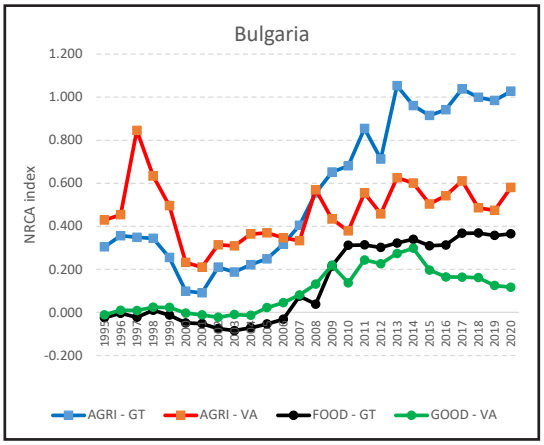
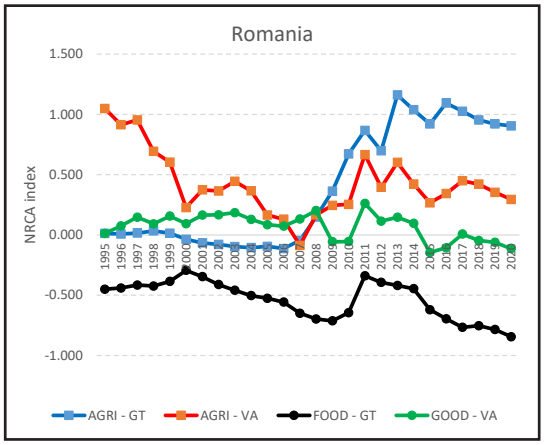
Appendix

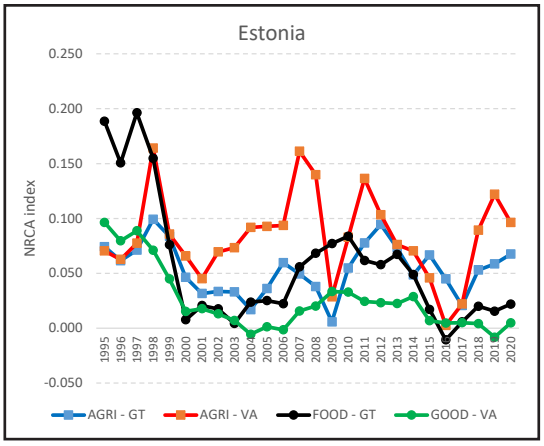


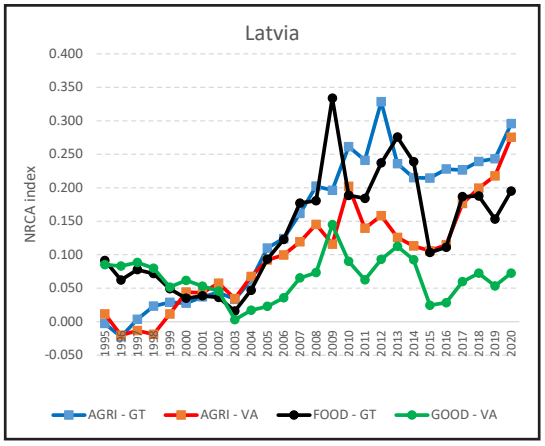
Source: own calculations, data from TiVA

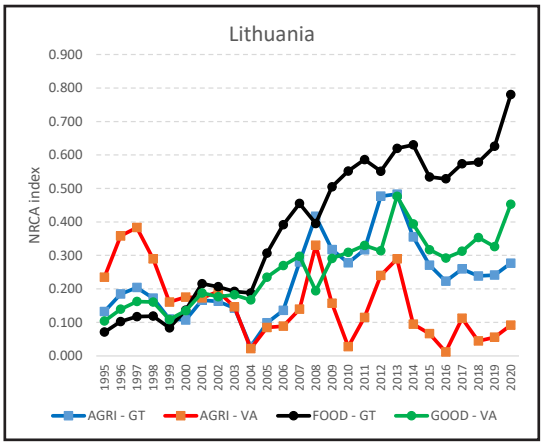
Figure A1: NRCA scores for agrarian and food processing sectors using gross trade and value-added trade data. (To be continued).











Source: own calculations, data from TiVA

Figure A1: NRCA scores for agrarian and food processing sectors using gross trade and value-added trade data. (Continuation).

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