ISSN 0971-3441
Online ISSN 0974-0279

July-December 2024
Volume 37
Number 2

Agricultural Economics Research Review

Agricultural Economics Research Association (India)

ISSN 0971-3441
Online ISSN 0974-0279

Agricultural Economics Research Review

Agricultural Economics Research Association (India)
National Agricultural Science Centre Complex
Dev Prakash Shastri Marg, Pusa
New Delhi - 110 012

Agricultural Economics Research Review
Vol. 37 (No.2) 2024

Financial support from:

Indian Council of Agricultural Research (ICAR), New Delhi

Published by:
Dr Anjani Kumar, Secretary, AERA on behalf of Agricultural Economics Research Association (India)

Printed at:
Cambridge Printing Works, B-85, Phase II, Naraina Industrial Area, New Delhi 110 028

ISSN 0971-3441

Agricultural Economics Research Review

[Journal of Agricultural Economics Research Association (India)]

Volume 37 **Number 2** **July-December 2024**

Contents

Author index

Agricultural Economics Research Review 2024, 37 (2), 147-164
DOI: 10.5958/0974-0279.2024.00011.3

Agricultural sector amidst rising food insecurity: Quantifying the impact of market access barriers

Murali Kallummal, Simran Khosla, Ankit Kundu, and Akanksha Sinha

Centre for WTO Studies (CWS), Centre for Research in International Trade (CRIT),
Indian Institute of Foreign Trade (IIFT), 7th Floor Nafed House, New Delhi –100014, India

*Corresponding author: muralik@iift.edu

Abstract Global conflicts are leading to worsening of food insecurity. Additionally, the trade policies adopted by the developed world by way of application of non-tariff measures (NTMs) are further contributing to the already worsened food security scenario. This paper quantifies the impact of Non-Tariff Measures on the agricultural exports of the low-middle income countries at HS- 4-digit level. While the existing literature has mostly focused on bilateral trade analyses, this paper encompasses a multilateral trade model involving multiple exporters, importers, and agricultural products. The model employs a gravity model framework which is estimated using a Feasible Generalized Least Square estimator. The results reveal that, the impact of SPS and TBT are significant. A single SPS notification corresponds to a 0.3% decrease in exports, while an additional TBT notification increases the trade between countries by 2.7%. The paper brings forth the reasons for the differential impact on the exporters of an SPS measure in comparison to a TBT measure and suggests measures to improve the state of global food security.

Key words Non-Tariff Measures (NTM), Sanitary and Phytosanitary Measures (SPS), Technical Barriers to Trade (TBT), Agricultural Trade, Ad-Valorem Equivalent Tariffs, Food Security

JEL codes F11, F13, Q13, Q17

Introduction

The Food and Agriculture Organization (FAO) have reported that globally 735 million people were grappling with hunger in 2022, marking an increase of 122 million individuals since the onset of the global pandemic in 2019 (FAO and others 2023). With just six years to go in achieving the Sustainable Development Goal (SDG) of Zero Hunger, the world seems to be going more off-track and the task is getting more formidable with each passing day. The researchers closely monitoring the global food market outlook have identified a wide range of contributing factors including the outbreak of the COVID 19 pandemic, rising frequency and intensity of extreme weather events, inflation, and deterioration in the overall terms of trade which exert pressure on the global food supplies (Durant, 2022; Baptista et al., 2022; Rother et al., 2022; Rother et al.,2023). Another influential yet less explored factor, which weighs on food supplies is the sharp increase in trade policy measures. Since the formation of the World Trade Organization (WTO), its members have continued to seek trade policy reforms in agriculture with a view to make markets fairer and more competitive. The Uruguay Round led to the binding of tariff lines to a maximum level. However, most of the discussions stopped short of any conclusive agreement on non-ad valorem tariffs and there was a lack of disciplining of WTO compatible non-tariff measures (NTMs) at the multilateral level (Kallummal, 2015; Bureau et. al, 2004). Hence, at a time when the nations are struggling to tackle hunger, this marks a good time for the policymakers and trade negotiators to have a closer look at NTMs, which have taken on a more central role in policy formulations as economies have developed and tariffs have declined.

The NTMs are policy measures other than ordinary customs tariffs that can potentially have an economic effect on international trade in goods, changing quantities traded, or prices (cost enhancing) or both (UNCTAD, 2019). What should be kept in mind is that NTMs are diverse and affect different economies and products differently. The evidence from ITC business surveys suggests that NTMs like TBT/SPS measures are the most burdensome for developing countries' exporters (WTO, 2012). Moreover, even in 2024 trade costs for developing economies including least developing economies still remain almost 30 per cent higher than high income economies, and trade costs in agriculture are 50 per cent higher than those in the manufacturing sector (WTO, 2023). These are some of the most contentious issues at present for achieving food security since the biggest hindrance for exporters at low stages of development is to meet the onerous compliance and procedural costs (Murina et al., 2017). Moreover, ongoing discussions accentuate that the same NTM used to pursue a public policy objective can also be used for protectionist purposes. This underlines the difficulty of distinguishing between legitimate motivations for NTMs, and of identifying instances where NTMs create unnecessary trade costs which disrupt food supply and make access to food beyond the reach of many (Peci et al., 2020; WTO, 2012,).

Against this background, the paper addresses the question of whether regulatory trade barriers such as NTMs have a role in rising food insecurity, with particular focus on the low-middle-income exporters, who are the food baskets for the world and at the same time are most vulnerable to such measures. The previous studies have been able to formalise a significant channel through which these policy actions can destabilize global food markets and posit that trade policies are a major source of risk for global food stability.The analysis by Giordani et al. (2016) over 2008–11, has shown the existence of a multiplier effect in food trade policy. Similarly, Disdier et al. (2008); Murina et al. (2017); Henson et al. (2001); Ferro et al. (2015) have also illustrated the negative impact of trade policy measures. A more recent and micro level evidence Maziku et al. (2024), wherein over 400 small farmers in Tanzania were surveyed has indicated an alarming finding that a unit increase in transaction costs attributed to NTMs could reduce the quantity produced by 16 per cent. Nevertheless, there are studies which have found NTMs can be trade and welfare-enhancing (UNCTAD, 2019; Assoua et al., 2022; Gibson et al., 2018). This contradiction still remains a mystery with some scholars asserting that the mixed evidence found in literature may be partly explained by methodological and structural differences and the direction of the effect may also depend on product categories under investigation (Santeramo et al., 2019; Gibson et al., 2018).

Despite a rich body of literature investigating the impact of trade policy instruments on agriculture products, we find that existing studies are narrow in their coverage. In other words, they often concentrate on specific NTMs, products, or importer/exporter case studies. Our paper strives to transcend these limitations and makes several significant methodological contributions to the existing gap in the literature. Firstly, although much of the literature remains curious about the impact of NTMs by developed economies, their focus has remained primarily on two economies: European Union (EU) and the United States of America (USA). However, these behind the border measures are being utilised intensively by several developed markets which remain unexamined. Our study uniquely encompasses a comprehensive examination of ten developed economies which are the most proliferate users of these measures. Secondly, while the existing studies attempt to analyse the impact of technical NTMs in their entirety, they commonly narrow their focus to specific facets of these measures, such as standards or tolerance limits and generalise results which, in our view, can be very misleading. In instances where research encompasses the entirety of NTMs, it tends to be constrained to one particular exporter, such as exports from China, Chile, or Peru to mention a few. In contrast, our paper adopts a holistic perspective, scrutinizing technical NTMs (SPS and TBT)[1] in their entirety and since NTMs can have heterogenous effects, our study entails analysis over ten low middle-income exporters and large number of agricultural products. We have also observed a major gap in the literature,

[1]SPS = Sanitary and Phytosanitary Measures; TBT = Technical Barriers to Trade

wherein studies which tend to look at the impact of NTMs of European Union as a group, do not consider that members within the EU can also set their own NTMs in addition to EU NTM's and fail to include their measures which could lead to underestimated results. Hence, a crucial methodological contribution that our paper makes is that we not only scrutinize the NTMs of the European Union but also integrate the NTMs imposed by individual member states of the European Union. This approach allows for a more comprehensive and accurate understanding in the impact of SPS and TBT measures on exports.

Literature review

There is abundance of literature that seeks to measure how NTMs affect the way trade operates. However, the conclusions drawn from the theoretical and empirical studies remain multifaceted. Predominantly, research suggests that these measures often pose as barriers to trade. Using cluster analysis, Disdier et al. (2010) have examined the correlation between NTM occurrence, trade coverage, and trade frictions for agricultural products. Their finding have revealed a potential protectionist effect of NTMs wherein the domestic producers may seek protection of their economic interests by limiting foreign competition. The most of the studies in literature have focused on policy measures by a singular developed importer such as European Union (EU) or United States of America (USA). For instance, Murina et al. (2017) have found that EU's SPS measures significantly impede agricultural exports from low-income countries, highlighting the challenge for less-developed nations in complying with regulatory frameworks. This result is consistent with the hypothesis that since market access is increasingly determined by capability to comply with the regulatory framework, the countries at lower level of development find themselves outcompeted by exporters who operate in countries where the costs of compliance are lower. Similarly, Henson et al. (2001) and Ferro et al. (2015) have underscored the pivotal role of SPS measures in shaping the developing countries' access to developed markets and have emphasize on the constraints posed by behind-the-border measures that limit the effective participation of developing countries in the WTO.

It is intriguing to observe the discriminatory trade-dampening impact these measures can have. For example, Disdier et al. (2008) have estimated the stringency of Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) agreement on food products, and have revealed a significant reduction in developing countries' exports to OECD countries. They have found that NTMs significantly reduce developing-countries' exports to OECD countries, but do not affect the trade between OECD members. Similarly, Melo et al. (2014) employing a gravity model, have scrutinized the impact of technical NTMs on Chile fruit exports. They introduced a composite stringency-perception index encompassing various trade requirements and their results indicate that high stringency correlates with a substantial negative effect on export volumes, particularly heightened when stringency intensifies in the developed economies. Other studies such as by Peterson et al. (2013) have analysed the influence of USA's SPS measures on fruit and vegetable imports from 89 exporting nations during 1996–2008. Their finding have suggested that these technical measures generally dampen trade, however the restrictiveness to export due to these measures diminishes notably as exporters accumulate experience, and eventually trade-dampness disappears beyond a certain threshold. Beyond SPS and TBT, the impact of standards has also garnered attention. Gupta et al. (2022) have explored how food standards affect marine product exporters from high-income versus low-income countries. Their findings also reiterate the discriminatory impact of behind the border measures wherein the wealthier nations tend to expand exports under such standards, while exports of poorer nations decrease.

Since the acceptance of the notion that different NTMs can have different impacts, some scholars have endeavoured to investigate and quantify this phenomenon. There is a growing consensus that NTMs have disparate impacts across agricultural and non-agricultural sectors. Bratt (2017) have studied how the impact of NTMs on trade can vary across exporter-importer pairs. This study is methodologically unique since it estimates the trade costs associated with NTMs in terms of ad valorem equivalents (AVEs), instead of using frequency or count of NTMs. It has demonstrated that the same NTM can have asymmetric effects across exporting countries. Secondly, it has found that high-income exporters are less affected by NTMs than low-income exporters and this seems to be the case regardless of whether it is agricultural or manufacturing goods. Webb et. al (2020) studied the econometric estimates of the effect of different types of NTMs on imports into six ASEAN countries. In their study, they differentiated between NTMs on intermediate and final goods, as well as distinguishing between whether they are applied to agricultural products or non-agricultural products. Their findings accentuate of the NTMs that have a statistically significant impact, their effect is greatest on agricultural intermediates with an average impact of 74% on the affected products and smallest for non-agricultural products for final consumption with an average of 49% on the affected products. According to them, applying a microbiological requirement to imports of agricultural product for final consumption is expected to decrease imports by 63%, whereas applying a certification requirement to a non-agricultural intermediate good is expected to decrease imports by 32%.

Contrary to the above studies, some researchers have either found NTMs to be trade enhancing or have reportedmixed results. For example, Schuster et al., (2015) analysed the impact of private food standards on the export performance of asparagus firms in Peruusing panel data from 87 firms. They did not find any evidence that certification to private standards in general and to specific individual private standards, has an effect on firms' export performance. However, since this wasa specific case-study at firm level on asparagus exports from Peru, one should be careful to generalize results. Gibson et al. (2018), have found some evidence of positive relationships among SPS measures, and exports. According to them, the successful and experienced exporters quickly learn how to deal with these measures on their own and are able to expand their trade. Luwedde et al., (2022) have examined the effects of subset of SPS measures on Uganda's fish exports. They have used a gravity model variant and panel data from 28 countries for the period 2001-2018. They have revealed that SPS measures such as microbiological and parasitic contamination, have a negative effect on fish exports while certification about the absence of Genetically Modified Organisms (GMO) has an opposite effect. Till date, that the gravity model is the most popular choice for empirical analysis due to its strong theoretical underpinnings, high empirical explanatory performance, and ability to address the potential endogeneity induced by omitted variables (Peci et al., 2020; Anderson and van Wincoop, (2003). However there do exist a few papers that have adopted qualitative tools for estimation. For example, Assoua et al., (2022) have studied the effect of SPS measures on Cameroon's cocoa exports using a mixed methodological approach, consisting of both qualitative and quantitative approaches using business surveys and gravity-based models, respectively. The major institutional actors in the cocoa sub-sector were interviewed for the same. The findings have suggested that cocoa export from Cameroon is not significantly influenced by the SPS measures in the major importing markets. However, the paper has necessitated the need to strengthen Cameroon's standards-setting institutions and the regulatory framework to improve Cameroon's capacity to comply with SPS measures and to improve the export quality. Ridley et al., (2024) have estimated the impacts of tariffs and NTMs such as SPS, TBT, quantitative restrictions, and special safeguard measures on three meat products trade using a structural gravity model. Their baseline regression results have shown tariffs hinder trade, but SPS measures and TBTs, on an average, expand trade. The simulation results have shown that tariff reductions during this period expanded global trade by a cumulative US$ 466.2 million for the three products. In contrast, growth in the number of NTMs caused global meat trade to rise by US$ 8.4 billion.

Hence, the effect of technical NTMs can be two-fold; firstly, these measures whose compliance requires a significant cost outlay reduce trade; and secondly, information on the safety and quality of products can increase consumer sureness and confidence in foreign products, reduce fixed costs and increase trade in the long-run (Murina et al., 2017). Therefore, the literature underscores the multifaceted nature of the relationship between trade and technical NTMs which is influenced by two variables, (a) the stage of development of an economy, and (b) the size of participating firm.

To sum up, the existing literature can be segmented into two distinct categories: (1) studies which have focused on specific agricultural products, and (2) studies which have covered the whole ambit of agricultural products in their analysis. We find that studies in the second cluster are less abundant compared to the former group and our paper aims to address this gap by examining a wide range of agricultural products at the maximum disaggregate level possible, i.e. HS 4-digit level. Secondly and most importantly, the

Table 1 List of exporting and importing countries selected for study

S. No.	Exporting Countries	Importing Countries
1	Egypt	Belgium
2	India	France
3	Lebanon	Germany
4	Morocco	Italy
5	Pakistan	Japan
6	Philippines	Netherlands
7	Sri Lanka	South Korea
8	Tunisia	Spain
9	Ukraine	United Kingdom
10	Vietnam	United States

Source Based on authors calculation.

investigation into the impact of non-tariff measures on the escalation of food insecurity remains unexplored. According to our limited knowledge, our study is first such study which endeavours to shed light on this critical policy challenge, which holds significant relevance in the contemporary landscape

Data sources and methodology

For the study, 10 exporters, 10 importers, and 20 agricultural products (HS 4-digit level)were taken over the span of 22 years from 2000 to 2021. The process of selecting the exporters and importers was done in three key steps: (i) shortlisting of exporting countries, which were categorised as low middle-income countries on the basis of the World Bank's latest income categorisation (2023), (ii) shortlisting of high-income importing countries who were the most proliferate users of NTMs, and (iii) selection of countries who were actively engaged in trade, or more precisely, for which trade data (exports) was readily available (Table 1).

The chosen product categories were those which were subject to a greater cumulative number of Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) notifications. Table 2 shows the selected agricultural products (HS 4-digit) along with their product description.

To assess the influence of NTM measures on exports, augmented gravity model has been used. In our model, the Multilateral Resistance Index (MRI) and other gravity variables (common language, common border, and common coloniser on the basis of framework provided by Timini et al. (2019); and Anderson et al. (2003) have been included. The MRI index has been proposed as a remedy for the computational challenges associated with structurally estimating exporter- and importer-specific terms based on the economic model's variables. One key issue addressed by the MRI Index is the challenge of multicollinearity (Cipollina et al., 2016). This issue arises when we include gravity variables as a factor in the gravity model. Multicollinearity can lead to unreliable estimates and difficulties in interpreting the individual effects of variables. The computation of the MRI Index becomes particularly relevant in managing and mitigating these challenges, providing a more robust and accurate framework for gravity estimations in econometric analyses.

The exports data and tariffs data were sourced from the UN Comtrade database. The exports were our dependent variables and we have taken the logarithmic transformation of the variable; hence we have replaced the 0-export value by any exporting countries with 1. Data on NTMs was gathered from the Centre for WTO Studies online web databases on SPS measures[2] and TBT measures[3]. The aggregate number of SPS and TBT notifications were taken for the reporting country's trade partner at HS 4-digit level in a particular year. The countries that are members of the European Union adopt the SPS and TBT notifications issued by the EU. Additionally, these member countries also issue their own notifications for certain product categories. In such instances, the total count of SPS and TBT notifications was calculated as the sum of the notifications released by the EU and those which were released by each individual member country for the respective product category. For the UK we adhered to the notification count of the European Union until the occurrence of Brexit in 2019. Subsequently, from 2020 onwards, we have considered the notifications released by the UK itself instead of continuing to follow those of the EU. This approach ensured a comprehensive assessment of regulatory notifications for effective analysis and

[2]Centre for WTO Studies online database on SPS measures, https://cc.iift.ac.in/sps/index.asp.
[3]Centre for WTO Studies online database on TBT measures,https://cc.iift.ac.in/tbt/index.asp.

Table 2 Selected Agricultural products (HS4-Digit level) and product description

S. No	HS Code	Product Description
1	0303	Fish, frozen, excluding fish fillets and other fish meat of heading No. 03.04.
2	0709	Other vegetables, fresh or chilled.
3	0804	Dates, figs, pineapples, avocados, guavas, mangoes and mangosteens, fresh or dried.
4	0810	Other fruits, fresh.
5	0902	Tea, whether or not flavoured.
6	0904	Pepper of the genus Piper; dried or crushed or ground fruits of the genus Capsicum or of the genus Pimenta.
7	0910	Ginger, saffron, turmeric (curcuma), thyme, bay leaves, curry and other spices.
8	1211	Plants and parts of plants (including seeds and fruits), of a kind used primarily in perfumery, in pharmacy or for insecticidal, fungicidal or similar purposes, fresh or dried, whether or not cut, crushed or powdered.
9	1704	Sugar confectionery (including white chocolate), not containing cocoa.
10	1902	Pasta, whether or not cooked or stuffed (with meat or other substances) or otherwise prepared, such as spaghetti, macaroni, noodles, lasagne, gnocchi, ravioli, cannelloni; couscous, whether or not prepared.
11	1905	Bread, pastry, cakes, biscuits and other bakers' wares, whether or not containing cocoa; communion wafers, empty cachets of a kind suitable for pharmaceutical use, sealing wafers, rice paper and similar products.
12	2001	Vegetables, fruit, nuts and other edible parts of plants, prepared or preserved by vinegar or acetic acid.
13	2005	Other vegetables prepared or preserved otherwise than by vinegar or acetic acid, not frozen, other than products of heading No. 20.06.
14	2007	Jams, fruit jellies, marmalades, fruit or nut pur,e and fruit or nut pastes, being cooked preparations, whether or not containing added sugar or other sweetening matter.
15	2008	Fruit, nuts and other edible parts of plants, otherwise prepared or preserved, whether or not containing added sugar or other sweetening matter or spirit, not elsewhere specified or included.
16	2009	Fruit juices (including grape must) and vegetable juices, unfermented and not containing added spirit, whether or not containing added sugar or other sweetening matter.
17	2103	Sauces and preparations therefor; mixed condiments and mixed seasonings; mustard flour and meal and prepared mustard.
18	2106	Food preparations not elsewhere specified or included.
19	2202	Waters, including mineral waters and aerated waters, containing added sugar or other sweetening matter or flavoured, and other non-alcoholic beverages, not including fruit or vegetable juices of heading No. 20.09.
20	3301	Essentials oils (terpeneless or not), including concretes and absolutes; resinoids; extracted oleoresins; concentrates of essential oils in fats, in fixed oils, in waxes or the like, obtained by enfleurate or maceratin; terpenic by-products of the deterpenat

Source Based on WTO Agreement on Agriculture

filledthe wide gap prevalent in the literature.

The data for the Nominal GDP of the exporting and the importing countries as well as the World GDP was collected from the World Bank's World Development Indicators (WDI). The gravity variables, including the distance between two countries, historical colonial connections, shared borders, and common language, were sourced from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) website. The measurement unit for distance was in kilometres, while the other variables were binary dummies, taking the value of 1 to indicate the presence of a past colonial

Table 3 Description of Variables

Variable	Code	Description	Type	Expected sign of the coefficient
Exports Value	TV_{ijst}	Exports arising to country (j) from country (i) in US$ of a particular HS4 code in a particular year (t)	Continuous	Dependent variable
MFN tariff	MFN_{jst}	Tariff levied on a particular HS4 code (s) by a particular importing country (j) at a particular year (t)	Continuous	Negative
MRI Index	$MRI\text{-}_{ijt}$	Multilateral Resistance Index between importing country (i) and exporting country (j) at a particular year (t)	Continuous	Negative
Contiguous	$Contig_{ijt}$	1 if the countries are contiguous (neighbours), bilateral	Dummy	Positive
Comlang_off	$CLang_{ijt}$	1 if countries share a common official or primary language	Dummy	Positive
Col45	$ColRelation_{ijt}$	1 if countries are or were in a colonial relationship post-1945	Dummy	Positive
Exporter GDP	$EXGDP_{it}$	GDP of the exporting country (i) at a particular year (t) in current USD	Continuous	Positive
Importer GDP	$IMGDP_{it}$	GDP of the importing country (j) at a particular year (t) in current USD	Continuous	Positive
SPS Count*	SPS_{jst}	Total number of SPS standards imposed on a particular HS4 code(s) by a particular importing country (j) at a particular year (t)	Integer	Negative or Positive
TBT Count*	TBT_{jst}	Total number of TBT standards imposed on a particular HS4 code(s) by a particular importing country (j) at a particular year (t)	Integer	Negative or Positive

Note * = count has been used and not the inventory method as it would reduce further the number of observations.
Source Based on authors calculations.

relationship, a common boundary, or language, and 0, otherwise.

We have used the Feasible Generalized Least Squares (FGLS) modelling technique to analyse the gravity model framework. The quantitative model comprised different variables taken from distinct sources. The list of the variables is outlined in Table 3.

For conducting a robustness check, we systematically excluded the observations of that country-pair with the highest count of trade values (exports), namely India and the USA. This exclusion aimed to analyse that there existed no country-pair specific biasness which was manipulating the estimation results and could distort the findings. After the robustness check, it was observed that there were no significant changes in the estimation results, which signified the reliability of the study and signified that the observed results were not unduly influenced by the idiosyncrasies within the India-USA trade pair. By demonstrating consistent findings despite the exclusion of the India-USA trade pair, the study has averred its robustness and the ability of the results to extend to a broader context.

Results and discussions

Descriptive analysis

The importance of agriculture and food for all countries is immense. This is accentuated by the growth in the annual value of trade in agricultural products which reached USD 2.16 trillion in 2021, largely driven by the trade in developing and least developed countries (LDCs).[4] The progressive liberalization of the global trading order has created opportunities for the developing and LDCs to become better integrated into

[4] WTO Stats

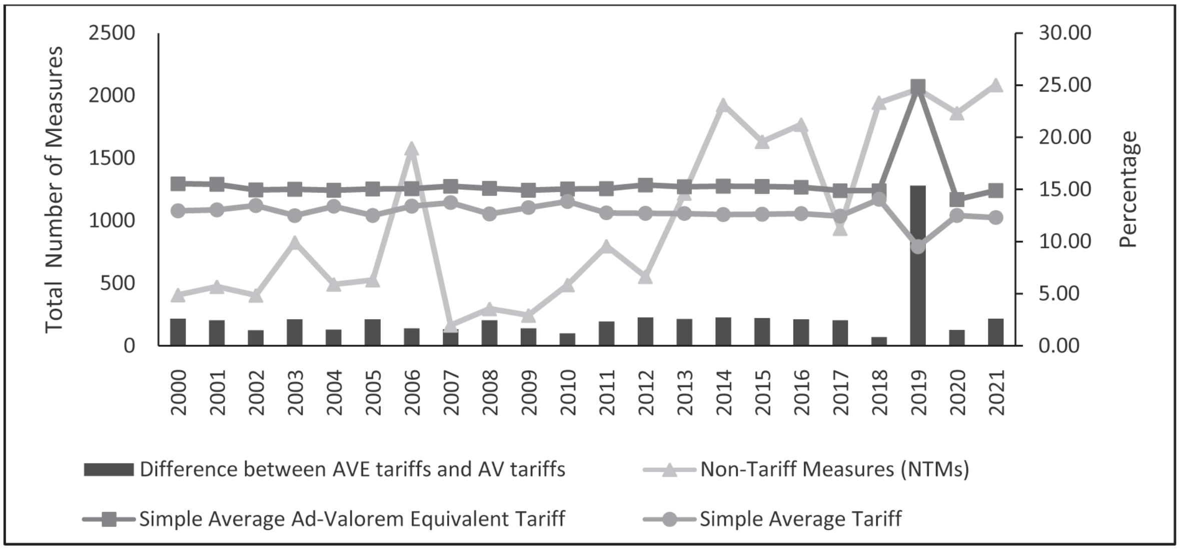

Figure 1 Simple Average Ad-Valorem Equivalent Tariffs and Non-Tariff Measures
Note Total number of measure is the total count of notification
Source Based on WITS and CWS database.

the trading system and to exploit their comparative advantage in the primary products such as agriculture commodities.

The analysis of the products undertaken indicates that tariff protection still remains a critical factor for these products since the simple average tariff after taking ad valorem equivalents has declined marginally (Figure 1). In early-2000s, the ad-valorem equivalent (AVE) tariff stood at approximately 16% and by the end of 2021, it declined to only 15%. The year 2019, saw very high tariff rates of approximately 25%. We have found that this simple average AVE tariff hike was driven by one market/importer. Upon deeper analysis, we observed that USA extended high AVE tariffs on products within the Beverages, Spirits and Vinegar category i.e, on products within the chapter 22. For example, in 2019 USA levied approximately 2574% tariff on HS 2202. In the remaining years and products, the AVE tariffs never exceeded even 300%. In our empirical analysis we have taken AVE tariffs since ad-valorem tariffs alone do not depict the correct picture. In Figure 1, we can see that on an average, there is a difference of 3% between AVE tariffs and ad-valorem tariffs. Moreover, in all years ad-valorem tariffs were lower than AVE tariffs. Our findings are reiterated by the (UNCTAD, 2019) report which states, "Moreover, tariffs remain relatively high in some sectors and tariff peaks are present in important sectors, including some of key interest to low-income countries such as agriculture, apparel, textiles and leather products." Hence, for the subset of these agricultural products tariffs are still an important trade policy tool used by the developed economies (Babili, 2009).

Simultaneously, we have found that over the years NTM notifications have increased for all the developed countries. Figure 1 reveals that in 2000, only 474 technical NTMs were notified at the WTO, whereas in 2021 as many as 2085 notifications were notified. It is interesting to note that since the breakdown of the Doha negotiations in 2008, the NTMs have rapidly risen. During the period 2000-2008, approximately 5,000 measures were notified. However, in the period after 2008, the measures notified increased by three times. In other words, more than 17,000 measures were notified in the post-2008 period. In absolute terms, there has been a proliferate usage of NTMs, with approximately 23,000 NTMs being notified during the period 2000-2021. At this point, it is important to highlight the stark contrast between our finding and the literature reports. The general academic discussion uniformly agrees that the ad-valorem tariffs which are expressed as a percentage of price, at the macro level have been on a decline, and at the same time, NTMs have been on an incline and have played a central role in protecting domestic market from imports in the recent years. However, Figure 1 accentuates that across

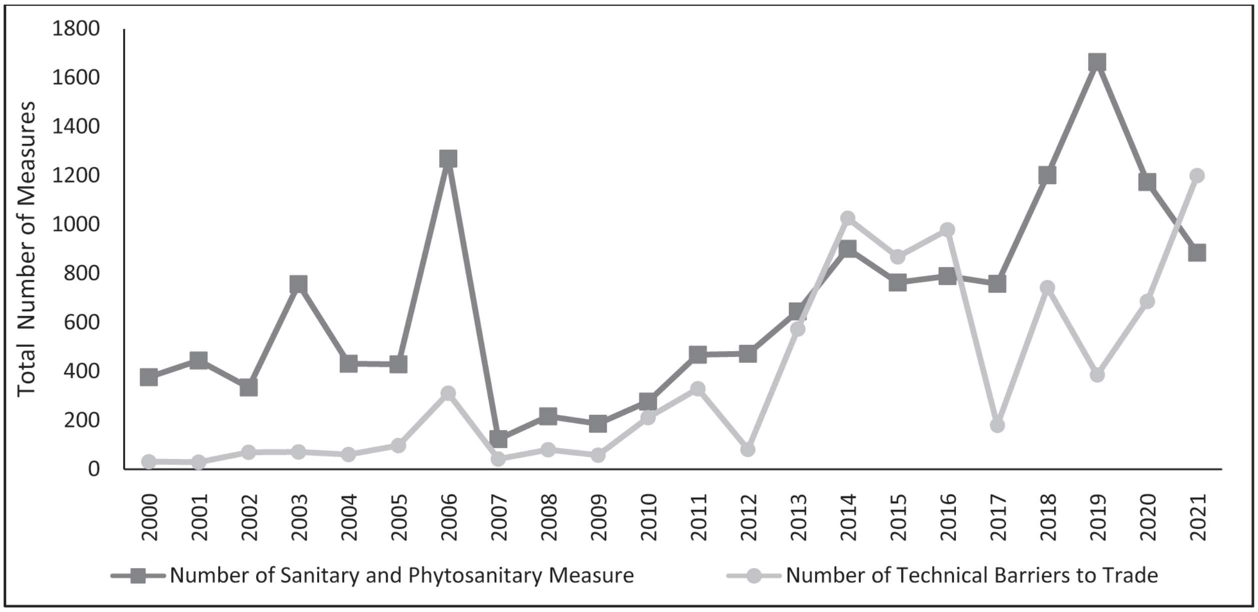

Figure 2 Technical NTMs: Sanitary and Phytosanitary Measures and Technical Barriers to Trade: 2000-2021
Note Total number of measures is the total count of notifications.
Source Calculation based on CWS database.

various agricultural products, tariffs still are a crucial tool to protect domestic producers for certain countries since the decline has only been marginal. Moreover, specific developed economies have armed themselves with another tool, namely NTMs such as SPS and TBT to name a few. Both of these measures together are increasingly shaping trade, influencing who trades what and how much.

Figure 2 depicts the intricacies of technical NTMs. At the beginning of 2000, mere 31 TBT and 377 SPS measures were notified. By 2021, the TBT measures saw a jump of approximately 39 times, with approximately 1200 TBT notifications in 2021 alone. On the other hand, SPS measures saw a jump of more than 2 times, with notifications of 885 SPS measures in 2021. As of 2021, a noteworthy tally of around 15,000 SPS measures has been officially communicated, juxtaposed with a cumulative count of 8,000 TBT measures within the same timeframe. However, compared to the SPS measures which have exhibited a Compound Annual Growth Rate (CAGR) of approximately 4%, the TBT measures have observed a remarkable CAGR of 18%. If we look at the period from 2000 to 2008, a total of 5178 measures were put in place, with 4386 SPS measures accounting for 85% of these measures and 792 TBT measures accounting for 15%. In the post-Doha round, negotiations (2009-2021), a total of 17509 measures have been notified, a jump of more than 3-times. The SPS measures saw a jump of more than 2-times, with 10,190 measures notified and TBT saw a significant jump of more than 9-times with 7319 measures. It can also be seen that the number of SPS notifications from 2000 to 2013 was higher than the number of TBT notifications, however, the trend reversed between 2013 and 2016, and thereafter, SPS dominance over TBT continued. The dominance of TBT notifications during 2013-2016, could be due to the fact that by 2013, the worst of the global financial crisis was over and firms were taking active part in the global trading arena and TBT notifications which are developed based on the organisations profit generation objective, could be actively employed by the developed economies worldwide. On the other hand, the SPS notifications are decided based on scientific principles to regulate health and safety standards of the product and take much longer to develop. So, it also suggested the pace of functioning public-led (social welfare) institutions and private-led (profit) institutions. Safeguarding human health and well-being are legitimate goals, which contribute directly and positively to an economies well-being. However, NTM measures such as SPS and TBT, can become significant barriers for

Figure 3 Exports and Non-Tariff Measures (NTMs): 2000-2021
Note Total number of measure is the total count of notifications
Source Based on WITS and CWS database

exporters to access international markets, in particular to key developed and developing economies.

Figure 3 illuminates the prevailing trajectory in the exports of lower-middle-income economies, specifically focusing on the products undertaken in this analysis. Notwithstanding the escalation in NTMs, there is an observable augmentation in exports on the whole. In the year 2021, the exports alone amounted to $8 billion, a substantial leap from the $1 billion recorded in the year 2000. During the period from 2000 to 2008, $16 billion in total exports were recorded and post-2008, a 4-times jump in exports value was seen with a total of approximately $64 billion exported to the markets in the developed economies. Upon deeper analysis, we found that the exports not only grew at a much faster rate post-2008 (4-times jump from the pre-2008 value), but they also grew faster than the jump in NTMs in the post-2008 period, which saw a jump of 3-times from the pre-2008 value. Moreover, the CAGR in exports over this interval stands at 9%.

Consequently, our preliminary analysis contradicts a segment of the scholarly discourse positing that the escalating deployment of SPS and TBT measures jeopardize a substantial portion of exports, particularly from the LDCs. One explanation for this positive relation between the two could be that the recent times have witnessed concerted efforts from developed nations and international entities which have engaged in providing capacity building, technical support, and the establishment of robust quality infrastructure for developing countries and LDCs. A considerable influx of international financial and non-financial aids has also been directed towards fortifying the capacities of the developing nations and LDCs, empowering them to adhere to evolving NTMs. These requisites assume paramount importance if WTO members aspire to evade uncertainties and ensure the transparency and stability of the multilateral trading system.

Econometric model framework

To assess the impact of SPS and TBT measures on exports of lower middle-income countries, we have developed a four-dimensional panel regression equation wherein the dimensions encapsulate the exporting country i and importing country j for the product s at the time period t. The regression equation is in the log-linear form with $\log(TV)_{ijst}$ being the dependent variable representing the log of exports from country i to j of a specific product s in a particular year t. The independent variables consist of six gravity variables to reduce the omitted-variable bias, out of which three are dummies capturing the impact of common language, common borders, and their colonial relationships impact on exports. The other three are the GDPs at the current USD of the exporting country, of the importing country and the last one represents the MRIijt that was theorized by (Anderson et al., 2003)[5].

Apart from gravity variables, we have introduced three more control variables. The first is the Most Favoured Nation (MFN) simple average ad-valorem equivalent (AVE) tariff which is the customs duties imposed by the importing country 'j' during time 't' on a particular HS 4-digit agriculture product 's'. The second and third variable and the primary variable of interest are the sum of SPS notifications and the sum of TBT notifications on a particular product s in a year t. μ_i and μ_j represent the exporting and importing countries fixed effects, respectively and μ_t represents the time fixed effects. The estimated equation is:

$$\log (TV)_{ijst} = \beta_0 + \beta_1 MFN_{jst} + \beta_2 MRI_{ijt} + \beta_3 Contig_{ijt} + \beta_4 CLang_{ijt} + \beta_5 \text{ColRelation}_{ijt} + \beta_6 \log (\text{EXGDP})_{it} + \beta_7 \log (\text{IMGDP})_{jt} + \beta_8 \text{SPS}_{jst} + \beta_9 \text{TBT}_{jst} + \mu_i + \mu_j + \varepsilon_{ijst}$$

To address the challenges related to heteroscedasticity and autocorrelation in our model, we opted for the FGLS model instead of the Generalized Least Squares (GLS) model. Kareem et al. (2019) have pointed out that FGLS is well suited to estimating parameters in the presence of heteroscedasticity. Due to uncertainty about the specific nature of heteroscedasticity, the FGLS appeared to be a fitting choice, as it is a flexible model and estimates the variances and covariances of the error-term from the data itself. We also considered the Poisson pseudo maximum likelihood (PPML) regression for this study. However, the PPML estimator (proposed by Silva et al., 2006) is not always the best estimator as they are outperformed by both the OLS and FGLS estimates in the sample forecast. In addition, the PPML assumption regarding the pattern of heteroscedasticity is rejected by the data in most cases. Therefore, even in the presence of an unknown form of heteroscedasticity, the FGLS can still be applied because it is an efficient estimator within the class of least squared estimators, but the variance of the disturbances should then be re-estimated to correct for heteroscedasticity errors. Moreover, our regression technique is validated by the fact that the choice of the performance of the model is sensitive to the sample size; for a small sample size, FGLS could be the perfect way to deal with the heteroscedasticity problem, while the PPML will be appropriate when the sample size is large and there is measurement error in the dependent variable. Given the data set and regression equation of this paper, FGLS suits better for this regression.

Results

In the results presented in Table 4, the first column represents the simple pooled OLS regression on all of the independent variables considered in the regression equation, followed by a fixed effect, random effect and then FGLS model. The Hausman test has provided a p-value of 0.000, implying that Fixed Effects should be used over Random Effect. The Fixed Effects model was then checked used to check for heteroskedasticity (we used Wald-test for groupwise heteroskedasticity and obtained p-value = 0.000), implying this model is suffering from heteroskedasticity. Therefore, to deal with this problem Feasible Generalized Least Squares (FGLS) methodology including dummy variables for country pairs to control for fixed effects, was considered. The FGLS estimators were found consistent and efficient as this method considered heteroskedasticity across panels, auto-correlation within panels and cross-sectional correlation/ dependence.

The NTMs independent variables were found to have a significant impact on the exports of lower middle-income countries. The FGLS results indicated that an additional TBT notification could increase the exports between countries by 2.7%, whereas an additional SPS notification could result in a 0.3% decrease in exports.

The positive impact of TBT on exports can be explained by several factors. Firstly, the introduction of an NTM could lead to a reorientation in the domestic economy, where smaller exporters, rather than exporting directly, may choose to supply their products to larger domestic exporting firms. As a result, the domestic exports continue to grow since larger domestic firms have capacity to export larger volumes and tackle the NTMs. Secondly, we have considered gross exports based on FOB export data, and therefore, even if a product gets rejected by a country which has

[5] $MRI_{it} = \frac{\left(\sum_{j=1}^{n} Y_{jt}\right)}{Y_{wt}} \ln(Dist_{ij})$

Table 4 Regression Results

Variables/Models log (Exports in USD)	(1) Pooled OLS	(2) Fixed Effects Model	(3) Random Effects Model	(4) FGLS
TBT_{jst}	0.035***	0.046***	0.045***	0.027***
	(0.009)	(0.005)	(0.005)	(0.001)
SPS_{jst}	-0.027***	0.007*	0.002	-0.003***
	(0.005)	(0.004)	(0.003)	(0.001)
MFN^{1}_{jst}	0	0	0	0**
	(0)	(0)	(0)	(0)
log $(IMGDP)_{it}$	0.485***	1.008***	0.68***	0.413***
	(0.028)	(0.138)	(0.062)	(0.013)
log $(EXGDP)_{it}$	0.686***	-0.01	0.472***	0.628***
	(0.021)	(0.068)	(0.044)	(0.011)
MRI_{ijt}	0.03	-0.575***	-0.259***	-0.106***
	(0.046)	(0.069)	(0.046)	(0.01)
$ColRelation_{ijt}$	1.265***	.	1.638***	1.372***
	(0.104)		(0.294)	(0.066)
$CLang_{ijt}$	0.79***	.	0.966***	0.876***
	(0.085)		(0.232)	(0.049)
$Contig_{ijt}$	2.45***	.	2.606***	0.986***
	(0.227)		(0.648)	(0.335)
Constant	-20.127***	-14.319***	-19.675***	-16.225***
	(0.968)	(4.413)	(2.123)	(0.36)
Observations	13234	13234	13234	13145
R-squared	0.133	0.096	0.092 (within) 0.145(between)	
F-test	226.256	202.517		
Prob>F	0.000	0.000		
Chi-square			1462.045	15444.556
Prob>chi2			0.000	

***p<0.01, **p<0.05, *p<0.1Standard errors are shownwithin parentheses

Source Based on authors calculation

[1]*Note* MFN: Most Favoured Nation Tariff; IMGDP: Importer GDP; EXGDP: Exporter GDP; MRI: Multilateral Resistance Index; ColRelation: Colonial Relationship; Clang: Common Official Language; Contig: Countries are Neighbours

introduced a measure, the exporter may have re-negotiated the export consignment or the product may have been re-routed to another country. Due to both these reasons, it is possible to have positive effect of TBT on exports value and could reflect an increase in export value when there is an introduction of an additional TBT notification on any product. Additionally, the TBT measures were half the total observations and in comparison to SPS measures TBT measures were less stringent and therefore were easy to comply with in the case of agricultural goods. All this could have led to a positive and significant impact of TBT notification on trade from lower middle-income countries.

On the other hand, the negative coefficient of SPS could be explained by the higher absolute number of SPS notifications in our dataset as compared to TBT. Moreover, SPS are more stringent in their compliance since they focus on the health concerns of consumers. Our results get support from Shepotylo (2016) who has also found that while SPS measures increase extensive trade margins and reduce intensive trade margin, the TBT has the opposite effect.

The simple average AVE tariffs' impact on exports was insignificant since the tariff over the years on these specific 20 HS 4-digit agriculture products had remained constant. All the gravity variables result had the expected sign as provided in the literature. The presence of a common language, having a common border and colonial relationship could increase the exports, on an average, by 87%, 98% and 137%, respectively. Among other control variables, a percentage increase in importers' GDP, on an average, led to a 0.48% - increase in exports, where as a percentage increase in exporter-GDP, led to a 0.68% - increase in its exports. For MRI, a unit increase in the index value could decrease the exports by 10.6%.

To ensure the robustness of the empirical results, we considered a set of alternative specifications where in the pair of the largest trading countries within these products were identified, and that country-pair was excluded from the dataset. By undertaking this exercise of excluding the largest pair of trading partners, we ensured that any extreme values influencing the results were removed. Based on our select set of countries, the trade from India to the USA for selected 20 products at HS4 accounted for 14% of the total trade in the dataset. Hence, to check whether results were not driven by this important trade relationship, we omitted the exports between India and USA. After removing this pair-specific bias, we performed all four regressions again with the required tests. Hence, this ensured the robustness of the regression model. The results are presented in Table 5. It is worth noting that across all

Table 5 Regression Results after Robustness Check

Variables/Models log (ExportsinUSD)	(1) Pooled OLS	(2) Fixed Effects Model	(3) Random Effects Model	(4) FGLS
TBT_{jst}	0.036***	0.046***	0.045***	0.018***
	(0.01)	(0.005)	(0.005)	(0.002)
SPS_{jst}	-0.025***	0.008**	0.003	-0.003***
	(0.006)	(0.004)	(0.004)	(0.001)
MFN_{jst}	0	0	0	0
	(0)	(0)	(0)	(0)
log $(IMGDP)_{it}$	0.439***	1.015***	0.637***	0.354***
	(0.028)	(0.139)	(0.063)	(0.014)
log $(EXGDP)_{it}$	0.647 ***	-0.011	0.443***	0.633 ***
	(0.022)	(0.069)	(0.045)	(0.013)
MRI_{ijt}	0.001	-0.579***	-0.295***	-0.101***
	(0.047)	(0.069)	(0.047)	(0.012)
$ColRelation_{ijt}$	1.452*** (0.109)	.	1.881***	1.571 ***
			(0.303)	(0.075)
$CLang_{ijt}$	0.57 ***	.	0.669***	0.647***
	(0.092)		(0.249)	(0.062)
$Contig_{ijt}$	2.386***	.	2.542***	0.938***
	(0.228)		(0.065)	(0.337)
Constant	-17.728***	-14.509***	-17.564	-14.659***
	(1.036)	(4.474)	(2.229)	(0.523)
Observations	13053	13053	13053	12964
R-squared	0.114	0.096	0.092(within) 0.123(between)	
F-test	186.702	199.534		
Prob>F	0.000	0.000		
Chi-square			1392.250	13998.669
Prob>chi^2			0.000	

***p<0.01, **p<0.05, *p<0.1Standard errors are shown in parentheses

Source Based on authors calculations

specifications, there were no changes in the sign or significance of the main variables of interest and the elasticity of exporters' and importers' GDP remained stable with a variance of 0.005 and 0.059, respectively; the impact of the simple average tariff also remained insignificant, aligning with the descriptive analysis of average tariff over the years.

Conclusions and policy implications

The escalation of NTMs, particularly within developed nations over the past two decades, alongside divergent standards among trading counterparts, has resulted in a heightened frequency of notifications of technical measures to the WTO and is one of the factors weighing on food supplies. The prevalence of NTMs is notably pronounced in the agricultural and the food sector, primarily due to scientific and technical requisites imposed predominantly by SPS and TBT measures.

This paper delves into the nuanced dynamics through which non-tariff measures (NTMs) may either facilitate or impede the participation of lower-middle-income countries in the export of agricultural commodities. The results indicate that an additional TBT (Technical barriers to trade) notification increases the exports between countries by 2.7%, whereas an additional SPS (Sanitary and phytosanitary) notification leads to a 0.3% decrease in exports. The paper identifies several contributing factors to explain the increase in exports despite imposition of an additional TBT measure by the developed nations. Firstly, since the paper only considers the frequency of TBT measures and not the stringency of each measure, there exists the possibility that the imposed measures are not stringent, and exporters have been able to comply with them. Secondly, although small exporters may no longer be able to export directly due to the measure, they, in turn, supply to larger domestic producers who continue to export in larger quantities. Thirdly, since exports are examined in FOB terms, it is conceivable that products may have been either re-routed to destinations where the NTM does not exist or the actual impact of the NTMs has not been factored. Fourthly, the applicability of TBT measure is largely on processed food products and the countries capable to export these would be relatively larger economies. The fifth aspect is that of 20 selected agriculture products, 7 are raw agriculture products with a higher impact of MRL-based SPS measures influencing the effects on exports and complex and cumbersome to adopt. The rest of the sample consists of 13 processed food products with relatively addressable measures like labelling, which are simple for exporters to adopt. The TBT notifications and measures suggested a positive impact on the exports.

Our findings get support from several earlier studies. Some extant studies have found that when NTMs are proxied by dummy or count variables, the results have yielded positive outcomes, as demonstrated in prior studies (Cardamone, 2011; Shepherd et al., 2013). Hence, the form of variable chosen could also possibly explain the positive effect of TBT measure. Lastly, the literature also indicates that different types of data matter; wherein using data aggregated at HS 4-digit level reveals a positive effect on trade (Santeramo et al., 2019). To ensure robustness of our empirical results, a series of robustness checks have been performed. It is crucial to note that across all specifications, there are no changes in the sign or significance of the main variables of interest.

Policy recommendations

Based on the study, following suggestions are made:

1. There is an urgent need for the WTO to make it mandatory for the countries to notify the technical NTMs with Harmonized System (HS) codes. Further, it is also being observed that increasingly notifications with broad product coverage are being notified. For example, animal products, genetically modified organisms (GMO's), pre-packaged food products; food additives; or agricultural products. In other words, no specific HS code is being notified but a vague list of products is mentioned. In such a scenario, at one hand the already increasing use of NTM measures is making market access challenging, now without any HS nomenclature, entering markets becomes even more cumbersome since it is left to the discretionary powers vested in customs authority at the border of the importing country. Although Article 10, and in particular 10.8, of the Trade Facilitation Agreement does provide some

solutions but they lack effective solution to the overall problem.[6] Hence, mandatory mentioning of HS Codes (at the most disaggregated level as found fit by the member) along with accurate product description in the notifications by all Members should be agreed upon.

2. In order to identify stringency, Members should clearly mention and be encouraged to tell whether the measure is more/less/equal in stringency to the relevant international standards (if it exists) (Hudson et al., 2003). Thirdly, the WTO supporting documents should be in the three official languages and not in regional languages. Lastly, the use of precautionary principle beyond mandated provision under the SPS agreement should be avoided however if used, the trade remedial measure should not be stringent and be in lines with Article 5.7 of SPS Agreement and Article 10.8 of Trade Facilitation Agreement. That is if the goods presented for import are rejected by the competent authority of a Member on account of their failure to meet prescribed SPS regulations, the Member shall, allow the importer to re-consign or to return the rejected goods to the exporter or another person designated by the exporter within a reasonable period of time in order as agreed by the WTO members under the trade facilitation agreement (TFA) of 2017. This aids in avoiding huge financial loss which exporters from LDCs and DCs have to face when their products are destroyed and would also ensure food security.

References

Assoua, J.E., Molua, E.L., Nkendah, R., Choumbou, R.F.D. and Tabetando, R., (2022). The effect of sanitary and phytosanitary measures on Cameroon's cocoa exports: An application of the gravity model. *Heliyon*, *8*(1).

Anderson, J.E. and Van Wincoop, E., (2003). Gravity with gravitas: A solution to the border puzzle. *American economic review*, *93*(1), 170-192.

Babili, M., (2009). Ad Valorem equivalent in the WTO. Working paper no.43. (No. 1104-2016-91737). Damascus.

Baptista, D.M.S., Farid, M.M., Fayad, D., Kemoe, L., Lanci, L.S., Mitra, M.P., Muehlschlegel, T.S., Okou, C., Spray, J.A., Tuitoek, K. and Unsal, M.F.D. (2022). *Climate change and chronic food insecurity in sub-saharan Africa*. International Monetary Fund.

Bureau, J.C. and Salvatici, L., (2004). WTO Negotiations on Market Access: What We Know, What We Don't Know, and What We Should. In *Agricultural Policy Reform and the WTO,* 207-251. Edward Elgar Publishing.

Cardamone, P. (2011). The effect of preferential trade agreements on monthly fruit exports to the European Union. *European review of agricultural economics*, 38(4), 553-586.

Chauffour, J.P. (2008). Global food price crisis: trade policy origins and options. No. 44894, 1-8. The World Bank.

Cipollina, M., De Benedictis, L., Salvatici, L. and Claudio, V., (2016). Policy measurement and multilateral resistance in gravity models. *MPRA (Munich Personal RePEc Archive) paper*.

Dal Bianco, A., Boatto, V. L., Caracciolo, F., and Santeramo, F. G. (2016). Tariffs and non-tariff frictions in the world wine trade. *European Review of Agricultural Economics*, 43(1), 31-57.

Dhar, B. and Kallummal, M., (2007). Taming Non-Tariff Barriers: Can the World Trade Organization Find a Solution?. *Future Trade Research Areas that Matter to Developing Country Policymakers*, 131.

Disdier, A. C., Fontagné, L., and Mimouni, M. (2008). The impact of regulations on agricultural trade: evidence from the SPS and TBT agreements. *American Journal of Agricultural Economics*, 90(2), 336-350.

Disdier, A. C., and Van Tongeren, F. (2010). Non tariff measures in agri food trade: What do the data tell us? Evidence from a cluster analysis on OECD imports. *Applied Economic Perspectives and Policy*, 32(3), 436-455.

[6] In December 2013 WTO Members concluded negotiations on a new Trade Facilitation Agreement (WT/MIN (13)/36) aimed at expediting the movement, release and clearance of goods, including goods in transit, and at improving customs cooperation. The Agreement contains unique special and differential treatment (SDT) measures that link the requirement to implement with the capacity of developing countries and least developed countries (LDC) to do so. The Agreement also recognizes the need for donor Members to enhance assistance and support for capacity building.

Durant, I. (2022). Impact of the Covid-19 pandemic on trade and development: lessons learned. United Nations Conference on Trade and Development

FAO, IFAD, UNICEF, WFP and WHO. (2023). The State of Food Security and Nutrition in the World 2023. Urbanization, Agrifood Systems Transformation and Healthy Diets Across the Rural–Urban Continuum. Rome. FAO.

Ferro, E., Otsuki, T., and Wilson, J. S. (2015). The effect of product standards on agricultural exports. *Food Policy*, 50, 68-79.

Gibson, M. J., and Wang, Q. (2018). Sanitary and phytosanitary measures in Chinese agricultural exports: the role of trade intermediaries. *Applied Economics*, 50(27), 3007-3015.

Giordani, P. E., Rocha, N., and Ruta, M. (2016). Food prices and the multiplier effect of trade policy. *Journal of International economics*, 101, 102-122.

Gupta, A.K. and Sangita, S., (2022). Impact of Food Standards on Patterns of International Trade in Marine Products. *Foreign Trade Review*.

Henson, S., and Loader, R. (2001). Barriers to agricultural exports from developing countries: the role of sanitary and phytosanitary requirements. *World development*, 29(1), 85-102.

Hochman, G., Rajagopal, D., Timilsina, G. and Zilberman, D. (2014). Quantifying the causes of the global food commodity price crisis. *Biomass and Bioenergy*, *68*, 106-114.

Hudson, J., and Jones, P. (2003). International trade in 'quality goods': signalling problems for developing countries. *Journal of international Development*, 15(8), 999-1013.

Kallummal, M., (2012). *SPS measures and possible market access implications for agricultural trade in the Doha Round: An analysis of systemic issues* (No. 116). ARTNet Working paper series.

Kallummal, M., (2015). North–South imbalances in the Doha round: the use of specific duties as a trade policy instrument. *Agrarian South: Journal of Political Economy*, *4*(1), 85-124.

Kallummal, M., Gupta, A. and Verma, P., (2013). Agricultural trade of South Asia and impact of SPS measures: a case study of European Rapid Alert System for Food and Feed (RASFF). In *International Conference on Public Policy and Governance*.

Kallummal, M., and Gurung, H.M., (2020). Urgent Need for Market Access Disciplining of Agriculture Trade: Profiling of Stringent and Non-Codex SPS based MRL Standards.

Kallummal, M., Mendiratta, D. and Sangita, S., (2018). US import refusals of agricultural products and their impact on the participation of Indian firms. *Agrarian South: Journal of Political Economy*, *7*(1), 78-104.

Kareem, F.O. and Kareem, O.I., (2019). The issues of zero values in trade data and modelling. *Macro Management & Public Policies*, *1*(1), 36-50.

Luwedde, J., Kakuru, M., and Sunday, N. (2022). The Effect of Sanitary and Phytosanitary Measures on Uganda's Fish Exports: A gravity model approach. *African Journal of Economic Review*, 10(2), 182-205.

Martin, W. and Anderson, K. (2012). Export restrictions and price insulation during commodity price booms. *American Journal of Agricultural Economics*, *94*(2), 422-427.

Martin, W. (2017). Agricultural Trade and Food Security. ADBI Working Paper 664. Tokyo: Asian Development Bank Institute.

Melo, O., Engler, A., Nahuehual, L., Cofre, G., and Barrena, J. (2014). Do sanitary, phytosanitary, and quality-related standards affect international trade? Evidence from Chilean fruit exports. *World Development*, 54, 350-359.

Murina, M., and Nicita, A. (2017). Trading with conditions: The effect of sanitary and phytosanitary measures on the agricultural exports from low income countries. *The World Economy*, 40(1), 168-181.

Peci, J., andSanjuán, A. I. (2020). The dual trade impact of non-tariff measures: an empirical assessment of China's pork imports. *European Review of Agricultural Economics*, *47*(5), 1716-1739.

Peterson, E., Grant, J., Roberts, D., and Karov, V. (2013). Evaluating the trade restrictiveness of phytosanitary measures on US fresh fruit and vegetable imports. *American Journal of Agricultural Economics*, 95(4), 842-858.

Rother, B., Sosa, S., Debbich, M., Castrovillari, C. and Prifti, E. (2023). Global Food Crisis Update: Recent Developments, Outlook, and IMF Engagement. IMF Notes, 2023(002).

Rother, M.B., Sosa, M.S., Kim, M.D., Kohler, M.L.P., Pierre, M.G., Kato, N., Debbich, M., Castrovillari, C., Sharifzoda, K., Van Heuvelen, M.E. and Machado, F. (2022). *Tackling the Global Food Crisis: Impact, Policy Response, and the Role of the IMF*. International Monetary Fund.

Ridley, W. C., Luckstead, J., and Devadoss, S. (2024). Impacts of tariffs and NTMs on beef, pork and poultry trade. *Journal of Agricultural Economics*, *75*(2), 546-572.

Santeramo, F. G., and Lamonaca, E. (2019). The effects of non tariff measures on agri food trade: A review and meta analysis of empirical evidence. *Journal of Agricultural Economics*, 70(3), 595-617.

Schuster, M., and Maertens, M. (2015). The impact of private food standards on developing countries' export performance: An analysis of asparagus firms in Peru. *World Development*, 66, 208-221.

Shepherd, B., and Wilson, N. L. (2013). Product standards and developing country agricultural exports: The case of the European Union. *Food Policy*, 42, 1-10.

Shepotylo, O. (2016). Effect of non-tariff measures on extensive and intensive margins of exports in seafood trade. *Marine Policy*, 68, 47–54.

Silva, J.S. and Tenreyro, S., (2006). The log of gravity. *The Review of Economics and statistics*, *88*(4), 641-658.

Timini, J. and Conesa, M., (2019). Chinese exports and non-tariff measures. *Journal of Economic Integration*, *34*(2), 327-345.

UNCTAD, 2019. International classification of non-tariff measures. UN.

Webb, M., Strutt, A., Gibson, J., and Walmsley, T. (2020). Modelling the impact of non tariff measures on supply chains in ASEAN. *The World Economy*, *43*(8), 2172-2198.

WTO, 2012. Trade and Public Policies: A Closer Look at Non-Tariff Measures in the 21st Century. World Trade Report

WTO, 2023. Re-globalization for a secure, inclusive and sustainable future. World Trade Report

Received 22 September 2024 Accepted 12 December 2024

Annexure Table 1 Summary Statistics

Variable	Unit	Observations	Mean	Std. Dev.	Min	Max
log (Exports)	Number	30,340	11.62	3.16	0.00	19.65
TBT	Count	22,370	3.63	2.90	1.00	18.00
SPS	Count	32,740	4.45	5.18	1.00	57.00
Simple Average	Percentage	43,730	15.49	45.69	0.00	2573.90
log (EXGDP)	Number	44,000	25.51	1.17	23.48	28.78
log (IMGDP)	Number	44,000	28.34	0.99	26.19	30.78
MRI	Index	44,000	4.74	0.78	3.01	6.56
Contingency	Dummy	44,000	0.01	0.10	0.00	1.00
Common Language	Dummy	44,000	0.12	0.32	0.00	1.00
Colonial Relation	Dummy	44,000	0.07	0.26	0.00	1.00

Source Based on Authors calculation

Agricultural Economics Research Review 2024, 37 (2), 165-181
DOI: 10.5958/0974-0279.2024.00012.X

Transforming agricultural trading and commerce in India: Role of e-NAM and potential of digital trade

Raya Das*, Bidisha Chanda, Gauri Krishna, and Ashok Gulati

Indian Council for Research on International Economic Relations (ICRIER), New Delhi, India

*Corresponding author: das.radhika.raya@gmail.com

Abstract This paper explores the transformative role of digital platforms, such as e-NAM (electronic National Agriculture Market) and ONDC (Open Network for Digital Commerce), in reforming agricultural marketing in India. By increasing market access, transparency, and efficiency, these platforms reduce middlemen dependency and improve price realization of farmers. In this context, the study evaluates e-NAM's influence on price realization and spatial price integration for key agricultural commodities, including rice, wheat, tomato, onion, potato, and turmeric, from January 2011 to April 2024. The study has found that spatial price integration of some of these commodities has improved in the post-e-NAM period compared to the pre-e-NAM period (January 2011 to December 2015). Further, the farmers using the e-NAM platform have experienced significantly higher price realizations than those trading in non-e-NAM APMC mandis for the same commodities. However, despite these positive outcomes, e-NAM's contribution to the total APMC trade volume remains minimal, accounting for only 6 per cent as of Financial Year 2023-2024, with just 20 per cent of APMCs onboarded to the platform. The study also identifies significant challenges of e-NAM platform, including low inter-state trade and the dominance of intra-mandi transactions. The paper also highlights the ONDC's potential to foster direct connections between farmers and buyers while democratizing the digital landscape, offering significantly lower commission rates compared to traditional platforms. However, addressal of digital divide and development of rural infrastructure are crucial for increasing farmers' participation and advancing digital integration in the agricultural marketing sector of India.

Keywords Digital trade, crop price, agricultural trading, spatial co-integration, e-NAM, farmers' profit

JEL codes Q13, Q16, Q18

Introduction

In an era of fast internet and expanding technology, India's agricultural sector is undergoing a transformation through the integration of digital tools. This shift is crucial, as a significant portion of agricultural marketing in India remains unorganized (MoA&FW, 2016). Technology plays a vital role in achieving market efficiency through better access to information, integrating markets spread over different geographies, monitoring real time market performance, moving from physical trading platforms to virtual platforms and linking spot to futures trade. The digital platforms are streamlining market access for farmers, improving price transparency, and reducing the influence of middlemen. Initiatives like e-NAM (electronic National Agriculture Market) and various Agri-tech startups are helping farmers connect directly with buyers, access real-time price information, and secure better price realization. The need for such digital interventions arises in the backdrop of existing complexity of India's agricultural marketing system.

The Agricultural Produce Market Committee (APMC) Act, established in the 1960s was aimed to protect farmers from exploitation through regulating agricultural markets and ensuring fair prices. However, it has led to inefficiencies and reliance on the middlemen, as farmers are mandated to sell through licensed traders in the regulated markets, which can limit their market access and price information (Dev, 2020). The Doubling Farmers' Income (DFI) Committee's 2022 report emphasized that digital marketing platforms could enhance farmers' market access and provide better price discovery, risk management, and financial services. Digitalization can also shorten the value chain by connecting farmers directly with consumers, thus reducing the role of intermediaries (Nedumaran & Manida, 2020). The COVID-19 pandemic highlighted these inefficiencies, as farmers faced restrictions due to their dependence on the traditional marketing methods. In summary, while the APMC Act was intended to protect farmers, it has inadvertently fostered monopolistic behaviours and has limited direct market access. Therefore, embracing digital solutions could significantly improve the agricultural value chain by empowering farmers with more options and better financial integration.

This paper examines the impact of digital commerce on India's agricultural marketing, with a focus on e-NAM and Open Network for Digital Commerce (ONDC). It discusses how digital platforms can increase efficiency of agricultural markets, reduce transaction costs, improve transparency, and facilitate better price discovery for farmers. The paper provides an overview of digital marketing's potential in addressing inefficiencies in agricultural markets, highlighting e-NAM's role in integrating markets. It critically evaluates e-NAM, assessing its challenges and impact on farmers' price realization and spatial price integration. This study contributes to the literature on the ONDC's potential to transform agricultural marketing by directly connecting farmers with buyers and enhancing trade transparency. Finally, the paper outlines policy recommendations for expanding digitalization in India's agricultural marketing sector

Literature review

Developed countries are benefiting from digital marketing in agriculture, particularly because the consumers demand better food traceability (D'souza & Joshi, 2020). Digitalization in agricultural marketing involves integration of digital technologies throughout the value chain (Klerkx & Rose, 2020; Mushi et al., 2022). The Fourth Industrial Revolution (C4IR) is transforming agriculture in developing countries through technologies like AI and IoT (Internet of Things). In 2018, India launched its C4IR initiative, focusing on agriculture and leveraging its extensive digital infrastructure, including the Aadhaar program and digital payment systems. The major platform economies such as Amazon and Microsoft are now enhancing India's agricultural marketing, providing farmers with access to new markets and improved price discovery.

The developing countries in Asia and Africa are increasingly adopting digital market reforms to enhance agricultural efficiency. For instance, Indonesia's 'Tanihub', established in 2016, connects isolated farmers directly to consumers via a farmer bidding app, improving their negotiation leverage and providing consumers with higher quality produce at better prices (Asian Development Bank, 2022). Similarly, 'Twiga Foods' in Kenya, launched in 2014, addresses market fragmentation by linking smallholder farmers to vendors through a mobile app, ensuring guaranteed market access and reducing post-harvest losses (GSMA, 2018). The research by Okello et al. (2010) indicates that mobile phone usage among Kenyan farmers enhances their market linkages.

In developed countries like the USA, online grocery shopping has become widespread, with online grocery sales doubling between 2014 and 2018, accounting for 7 per cent of the total grocery market by 2019 (Joiner & Okeleke, 2019). The adoption of agri-e-commerce is more common in these markets as established e-commerce platforms expand into the grocery sector. In contrast, developing countries face challenges such as lack of standardization in agricultural produce, logistical difficulties, underdeveloped infrastructure (including internet connectivity in rural areas), and low levels of technical capacity.

In India, grocery expenditure is estimated to account for 23 per cent of India's economy by 2025. In 2024, the market value of online groceries is estimated to be over one trillion Indian rupees (Statista, 2024). Integrating information and digital technology is crucial for meeting the rising food grain demands by 2030, particularly in populous countries like India. The e-NAM initiative exemplifies this integration by spatially connecting inter-state mandis, facilitating better spot price discovery (Balkrishna and Acharya 2024). Since its adoption, e-NAM has promoted integrated markets, enhanced the efficiency and benefitted farmers through increased price realization and market arrivals (Swain et al., 2022). Various studies have explored market integration in India using different methodologies. For example, Behura & Pradhaun (1998) employed the Engel-Granger cointegration method to analyze fish prices in Odisha, finding that poor infrastructure hindered market integration. In contrast, Beag & Singla (2014) utilized Johansen's multivariate cointegration approach to confirm long-run price integration among five major apple wholesale markets. Additionally, Garg et al. (2023) examined price discovery and volatility spillover between e-NAM spot prices and NCDEX markets, revealing that NCDEX dominates the price discovery mechanism. Bhattacharya & Chowdhury (2021) assessed onion market integration before and after e-NAM, finding improved integration post-implementation. Overall, these studies highlight the positive impact of digital solutions like e-NAM on agricultural market efficiency in India.

Database and Methodology

The Law of One Price (LOP) is a principle used to assess how well markets are integrated. The weaker version of this law suggests that while prices are generally related to one another, they can differ because of various factors such as transportation and transfer costs.

Before going to the cointegration test, the study runs the Augmented Dickey-Fuller (ADF) which is a statistical method used to determine the stationarity of a time series, particularly by checking for the presence of a unit root. A unit root indicates that the series exhibits a stochastic trend, causing it to drift from its mean over time, which makes it non-stationary. If the test statistic is smaller than the critical value, or if the p-value falls below a pre-determined significance level (e.g., 0.05), the null hypothesis of a unit root is rejected, indicating that the series is stationary. Conversely, if the test statistic exceeds the critical value, the null hypothesis cannot be rejected, and the time series remains non-stationary.

When the price series p^i_t and p^e_t are stationary, we can evaluate the Law of One Price (LOP) or market integration by estimating an Ordinary Least Square (OLS) regression model.

$$\ln p_t^i = a + b \ln p_t^e + \epsilon_t \quad \text{... (1)}$$

However, if the price series are non-stationary, using co-integration becomes the suitable approach to test for market integration. Cointegration occurs when two or more time series, though individually non-stationary, exhibit a stable long-term relationship through a stationary linear combination. This study has employed the Johansen cointegration test to assess the spatial integration of agricultural commodity prices across selected markets. The Johansen test (Johansen, 1988) has been used to detect multiple cointegration vectors and determine their count. Unlike simpler approaches, the Johansen method is well-suited for analyzing multivariate systems, providing a more robust framework for cointegration analysis. The optimal lag length for the VAR model has been determined using criteria of Akaike Information Criterion (AIC).

If P_t denotes an $(n\times1)$ vector of I (1) prices, then the k^{th} order VAR representation of it may be denoted as Equation (2)

$$P_t = \Sigma_{i=1}^{k} P_{t-i} + \mu + \beta t + \varepsilon_t \quad (t=1,2,3\ldots, T) \quad \text{...(2)}$$

The procedure for testing co-integration is based on the error correction model (ECM) represented by Equation (3)

$$\Delta P_t = \Sigma_{i=1}^{k-1} \Gamma \Delta P_{t-i} + \Pi P_{t-k} + \mu + \beta t + \varepsilon_t \quad \text{... (3)}$$

where Γ_i is the short-term dynamics of price series; ε_t is an identically and independently distributed n-dimensional vector of residuals with zero mean and variance matrix, $\Omega_{t;}$ μ is a constant term and t is the trend. The rank of Π, r, determines the number of cointegrating vectors. If r = n, the variables are stationary in levels. If r = 0, no linear combination of P_t is stationary. If $0<$ rank $(\Pi) = r < n$, and $\Pi=\alpha\beta'$. The product of two matrices that capture cointegration relationships, where β is the cointegrating vectors representing long-term equilibrium relationships and α is the speed of adjustment coefficients, indicating how quickly deviations from equilibrium are corrected. The two test statistics have been used in this model; trace statistic and max eigen value. The trace statistics tests the hypothesis of having at most r cointegrating vectors against the alternative hypothesis of having more than r cointegrating vectors using the Equation (4):

$$\text{Trace Statistic } (\lambda - \text{trace}) = -T\Sigma_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \quad \text{...(4)}$$

The maximum eigen value statistics tests the null hypothesis of r cointegrating vectors against the alternative of r+1 [Equation (5)].

$$\text{Max eigen stat } (\lambda - \text{max.}) = -T \ln(1 - \widehat{\lambda_{r+1}}) \quad \ldots(5)$$

Where, λ is the obtained eigen values from the Π matrix; T is the number of observations. This statistic focuses on whether adding one additional cointegrating vector significantly improves the model. If the value exceeds the critical threshold, we reject the null hypothesis. The existence of one or more cointegrating vectors suggests a long-term equilibrium relationship among the market prices, indicative of spatial price integration. Conversely, the absence of cointegration implies market segmentation, where prices do not align in the long-run.

Evaluation of e-NAM

The establishment of the e-NAM in India marks a significant advancement in agricultural marketing, following the APMC reforms of 2003, the APMC Model Act of 2013, and the APLM Act of 2017 (Dey, 2016; MoA&FW, 2017). Launched on April 16, 2016, e-NAM aims to unify agricultural markets by integrating the existing APMCs into an online trading platform with a budget allocation of ₹ 200 crores (MoA&FW, 2016). With the motto "One Nation One Market," the e-NAM facilitates spot price discovery and provides real-time price information to both farmers and traders, connecting 585 regulated markets across India. The platform reduces information asymmetry and promotes better price realization for farmers, transforming the agricultural marketing landscape. It addresses the traditional APMC mandi issues such as intermediary dominance and market fragmentation while enhancing accessibility and efficiency in transactions. However, challenges such as limited coverage and difficulties in produce assaying constrain its effectiveness. Overall, e-NAM represents a critical step towards improving agricultural marketing in India by leveraging technology to create a more integrated and efficient market system.

Process flow of trade on e-NAM

The implementation of e-NAM enhances transparency and efficiency in agricultural trade. It starts with the computerized registration of farmers at the mandi gate, generating a unique lot entry ID that includes farmers' details and product information (Figure 1). The farmers present these IDs for quality assessments, which are uploaded to the e-NAM portal for e-auction processes. Buyers must obtain a trading license from the mandi officials to access national trading. The traders deposit a security amount before bidding, with auction details displayed in the mandi. The highest bid is communicated to the farmer, who can accept or reject it. Upon acceptance, the final weighing is done, and records are integrated into a central system for accurate tracking. The payments are processed through Real-Time Gross Settlement (RTGS), typically credited within one to two days. After payment confirmation, market officials issue an exit pass to the trader for collecting the consignment. This structured approach leverages technology and regulatory frameworks to enhance efficiency and fairness in agricultural trading.

Progress of e-NAM

With nearly a decade of progress from 2016 to 2024, the agricultural marketing in India is experiencing a significant paradigm shift, marked by improved farmer awareness and system functionality. Of a total of 7085 APMC market yards in the country (2599 principal regulated market yards and 4486 sub-market yards, regulated by the respective APMCs) only 1410 (~20%) are integrated through e-NAM at the all-India level in 2024. Also, uneven state-level implementation of e-NAM has limited its overall effectiveness. A detailed examination of APMC integration into e-NAM reveals disparities across states. Figure 2 explains the categorisation of states based on market density and the share of APMC onboarded with e-NAM.

For instance, eastern and north-eastern states show low onboarding rates and fewer existing markets, resulting in reduced inter-mandi trade and market co-integration. In contrast, states like Haryana stand out with e-NAM integration levels surpassing the national average of 20 per cent and a dense network of APMC mandis, categorizing it under high-performing states (Category 2). From a policy perspective, it is essential to prioritize states with a high number of APMCs but low e-NAM integration, such as Punjab, Maharashtra, and Odisha (Category 3). Khandagiri & Kannan (2022) analyzed the performance of e-NAM in Odisha using a binary logit regression approach for commodities like brinjal, tomato, maize, and cashew nut, finding that market arrivals significantly declined in the post-e-NAM

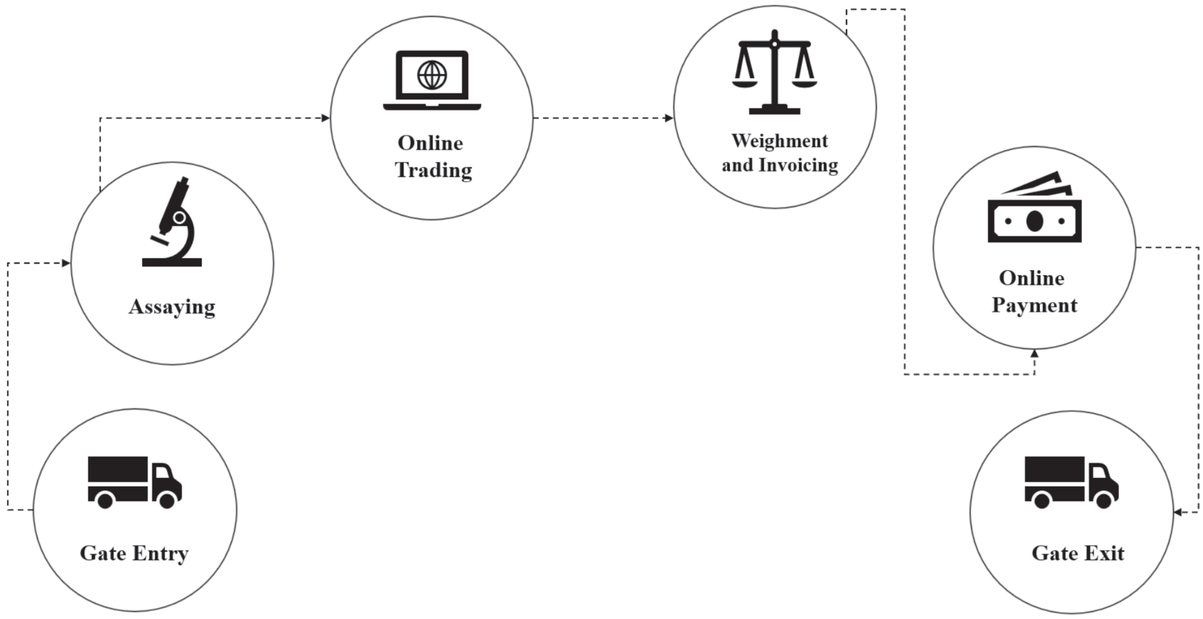

Figure 1 e-NAM Process Flow
Source Adapted from enam.gov.in

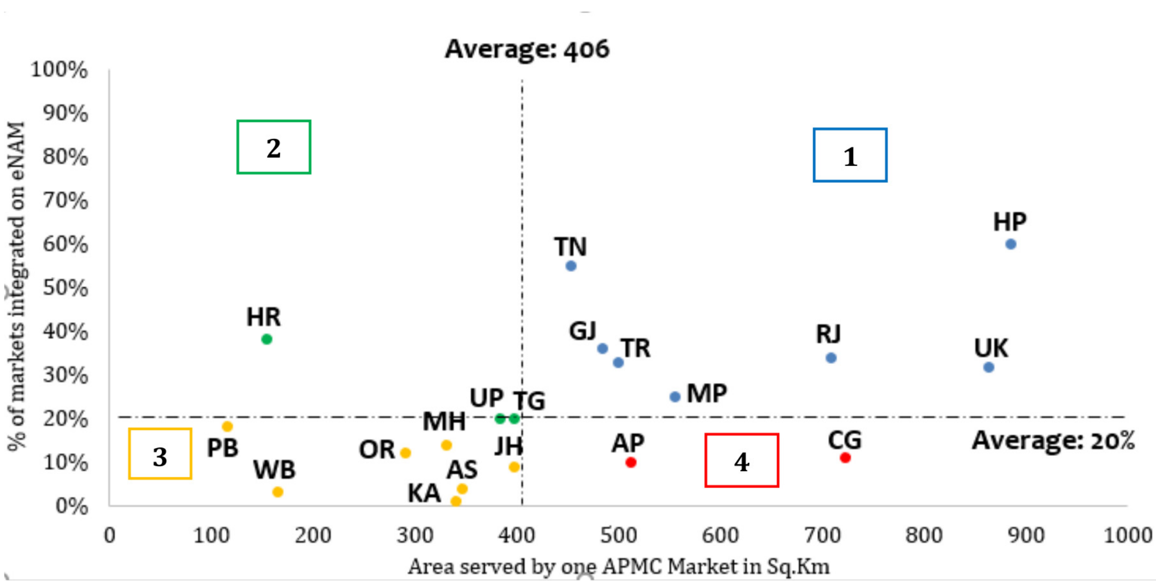

Figure 2 Categorization of states on basis of degree of integration on e-NAM
Source Calculated based on data from enamv.gov.in and Agmarknet

period, likely due to farmers' continued preference for traditional trading methods driven by limited awareness or inadequate access to the digital platform. States like Himachal Pradesh and Uttarakhand, while having a high percentage of their APMC markets onboarded with e-NAM, face challenges due to low mandi density (Category 1). Similarly, states like Andhra Pradesh and Chhattisgarh, characterized by both low mandi density and low e-NAM adoption (Category 4), require targeted interventions to boost their participation in the e-NAM platform. Enhancing their participation on the e-NAM platform could significantly improve price realization for farmers in these major agricultural production regions.

In FY 2023-24, the total traded volume is observed to be 19.4 MMT on the e-NAM, of which most was traded

Table 1 Progress on e-NAM in FY 2022-23 and FY 2023-24

Particulars	FY 2022-23	FY 2023-24
Total trade volume (MMT)	401	342
Total trade volume on e-NAM (MMT)	18.6 (5%)	19.4 (6%)
Inter-mandi trade volume (MMT)	0.24	0.47
Inter-state trade volume (MMT)	0.00	0.02
FPO trade volume (MMT)	0.02	0.04
Farmgate trade volume (MMT)	0.00	0.05
Total Trade Value (₹ crores)	74656	78424
Inter-mandi trade value (₹ crores)	723	1661
Inter-state trade value (₹ crores)	4	43
FPO trade value (₹ crores)	41	70
Farmgate trade value (₹ crores)	6	94

Source e-NAM.gov.in

inter-mandi. The inter-mandi trade volume (0.47 MMT) and value (₹ 1661 crores) was the highest among other trade categories. While the volume of farm-gate, inter-state, and inter-mandi trade remains low in comparison to the total volume traded, there has been a marginal increase of trade in this digital platform over the past two years. Between 2022-23 and 2023-24, the traded volume and value on the e-NAM platform have increased by 4 per cent and 5 per cent, respectively (Table 1).

The e-NAM's main objective was to achieve higher inter-state mandi trade, wherein the farmers get to have a larger consumer base for their products, making it profitable for them to grow the crop as well. Table 1 shows that inter-state trade volume is low on the platform, only 0.02 MMT traded in FY 2023-24. Notably, inter-mandi trade volume is higher than inter-state trade volume, with 0.47 MMT traded in FY 2023-24, which means that within a state, the farmers are trading more between different mandis.

The e-NAM represents a significant effort by the Indian government to connect buyers and sellers in agricultural marketing. However, its implementation faces several challenges categorized as informational, institutional, and infrastructural. Many farmers lack familiarity with the e-NAM platform and its bidding process, limiting their participation and often resulting in lower prices for their produce, particularly for items that do not meet quality standards (MSC, 2018). The slow amendments to APMC Acts in various states hinder the establishment of a unified trading platform. Additionally, resistance from the traditional market actors like commission agents obstructs e-NAM's growth and acceptance. The inadequate storage facilities, poor transportation networks, and insufficient quality assessment methods are some significant barriers. The requirement for reliable quality evaluation methods before remote bidding complicates the process, as many traders prefer visual inspections by their representatives. Furthermore, the farmers and traders continue to rely on the intermediaries for essential services such as storage and credit. Transitioning all stakeholders, including farmers, traders, and commission agents, to the e-NAM online platform poses significant challenges. The concerns about corruption among officials and delays in online payments further complicate this transition. Although the government claims that around one crore farmers are using e-NAM, reports indicate that most transactions still rely on traditional systems, and a unified national market remains unrealized.

Spatial co-integration of markets for selected commodities

In the context of the paper, we have selected six commodities based on higher production and APMC mandi arrivals to assess the role of the e-NAM for spatial integration across major markets. Rice, wheat, tomato, onion, potato and turmeric have been studied to check if markets in different states are spatially integrated. The dataset used was the monthly real wholesale prices of the commodities, spanning from January, 2011 to April, 2024. For all statistical tests, the time period was divided into pre-e-NAM and post-e-NAM, for gauging the difference made by the initiative.

To assess spatial integration across various markets, a co-integration test is suitable for analyzing non-stationary price data, determining statistically significant long-term relationships between different price series. For this analysis, we employed Johansen's multivariate co-integration method using seasonally adjusted, market-wise wholesale prices from Agmarknet, covering January 2011 to April 2024 for major-producing states in India. Before conducting the co-integration test, we performed the Augmented Dickey-Fuller (ADF) test to check for unit roots in the commodity prices of the selected states. The results are presented in Annexures 1 and 2. Of the commodities selected, only rice and wheat were found to have non-stationarity, which led to co-integration test conducted (Tables 2 and 3).

At maximum rank 0, the null hypothesis asserts that no co-integration exists, whereas the alternative hypothesis suggests the presence of co-integration. In this scenario, the trace statistic exceeds the critical value. Thus, we reject the null hypothesis, confirming that the markets are indeed co-integrated. At maximum rank 1, the null hypothesis asserts the presence of co-integration in Equation (1). According to the Tables 2 and 3, the trace statistic does not surpass the critical value. Therefore, we accept the null hypothesis, indicating co-integration in Equation (1). Thus, based on the results of the Johansen co-integration test, Vector Error Correction models could be applied. The results of the co-integration analysis have indicated that prices in majority of the markets for rice and wheat were spatially co-integrated.

For wheat, in the pre-e-NAM period, except Rajkot, prices in selected markets were non-stationary and their first differences were stationary. In the post-e-NAM period, except Shahjahanpur, prices in the selected markets were non-stationary and their first differences were stationary. The co-integration approach can be employed to determine whether a long-term equilibrium exists between the markets and how that relationship has changed in the two time periods. In our study, the co-integration in markets of Shahjahanpur and Kota and Ujjain to Kota existed in both pre-e-NAM periods well as post-e-NAM periods. For Shahjahanpur and Ujjain and Ujjain and Kota, the e-NAM was not observed to have any effect on the extent of market integration.

The commodities tomato, onion, potato and turmeric were found to be stationary for the markets and time period (Annexures 3-7), and hence, OLS regression was employed. The results show that the strength of relationship of prices across major markets measured by beta coefficient was higher in the post e-NAM period (Refer to Annexures 3-7).

Price realization through e-NAM

The major objective of e-NAM is to increase inter-mandi trade volumes, and as a result increase farmers' options of trade and their price realization. To test if e-

Table 2 Cointegration test using trace statistics for rice

Rice markets	H0:	H1:	Pre-e-NAM			Post-e-NAM			
	r=rank	r=rank	Eigen value coefficient	Trace Statistics	Critical Value	Eigen value	Trace Statistics	Critical Value	Long-run adjustment
Gorakhpur to Bardhhaman	r=0	r=1		6.22	15.41		8.85	15.41	
	r=1	r=2	0.04	1.89	3.76	0.33	2.79	3.76	
Gorakhpur to Nawarangpur	r=0	r=1		14.59	15.41		43.83	15.41	
	r=1	r=2	0.23	0.06	3.76	0.33	3.56**	3.76	-.046** (.023)
Gorakhpur to Shimoga	r=0	r=1		11.31	15.41		29.02	15.41	
	r=1	r=2	0.18	0.08	3.76	0.23	3.41**	3.76	-.169*** (.020)
Bardhhaman to Nawarangpur	r=0	r=1		13.22	15.41		61.34	15.41	
	r=1	r=2		1.49	3.76	0.28	28.10	3.76	
Bardhhaman to Shimoga	r=0	r=1		4.68	15.41		48.09	15.41	
	r=1	r=2	0.06	0.99	3.76	0.28	14.69	3.76	
Nawarangpur to Shimoga	r=0	r=1		12.87	15.41		86.25	15.41	
	r=1	r=2	0.18	0.18	1.25	0.53	9.72	3.76	

Source Estimated by authors from Agmarknet, DoCA.
Note Optimal lag length 1 for all the time series by AIC method; ; *, ** and *** denote 10%, 5% and 1% levels, respectively

Table 3 Cointegration test using trace statistics for wheat

Wheat Markets	H0:	H1:	Pre-e-NAM				Post-e-NAM			
	r=rank	r=rank	Eigen value	Trace Statistics	Critical Value	Long-run adjustment coefficient	Eigen value	Trace Statistics	Critical Value	Long-run adjustment coefficient
Shahjahanpur to Rajkot	r=0	r=1		25.89	15.41			27.90	15.41	
	r=1	r=2	0.32	4.13	3.76		0.18	7.60	3.76	
Shahjahanpur to Ujjain	r=0	r=1		23.61	15.41			22.89	15.41	
	r=1	r=2	0.30	3.35	3.76	-0.347***	0.17	4.72	3.76	
Shahjahanpur to Kota	r=0	r=1		18.15	15.41	(0.086)		19.10	15.41	
	r=1	r=2	0.25	1.93*	3.76	-0.435*** (0.101)	0.17	0.85*	3.76	-0.271*** (0.066)
Ujjain to Rajkot	r=0	r=1		31.84	15.41			14.34*	15.41	
	r=1	r=2	0.40	2.98*	3.76	-0.064* (0.037)	0.08	5.71	3.76	
Ujjain to Kota	r=0	r=1		16.46	15.41			26.39	15.41	
	r=1	r=2	0.23	1.48*	3.76	-0.274** (0.139)	0.22	1.86*	3.76	-0.265*** (0.103)
Rajkot to Kota	r=0	r=1		30.16	15.41			10.14	15.41	
	r=1	r=2	0.40	1.15*	3.76	-0.970*** (0.137)	0.08	1.26	3.76	

Source Estimated by authors from Agmarknet, DoCA.
Note Optimal lag length 1 for all the time series by AIC method; *, ** and *** denote 10%, 5% and 1% levels, respectively

NAM offers a better price compared to non-e-NAM prices for their produce, t-test has been performed on the real price (deflated by WPI 2011 base) of the five selected commodities (Table 4). The pre-e-NAM period was taken from January 2011 to December 2015; and the Post-e-NAM period was taken from January 2016 to April 2024.

Table 4 shows that in the major markets of the commodity, its prices increased significantly post e-NAM. A look at Figure 4 reveals that e-NAM prices taken from e-NAM website and prices taken from Agmarknet have a difference. Particularly in wheat, the e-NAM prices are clearly more than non-e-NAM prices. For other commodities, the e-NAM prices have either been same or more than non-e-NAM prices, showing that among other contributing factors, e-NAM is helping in increasing farm gate prices.

The box plot (Figure 5) shows that median prices offered to farmers increased after the introduction of e-NAM. In the case of rice, the median price has been

Table 4 t-test analysis for Pre- and Post-e-NAM prices for selected commodities

Commodity	Market	Pre-e-NAM Price	Post e-NAM Price	t statistic
Rice	Gorakhpur	₹ 1632	₹ 1872	-10.30
Wheat	Shahjahanpur	₹ 1246	₹ 1495	-12.77
Tomato	Kolar	₹ 774	₹ 988	-2.15
Onion	Nashik	₹ 830	₹ 852	-0.27
Potato	Bishnupur	₹ 748	₹ 908	-2.43

*Significant at p-value < 0.05
Source: Calculations based on data from Agmarknet. Note: Price was deflated by WPI of the commodity at 2011-12 prices

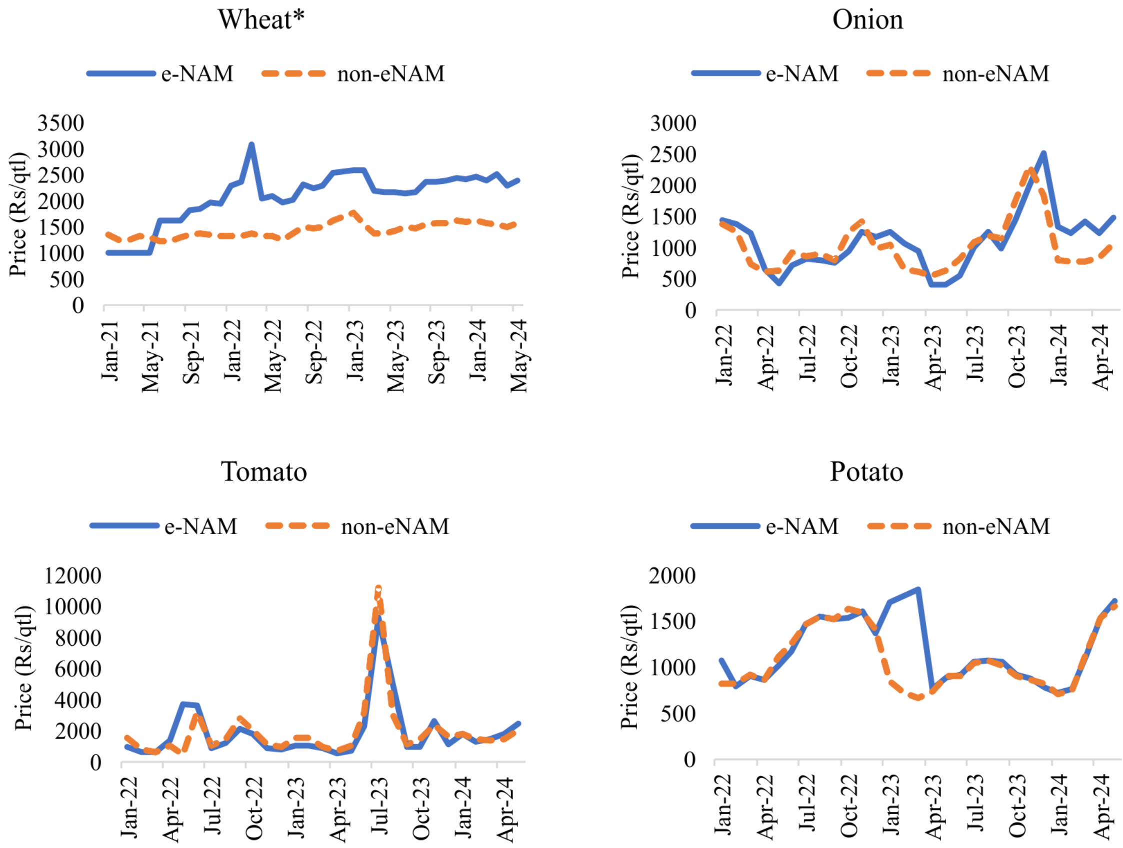

Figure 4 e-NAM vs non-e-NAM APMC prices for selected commodities: January 2022 to May 2024
Source e-NAM.gov.in and Agmarknet
*Data from January 2021 to May 2024

observed to rise from around ₹ 1600/q to ₹ 1800/q. This indicates that e-NAM has made the market more competitive, helping farmers to get better prices and potentially earn more. Wheat median prices have increased from about ₹ 1200/q to ₹ 1500/q. In the case of tomato, onion and potato, the median prices have not changed much during the two periods analysed.

By providing real-time market information and standardized trading protocol, the e-NAM has facilitated transparency in trade and improved price negotiations with farmers. This has led to reduced information asymmetry, that often favored the middlemen over farmers. As we see from analysis of selected commodities, e-NAM has potentially facilitated better integration between the markets across states and an increase in price realization.

Opportunities of digital marketing in India: A case study of ONDC

India has witnessed the emergence of agriculture e-commerce platforms since the early-2000s. Information and Communication Technology (ICT) has emerged as a critical enabler for enhancing market access, transparency, and efficiency for the farmers. By leveraging digital tools and platforms, ICT helps in bridging the information asymmetry, reducing transaction costs, and improving farmers' income and price realization. One of the key contributions of ICT is provision of real-time information on market prices, demand conditions, and weather forecasts. The mobile-based platforms like Kisan Mandi Online Agris, More by Reliance group, NAAPANTA App Portal offer crucial market intelligence to farmers (Reddy, 2021). Some positive outcomes are already evident; for instance, the 'Saagu Baagu' initiative has enhanced the chilli value chain in Telangana, benefiting over 70,000 farmers and boosting their incomes by more than Rs. 66,000 per acre per crop cycle (Aguilar, 2024).

Timely updates on crop prices and trends empower the farmers to make informed decisions about when and

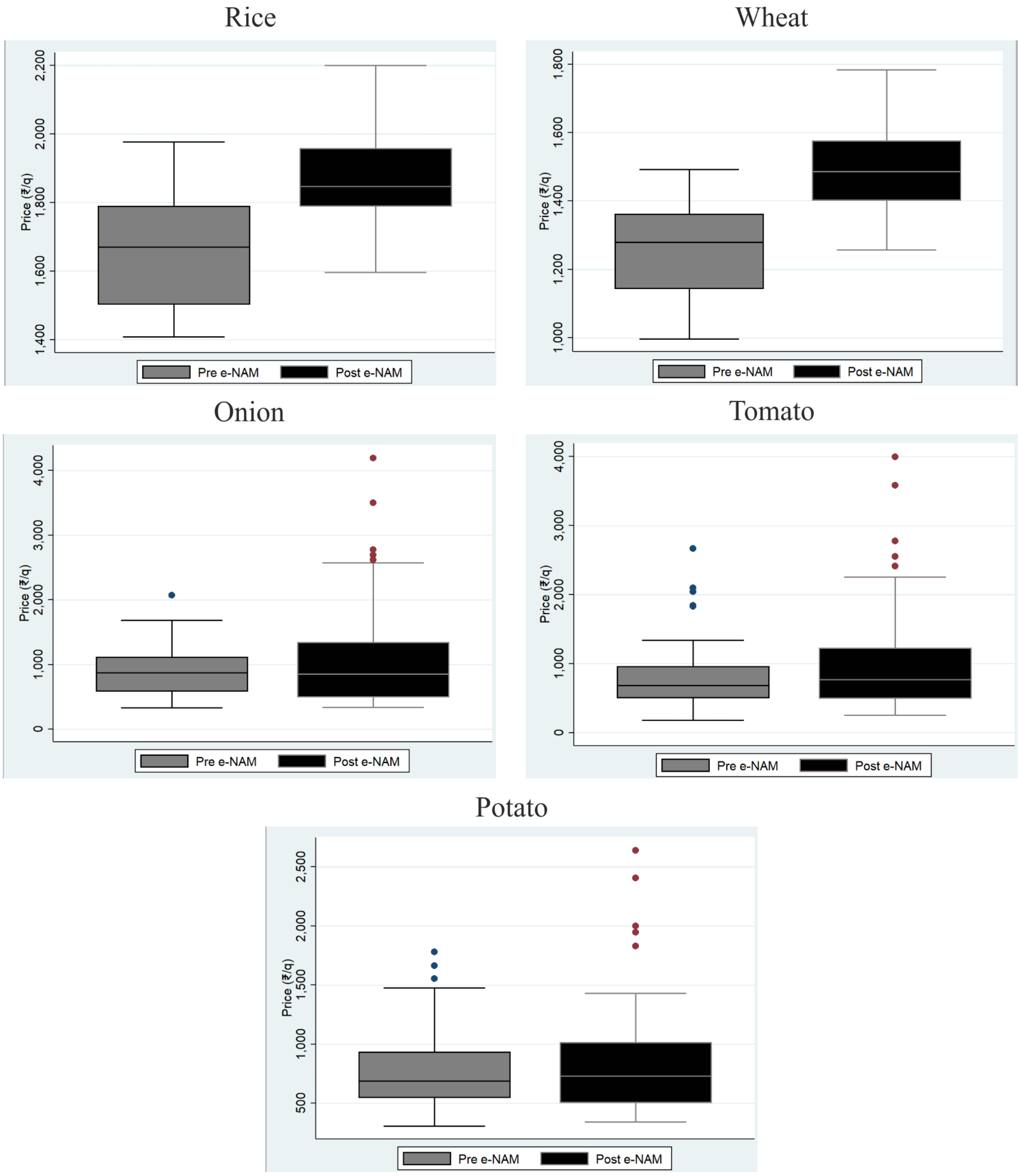

Figure 5 Boxplot for price in APMC pre- and post-e-NAM for selected commodities: January 2022 to May 2024
Source Authors' estimations based on Agmarknet data

where to sell their produce, thereby reducing the risk of distress sales and price volatility. The digital payment systems, such as UPI and Aadhaar, facilitate quick and secure transactions, enhancing the efficiency of agricultural trade. The examples of existing e-commerce models include ITC e-Choupal, AgriBazaar, Ninja Cart, DeHaat, NAPANTA app, and Agri Stack; however, these platforms often impose high commission fees, discouraging participation from various suppliers. In response to these challenges, India launched Open Network for Digital Commerce (ONDC) in 2023. This initiative is based on an open protocol using open-source specifications to connect all stakeholders in the e-commerce ecosystem, including sellers, buyers, and technology service providers. Unlike traditional platforms which rely on a single dominant entity like Amazon or Flipkart, the ONDC is "platform agnostic," allowing multiple platforms to collaborate while enabling merchants to set their own terms. The COVID-19 pandemic highlighted the digital gaps in agricultural value chains and ONDC aims to address them. With India's agriculture sector valued at approximately USD 500 billion in FY 2022—90 per cent from agricultural output—there remains significant fragmentation and inefficiency within the value chains. The ONDC initiative seeks to provide an end-to-end digital solution for farmers and consumers without intermediaries, fostering broader participation and scalability in the agricultural sector.

- Farmers get direct commerce- Farmers gain direct access to input providers for fertilizers, pesticides, and seeds through platforms like ONDC, enhancing their bargaining power over prices and quantities. Additionally, ONDC widens their customer base by enabling sales directly to businesses and consumers, eliminating middlemen and leading to higher transaction volumes and profits.
- Enhance transparency, traceability, and efficiency- Farmers can select the lowest-priced inputs from various providers, reducing their production costs. The retailers benefit from direct price discovery without relying on mandi prices. Additionally, ONDC allows for product tracking from farm to port, minimizing logistical inefficiencies and enabling sellers to expand distribution to under-served areas.
- Farmers get access to digitalized financial credits- The ONDC can help farmers access to a wider range of borrowing options, including banks and NBFCs, moving beyond reliance on the local shops. It may introduce innovative lending methods based on transaction history and alternative markers, simplifying the borrowing process and reducing paperwork, ultimately enhancing financial inclusion for farmers.

Potentially, ONDC could increase farmers' net incomes by 25 to 35 per cent. This is based on the following assumptions:(i) Around about 6-7 per cent lower cost of inputs due to better price discovery and bargaining power of farmers, (ii) This will presumably lead to 5-7 per cent increase in agriculture productivity due to better inputs, (iii) substantiated by a 15 per cent increase due to usage of mechanisation; (iv) Price realisation is at most improved by 3 per cent and (v) the reduction of middle-touch points cost will go down by about 2-4 per cent. If a farmer goes for formal loans, as ONDC offers, the interest rate offered to them is 7-8 per cent lower than conventional interest rates.

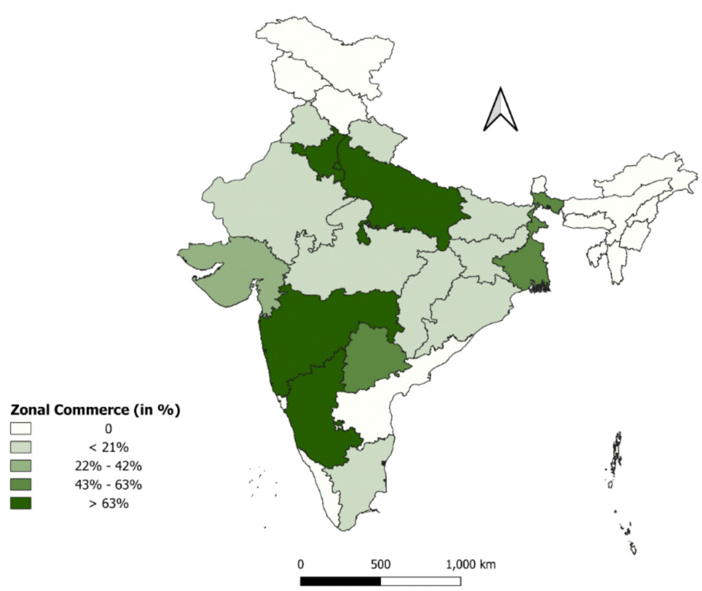

Figure 6 Zonal commerce concentration on ONDC platform in India during April, 2024 to August 2024
Source Prepared by authors based on ONDC data
Note: Not to scale

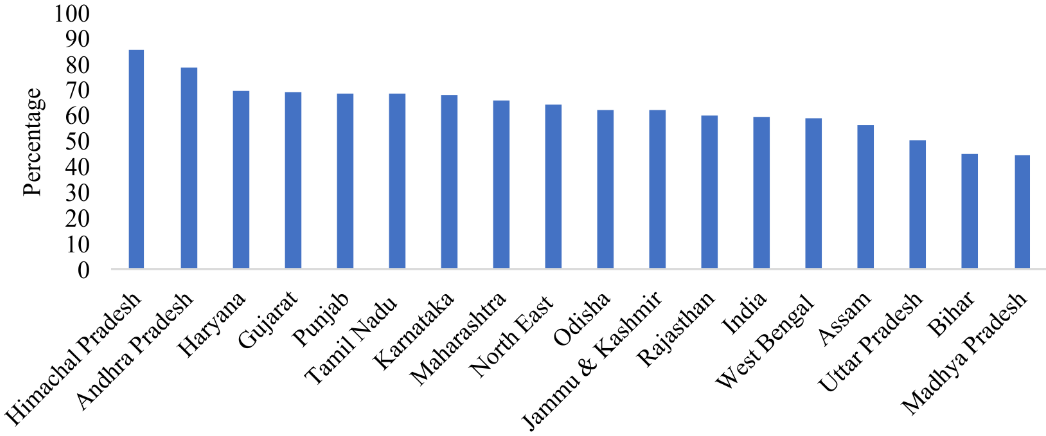

Figure 7 Rural tele-density in Indian States as on 31st March, 2024
Source The Indian Telecom Services Yearly Performance Indicators 2023-2024, TRAI

Regional dimension of ONDC trading in India

The regional dimension of digital agriculture marketing in India shows significant disparities in trade on platforms like ONDC. For example, Bihar has only 994 registered sellers, while Karnataka and Maharashtra have 30,353 and 36,552 registered sellers, respectively. In Bihar, just 11 per cent of digital trade is local, with most sourced from other states, whereas Karnataka enjoys a localized trade pattern with 82.5 per cent originating within the state.

The regional concentration of ONDC trade highlights the uneven development of digital public infrastructure across India. As of March 2024, India has about 1,199 million internet subscribers, with 45 per cent in the rural areas. However, only 31 per cent of the rural residents use the internet compared to 67 per cent in the urban areas, indicating significant digital disparity. While metropolitan regions enjoy advanced connectivity, rural areas like Bihar remain digitally under-served (Mahendru *et al*., 2022). The expansion of ONDC and digital agriculture marketing requires substantial improvements in the rural digital infrastructure to bridge this gap and enhance participation in the digital economy.

The rural tele-density in India is only 59 per cent, compared to 134 per cent in the urban areas (Figure 7). Less than half of the targeted 2.5 lakh village panchayats under the BharatNet project have Wi-Fi hotspots, with only about 65,000 operational. Additionally, internet prices have more than doubled, rising from ₹ 72/month in 2019 to ₹ 176/month in 2023 (TRAI, 2024).

The efforts to increase internet penetration in India are ongoing. As of 2023, Uttar Pradesh accounted for 12.6 per cent of the total internet subscribers, with 49 per cent being rural. The active internet users in rural areas rose from 20 per cent in 2018 to 41 per cent in 2022, driven by knowledge flow from urban areas and initiatives like Pradhan Mantri Gramin Digital Saksharta Abhiyan (PMGDISHA), which aimed to make 60 million rural residents digitally literate. Approximately 80 per cent of this target has been achieved (PIB, 2024), particularly in the northern and western regions, while states like West Bengal and Kerala lag behind, achieving less than 50 per cent and 7 per cent of their targets, respectively.

Conclusions and policy implications

The paper highlights the role of digitalization in agricultural marketing, enhancing efficiency and boosting farmers' incomes. The internet technology and smartphones have expanded access to market information, improving communication for farmers. The platforms like e-NAM facilitate direct access to buyers, enabling better price discovery and reducing intermediary costs. However, e-NAM faces challenges such as limited coverage, trust issues, and difficulties in produce assaying, resulting in relatively low trading volumes, despite positive impacts on spatial co-integration and price realization for some commodities. The paper has also analyzed the Open Network for Digital Commerce (ONDC), which democratizes digital trade by allowing farmers to participate without the rent extraction seen in other platforms. The regional disparities in infrastructure, such as internet access and logistics, exacerbate inequalities in digital agriculture marketing. To ensure better price realization for farmers, the policies must address these infrastructural gaps while strengthening the digital ecosystem. Overall, enhancing digital accessibility is essential for maximizing the benefits of digital agriculture in India.

To enhance the effectiveness of the e-National Agriculture Market (e-NAM), the paper has recommended several policy measures. First, addressal of infrastructural challenges is crucial, as e-NAM aims to facilitate direct trade and improve market efficiency. Expansion of e-NAM's reach to rural areas and integrating more mandis can increase access for smallholder farmers, who comprise 86 per cent of Indian farmers. The significant investments in rural infrastructure—especially in roads, transport logistics, and cold storage—are necessary to improve e-NAM's efficiency. The government should prioritize these needs and implement technological solutions for real-time price discovery, secure transactions, and transparent bidding processes.

The promotion of private investments in rural infrastructure and digital agriculture is vital to bridging gaps in logistics and storage. The government should incentivize private sector participation through tax breaks and subsidies for investments in rural logistics and cold storage. The establishment of public-private partnerships (PPPs) can help build and maintain infrastructure sustainably. Additionally, expansion of Farmer Producer Organizations (FPOs) on e-NAM would empower smallholders by enhancing their bargaining power and market access. The government should simplify FPO registration on digital platforms, provide training, and offer financial support, such as grants and low-interest loans, to improve their operations and market reach.

The development of logistics and rural infrastructure is crucial for the digital agriculture marketing, as efficient transportation and cold storage are essential for preserving produce quality and minimizing post-harvest losses. The investments on rural roads and transport logistics are necessary for timely deliveries. Additionally, promoting contract farming within a structured legal framework can provide farmers with stable markets and better prices through digital platforms, reducing market risks by ensuring price certainty and improved access to digital markets.

The addressal of these challenges in digital agriculture marketing requires a collaborative approach involving government agencies, private sector stakeholders, and FPOs to enhance market efficiency, increase farmers' income, and provide fair, remunerative prices.

Acknowledgements

The paper is a part of the project on *Getting Agriculture Market Right* between ICRIER and the NSE 2020-25. The views expressed and the responsibility for the analysis rest solely with the authors.

References

Aguilar, M. (2024, January 11). *AI for agriculture: How Indian farmers are harvesting innovation*. World Economic Forum. Retrieved from https://www.weforum.org/impact/ai-for-agriculture-in-india/.

Asian Development Bank. (2022). TaniHub: Building Indonesia's most efficient and reliable farm-to-business supply chain platform.

Balkrishna, A., Singh, S. K., Pathak, R., & Arya, V. (2024). E-governance paradigm in the Indian agricultural sector. *Discover Agriculture*, 2, Article 2. https://doi.org/10.1007/s44279-024-00012-7

Bhattacharya, R., & Chowdhury, S. (2021). How effective is e-NAM in integrating food commodity prices in India? Evidence from the Onion Market. *National Institute of Public Finance and Policy*. Retrieved from https://www.nipfp.org.in/publications/working-papers/1933/

Beag, F. A., & Singla, N. (2014). Cointegration, causality and impulse response analysis in major apple markets of India. *Agricultural Economics Research Review*, 27(2).

Behura, D., & Pradhaun, D. C. (1998). Cointegration and market integration: An application to the marine fish markets in Orissa. *Indian Journal of Agricultural Economics*, 53(3), September.

D'souza, D. J., & Joshi, H. G. (2020). Exploring the consumers' willingness of using e-commerce to purchase geographical indication based crops, a case study of Udupi Jasmine. *Agris on-line Papers in Economics and Informatics, 12*(2), 63-69. https://doi.org/10.7160/aol.2020.120206

Dev, S Mahendra. 2020. "Agricultural Reforms in India." *Indian Public Policy Review* 16-28.

Dey, K. (2016). National Agricultural Market: Rationale, Roll-out and Ramifications. *Economic and Political Weekly, 51*(19), 35-39. Retrieved from https://www.jstor.org/stable/44003474

Garg, M., Singhal, S., Sood, K., Rupeika-Apoga, R., & Grima, S. (2023). Price discovery mechanism and volatility spillover between National Agriculture Market and National Commodity and Derivatives Exchange: The study of the Indian agricultural commodity market. *Journal of Risk and Financial Management, 16*(2), 62. https://doi.org/10.3390/jrfm16020062

GSMA. (2018). *Twiga Foods: Improved market access for farmers and a reliable supply for vendors*. Retrieved from https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/wp-content/uploads/2018/05/Twiga-Foods-Improved-market-access-for-farmers-and-a-reliable-supply-for-vendors.pdf

ITC. (2024). *ITC e-Choupal*. Retrieved from https://www.itcportal.com/businesses/agri-business/e-choupal.aspx

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control, 12*(2–3), 231-254. https://doi.org/10.1016/0165-1889(88)90041-3

Joiner, J., & Okeleke, K. (2019). E-commerce in agriculture: New business models for smallholders' inclusion into the formal economy. *GSMA*. https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/wp-content/uploads/2019/05/E-commerce_in_agriculture_new_business_models_for_smallholders_inclusion_into_the_formal_economy.pdf

Khandagiri, C., & Kannan, E. (2022). Performance analysis of electronic national agricultural markets: Some evidence from Odisha. *Agricultural Economics Research Review*, 35(2). Agricultural Economics Research Association (India).

Nedumaran, G., & Manida, M. 2020. E-Agriculture and Rural Development in India. *JAC: A Journal of Composition Theory*, 105-114.

Mahendru, A., Dutta, M., & Mishra, P. R. (2022, December). *India Inequality Report 2022: Digital Divide*. Oxfam India.

MSC. (2018). *A study of eNAM in select APMCs across three states and recommendations for improvement*. Retrieved from https://www.microsave.net/wpcontent/uploads/2019/06/190624_eNAM-report.pdf

MoA&FW, Department of Agriculture, Cooperation & Farmers Welfare. (2017, April 24). *The State /UT Agricultural Produce and Livestock Marketing (Promotion & Facilitation) Act, 2017*.

MoA&FW, Department of Agriculture, Cooperation and Farmers' Welfare. (2016, September). *Operational Guidelines for Promotion of National Agriculture Market (NAM) through Agri-Tech Infrastructure Fund (ATIF)*. Retrieved from https://enam.gov.in/web/docs/namguidelines.pdf

Ministry of Agriculture and Farmers' Welfare. (n.d.). *National Agriculture Market (eNAM). Retrieved January 16, 2025, from https://enam.gov.in/web/*

Mushi, G. E., Di Marzo Serugendo, G., & Burgi, P.-Y. (2022). Digital technology and services for sustainable agriculture in Tanzania: A literature review. *Sustainability, 14*(4), 2415. https://doi.org/10.3390/su14042415

Okello, J. J., Ofwona-Adera, E., Mbatia, O. L. E., & Okello, R. M. (2010). Using ICT to integrate smallholder farmers into agricultural value chain: The case of DrumNet project in Kenya. *International Journal of ICT Research and Development in Africa, 1*(1), 23-37. https://doi.org/10.4018/jictrda.2010010102

ONDC. 2023. *Democratising digital commerce in India.* ONDC.

ONDC. n.d. *Handbook on building Open Networks: The journey of ONDC so far.* ONDC.

PIB. (2024, July 26). *7.35 crore candidates enrolled and 6.39 crore trained under Pradhan Mantri Gramin Digital Saksharta Abhiyan; 4.78 crore candidates certified under the scheme*. Retrieved from https://pib.gov.in/PressReleasePage.aspx?PRID=2037600

Pradhan Mantri Gramin Digital Saksharta Abhiyaan. (2024). *About PMGDISHA*. Retrieved from https://www.pmgdisha.in/about-pmgdisha/.

Reddy, T. S. (2021). *The Impact of Digital Marketing on Agricultural Business in India*. *Natural Volatiles & Essential Oils*, 8(4), 426–437.

Klerkx, L., & Rose, D. (2020). Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? *Global Food Security, 24*, 100347. https://doi.org/10.1016/j.gfs.2019.100347

Statista. 2024. Online grocery shopping in India - statistics & facts. *Statista*. Retrieved August 16, 2024, from https://www.statista.com/topics/9572/online-grocery-shopping-in-india/

Swain, P. K., Jamir, C., Dinerstein, M., & Narula, S. (2022). Impact of development of National Agriculture Market (e-NAM) on farmers. *The Indian Journal of Agricultural Sciences*, 92(12). https://doi.org/10.56093/ijas.v92i12.127701

TRAI. (2024). *The Indian Telecom Services Yearly Performance Indicators 2023-2024*. New Delhi: Telecom Regulatory Authority of India.

Received 9 September 2024 Accepted 18 December 2024

Annexures

Annexure 1: ADF test for rice

Market Name	Pre-e-NAM		Post-e-NAM	
	t stat	p-value	t stat	p-value
log of Gorakhpur prices	0.52	0.98	-1.88	0.34
Δ log of Gorakhpur prices	-5.58	0.00	-7.32	0.00
log of Bardhhaman prices	-0.88	0.79	-2.17	0.21
Δ log of Bardhhaman prices	-5.65	0.00	-9.95	0.00
log of Shimoga prices	-0.89	0.79	-3.92	0.12
Δ log of Shimoga prices	-6.27	0.00	-8.18	0.00
log of Nawarangpur prices	-3.38	0.11	-2.18	0.18
Δ log of Nawarangpur prices	-5.80	0.00	-6.90	0.00

Annexure 2 ADF test for wheat

Market Name	Pre-e-NAM		Post-e-NAM	
	t stat	p-value	t stat	p-value
log of Shahjahanpur prices	-1.80	0.38	-3.88	0.011
Δ log of Shahjahanpur prices	-5.66	0.00	-9.05	0.00
log of Rajkot prices	-3.52	0.04	-2.80	0.06
Δ log of Rajkot prices	-3.10	0.00	-8.15	0.00
log of Ujjain prices	-1.78	0.39	-2.16	0.22
Δ log of Ujjain prices	-6.08	0.00	-7.68	0.00
log of Kota prices	-1.09	0.72	-1.35	0.60
Δ log of Kota prices	-5.62	0.00	-6.20	0.00

Source Authors' estimations from Agmarknet data.

Annexure 3 OLS regression results for major potato markets in Pre- and Post-e-NAM

Potato	Pre-e-NAM			Post-e-NAM		
	Coefficient	Std. Error	Adj. R-squared	Coefficient	Std. Error	Adj. R-squared
log Ludhiana Market price						
log Agra	1.14***	0.08	0.76	0.81***	0.09	0.43
log Bishnupur	1.22***	0.13	0.61	0.92***	0.08	0.54
log Hassan	1.25***	0.25	0.30	1.41***	0.15	0.49
log Kanpur Market price						
log Ludhiana	0.94***	0.09	0.66	0.97***	0.08	0.58
log Bishnupur	0.93***	0.06	0.80	0.81***	0.05	0.74
log Hassan	1.04***	0.18	0.38	1.14***	0.11	0.52
log Bishnupur Market price						
log Hassan	0.92***	0.15	0.41	1.21***	0.11	0.56
log Agra	0.76***	0.05	0.81	0.88***	0.05	0.74
log Ludhiana	0.50***	0.05	0.61	0.59***	0.05	0.54
log Hassan Market price						
log Bishnupur	0.46***	0.07	0.41	0.47***	0.04	0.56
log Agra	0.37***	0.06	0.38	0.46***	0.04	0.52
log Ludhiana	0.25***	0.05	0.30	0.35***	0.04	0.49

Source Authors' estimations based on Agmarknet data
** significant at 5% level; *** significant at 1% level

Annexure 4 OLS regression results for major tomato markets in Pre- and Post-e-NAM

Tomato	Pre-eNAM			Post-eNAM		
	Coefficient	Std. Error	Adj. R-squared	Coefficient	Std. Error	Adj. R-squared
log Vayalapadu Market price						
log Kolar	1.16***	0.08	0.77	0.80***	0.06	0.63
log Bargarh	0.83***	0.16	0.31	0.49***	0.10	0.20
log Chhindwara	1.15**	0.39	0.12	0.53***	0.09	0.25
log Kolar Market price						
log Vayalapadu	0.67***	0.05	0.77	0.79***	0.06	0.63
log Bargarh	0.72***	0.11	0.41	0.61***	0.09	0.33
log Chhindwara	0.74***	0.30	0.08	0.59***	0.09	0.31
log Chhindwara Market price						
log Vayalapadu	0.11**	0.04	0.12	0.48***	0.08	0.25
log Kolar	0.13***	0.05	0.08	0.54***	0.08	0.31
log Bargarh	0.18***	0.06	0.14	0.70***	0.07	0.48
log Bargarh Market price						
log Vayalapadu	0.39***	0.07	0.31	0.43***	0.08	0.20
log Kolar	0.58***	0.09	0.41	0.55***	0.08	0.33
log Chhindwara	0.87***	0.26	0.14	0.68***	0.07	0.48

Source Authors' estimation based on Agmarknet data
** significant at 5% level; *** significant at 1% level

Annexure 5 OLS regression results for major onion markets in Pre- and Post-e-NAM

Onion	Pre-eNAM			Post-eNAM		
	Coefficient	Std. Error	Adj. R-squared	Coefficient	Std. Error	Adj. R-squared
log Nashik Market price						
log Shujalpur	0.42***	0.07	0.36	0.77***	0.09	0.41
log Sriganganagar	0.36***	0.07	0.31	1.12***	0.06	0.77
log Kurnool	0.50***	0.08	0.42	0.89***	0.06	0.69
log Shujalpur Market price						
log Nashik	0.87***	0.15	0.36	0.54***	0.06	0.41
log Sriganganagar	0.74***	0.07	0.67	0.65***	0.09	0.36
log Kurnool	0.99***	0.06	0.82	0.52***	0.07	0.33
log Sriganganagar Market price						
log Nashik	0.90***	0.17	0.31	0.70***	0.04	0.77
log Shujalpur	0.91***	0.08	0.67	0.57***	0.08	0.36
log Kurnool	1.01***	0.09	0.68	0.67***	0.05	0.62
log Kurnool Market price						
log Nashik	0.86***	0.13	0.42	0.78***	0.05	0.69
log Shujalpur	0.83***	0.05	0.82	0.65***	0.09	0.33
log Sriganganagar	0.68***	0.06	0.68	0.94***	0.07	0.62

Source Authors' estimations based on Agmarknet data.
** significant at 5% level; *** significant at 1% level

Annexure 6 OLS regression results for major turmeric markets in Pre- and Post-e-NAM

Turmeric	Pre-eNAM			Post-eNAM		
	Coefficient	Std. Error	Adj. R-squared	Coefficient	Std. Error	Adj. R-squared
log Nizamabad Market price						
log Erode	0.89***	0.04	0.89	0.63***	0.09	0.33
log Duggirala	0.87***	0.03	0.95	0.26***	0.06	0.13
log Sangli	0.58***	0.05	0.71	0.32***	0.07	0.16
log Erode Market price						
log Nizamabad	1.00***	0.05	0.89	0.54***	0.08	0.33
log Duggirala	0.89***	0.04	0.90	0.55***	0.03	0.76
log Sangli prices	0.64***	0.04	0.78	0.55***	0.05	0.55
log Duggirala Market price						
log Nizamabad	1.09***	0.03	0.95	0.55***	0.14	0.13
log Erode	1.01***	0.04	0.90	1.37***	0.08	0.76
log Sangli	0.68***	0.05	0.77	0.84***	0.08	0.51
log Sangli Market price						
log Nizamabad	1.23***	0.10	0.71	0.51***	0.12	0.16
log Erode	1.22***	0.08	0.78	1.01***	0.09	0.55
log Duggirala	1.14***	0.08	0.77	0.62***	0.06	0.51

Source Calculations based on Agmarknet data
** significant at 5% level; *** significant at 1% level

Agricultural Economics Research Review 2024, 37 (2), 183-193
DOI: 10.5958/0974-0279.2024.00013.6

Economic performance of contract and non-contract broiler farming in Punjab

Amarjot Singh Chahal, Parminder Kaur, and Shaikh Mohd Mouzam*

Department of Economics and Sociology, Punjab Agricultural University,
Ludhiana, Punjab–141027, India

*Corresponding author: profmouzam@pau.edu

Abstract The broiler farming has been a profitable venture in the Ludhiana district of Punjab. This study has reported a comprehensive investigation was undertaken on twenty broiler farming units each from contract and non-contract farming systems by using structured questionnaires for the reference year 2021-22. The study aimed to assess the economic performance of broiler farming under contract and non-contract farming systems. The findings have confirmed that the non-contract farmers receive higher net returns per bird and per kilogram of live weight, as they received market prices for their output. In contrast, the contract farmers faced income limitations due to pre-determined payment structures based on live weight. The overall benefit-cost ratio for contract farms was 2.17, indicating economic viability, while non-contract farms had a lower ratio of 1.20. This suggests that while contract farming is quite feasible, while non-contract farming may offer better financial returns despite higher risks. The study has suggested that contract farming could be a suitable option for farmers lacking sufficient capital to manage high variable costs, while non-contract farming would be more advantageous for those who can navigate market risks effectively.

Keywords Broiler farming, Contract farming, Costs & returns, Production efficiency

JEL codes Q12, Q13, Q18

Introduction

The Indian poultry industry since its inception, has seen remarkable growth and has established itself as a sunrise sector with growth rates of 8.51 per cent for egg production and 7.52 per cent for broiler production, which far surpass the 2.9 per cent growth rate in agricultural crops, underlining the sector's dynamic expansion (BAHS, 2019: Anonymous, 2020). According to expert market research (EMR), the Indian poultry market, valued at USD $28.18 billion, is expected to grow at a compound annual growth rate (CAGR) of 8.1 per cent in the forecast period of 2024-2032 to reach a value of approximately USD $44.97 billion by 2032. This growth is driven by the broiler and layer segments, which comprise 65.3 per cent and 34.7 per cent of the poultry business, respectively, with monthly turnover of 400 million chicks and 8,400 million eggs (Kolluri et al., 2021).

Livestock and poultry have been regarded as one of the flagship enterprises for farm diversification in the context of the Union Government's mandate to double farmers' income, which in turn helps to reduce farmers' income-fluctuations and increase revenues (Tripathy et al., 2022). Notably, the majority, 85 per cent of the one million poultry farmers has less than two hectares of land or has no land at all showing the accessibility and the evolution of India's poultry industry from a small backyard activity to a substantial commercial enterprise in just around four decades. The investments in breeding, hatching, rearing, and processing have been significant for this transformation (Kumar and Torane 2019).

During 2022-23, the poultry meat contributed 51.14 per cent to India's total meat production of 9.77 million tonnes with Maharashtra (12.2%), Uttar Pradesh (12.1%), West Bengal (11.6%) Andhra Pradesh (11.1%) and Telangana (10.8%) together accounting for about 60 per cent of the poultry meat (Anonymous, 2022: BAHS, 2023). The demand of poultry meat is on the rise and it is the most popular meat from any single livestock species. The rapid population growth, changing consumers' dietary preferences in favour of protein-rich foods, urbanization and inflating disposable incomes have all led to a tremendous increase in poultry demand. The rise in per-capita consumption of eggs and poultry meat can generate substantial employment opportunities, with estimates suggesting that an increase of one egg and 50g of poultry meat per-capita annually can create jobs for approximately 26,000 people (Dahake et al., 2016). The poultry meat and eggs both offer unique advantages and challenges, but their mode of addressing rural economic issues and meeting the growing demand highlight their critical role in farming sector.

The broiler meat production in the country is estimated at around 5 Mt annually and the sector is currently witnessing an annual growth of 6-7 per cent as per trade estimates (Poultry Trends 2023). The share of commercial broiler birds in total meat production is around 80-85 per cent and the rest 15-20 per cent is contributed by the backyard poultry. Broiler farming can be adopted under a wide range of climatic conditions and can generally be combined conveniently with other farm enterprises. The growth potential of this sector is significant due to the regular flow of income throughout the year. Additionally, broiler farming has the potential to address the issues of unemployment and underemployment by providing a convenient and profitable subsidiary occupation to farmers (Vijayakumar and Damodaran 2015: Chatterjee and Rajkumar 2015: Satapathy et al., 2017).

A farmer having interest in raising broiler has two choices: (a) Non-contract broiler farming (NCBF) and (b) Contract broiler farming (CBF). In NCBF, the farmer has to bear all costs, such as those on extension advisory and input services (EAS), purchasing of chicks, feed, medications, vaccines, etc. and overhead farm costs (labour, electricity, water, litter, farm sanitation, etc.). He has to accept all the three risks, viz. investment risk, production risk and market risk. In contract broiler farming (CBF)/ Integration, the integrator bears the costs on EAS, chicks, feed, medications, vaccinations, etc. The farmer provides shed, electricity, water, litter management, equipment, and other services. The contract specifies a predetermined rearing charge that the farmer receives. Thus, the integrator, who is the sole owner of the farm's movable assets, bears the burden of working capital (SAPPLPP, 2009). Based on the live weight of each bird in a condition that has been predetermined and agreed upon through contractual obligation, the farmer earns a guaranteed wage or growth charges (Singh et. al., 2018 a, b). In general, the payments are based on how effectively the birds are managed, such as weight, the amount of feed needed for producing that weight feed conversion ratio (FCR), the percentage of dead birds, etc. The farmers that surpass the performance benchmarks are offered additional rewards. If a farmer doesn't meet the requirements, a corresponding penalty, calculated per bird, is imposed and deducted from the wage bill. Therefore, the broiler production contracts can be viewed as a self-policing system of rewards and penalties. The contract ensures broilers production at a reasonable cost, agreed numbers and quality required by the market (Kalamkar, 2012).

However, broiler farming is not without its challenges. One of the major challenges faced by the broiler farmers is the high cost of its production. Feed accounts for a significant portion of the total cost of production, and fluctuations in feed prices can significantly impact the profitability of broiler farming (Mallick et al., 2020; Wongnaa et al., 2023; Satapathy et al., 2017). Additionally, disease outbreaks and mortality rates can also impact the profitability of broiler farming. To address these challenges, there is a need to improve the efficiency and profitability of broiler farming through scientific management. Broiler farming has enormous significance in Punjab because of land fragmentations in the rural areas. In 2019-20, about 44 per cent of the total broiler production in Punjab was from three districts viz. Hoshiarpur, Gurdaspur and Ludhiana (Goel and Toor, 2023). In Punjab, the productivity and output of foodgrains, particularly cereals, has already reached a point of saturation with little potential for further growth, leading to the consideration of broiler farming as a subsidiary occupation. In this backdrop, the present study was undertaken in the Ludhiana district of Punjab to find out the economic performance of broiler farming under contract and non-contract farming systems focusing on aspects such as, capital investment, productivity, costs and returns, and efficiency indicators.

Data and methodology

The district of Ludhiana was purposively chosen as it is the leading producer of broilers and being an industrial hub, the local market has the potential for poultry products in a good quantity. The iinformation regarding the number of broiler farms, their location, addresses and number of birds on each farm was obtained from the office of Deputy Director, Department of Animal Husbandry, Ludhiana. Twenty broiler farming units each from contract and non-contract farming systems were randomly chosen from two blocks, namely Ludhiana and Khanna of the selected district. Based on the number of birds, the broiler farms were divided into three strata using the cube root frequency method of stratification, viz. small, medium, and large. The selection of broiler farms was done based on profitability proportion to the number of broiler farms in each category. Consequently, 8 small, 5 medium and 7 large contract farmers and 7 small, 6 medium and 7 large non–contract farmers, making a total sample of 40 farmers were selected for study. The primary data were collected for the reference year 2021-22 by personal interview method using a specially designed and pre-tested schedule.

The economics of broiler farming was worked out taking into account fixed and variable costs separately for different categories of contract and non-contract broiler farms on per farm as well as on per bird basis, since the cost and return patterns on both the farming systems were found to be different. The gross returns accrued to non-contract farmers were from sale of broilers, manure, and empty bags whereas to the contract farmers these were from the incentives paid by the company, sale of manure and sale of gunny bags. Net returns were computed by deducting total cost from the gross returns. For measuring the production efficiency of different-sized broiler farms, various ratios such as feed conversion ratio, meat-feed price ratio and benefit–cost ratio were worked out as per Equations (1), (2), and (3):

(a) Feed conversion ratio (FCR)

$$\text{Feed conversion ratio} = \frac{\text{Feed consumed per bird in kg}}{\text{Live weight per bird}} \qquad \ldots(1)$$

(b) Meat-feed price ratio

$$\text{Meat-feed price ratio} = \frac{\text{Value of meat produced per bird}}{\text{Value of feed consumed per bird}} \qquad \ldots(2)$$

(c) Benefit-cost ratio

$$\text{Benefit-cost ratio} = \frac{\text{Gross returns from sale of meat, manure, \& gunny bags}}{\text{Total cost of inputs}} \qquad \ldots(3)$$

Results and discussions

Characteristics of broiler farmers

The characteristics of sample broiler farmers mentioned in Table 1 revealed that the average number of birds procured per flock in contract and non-contract farms was 7255 and 9457 but the number of birds alive per flock was 7117 and 9034, respectively due to mortality of birds. The mortality rate was found lower (1.90%) in contract farms since the companies provided birds in good condition to contract farmers. Overall, the total numbers of birds alive per annum in contract and non-contract farms were 36689 and 50388 respectively. The lower number of alive birds in contract farms was due to the supply of a smaller number of birds per flock by the companies than the capacity of the farm which also caused under-utilisation of poultry sheds.

Linkages of broiler farmers with companies

The information on linkages of selected contract farmers with companies, presented in Table 2, reveals that overall, the IB Group had the highest share of total contracts (35%), followed by Indian Agro (20%), Wing (15%), Saguna (15%) and Kalyan (10%), Easy Wood had the lowest share in total contracts. Farm size category-wise analysis showed that the majority of small farmers (50%) were tied up with the IB Group, while 40 per cent of medium farmers had contracts with Saguna. The majority of large farmers (42.9%)

Table 1 Characteristics of sample broiler farmers in Ludhiana

Particulars	Contract farms				Non-contract farms			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
No. of birds procured per flock	4262	6800	11000	7255	2800	8092	17286	9457
Total No. of mortality per flock	116	136	165	138	140	380	743	423
Total No. of birds alive per flock	4147	6664	10835	7117	2660	7711	16542	9034
No. of birds procured per annum	22000	35400	56429	37400	14514	44383	98143	52745
Total No. of mortality per annum	594	708	846	711	726	2086	4220	2357
Total No. of birds alive per annum	21406	34692	55582	36689	13789	42297	93923	50388
Mortality rate (%)	2.70	2.00	1.50	1.90	5.00	4.70	4.30	4.47

Source: Field survey data

Table 2 Linkages of contract broiler farmers with different companies in Ludhiana

Sl. No.	Name of the company	Farm size category			
		Small	Medium	Large	Overall
1.	Wing	1	0	2	3
		(12.50)	(0.00)	(28.57)	(15.00)
2.	IB Group	4	1	2	7
		(50.00)	(20.00)	(28.57)	(35.00)
3.	Kalyan	1	1	0	2
		(12.50)	(20.00)	(0.00)	(10.00)
4.	Saguna	1	2	0	3
		(12.50)	(40.00)	(0.00)	(15.00)
5.	Indian Agro	1	0	3	4
		(12.50)	(0.00)	(42.86)	(20.00)
6.	Easy Wood	0	1	0	1
		(0.00)	(20.00)	(0.00)	(5.00)
7.	Total	8	5	7	20
		(100)	(100)	(100)	(100)

Note Figures within parentheses indicate the percentages to their respective totals.
Source Field survey data

were found operating with the Indian Agro. The choice of contracting with a particular company by the broiler farmers depended on timely supply of birds, provision of inputs, extension services provided by company and sufficiency of own capital/funds with the broiler farmer.

Fixed capital investment pattern on contract and non-contract broiler farms

The pattern of per farm fixed capital investment on different sizes of contract and non-contract broiler farms is presented in Table 3. The total fixed investment was found to be highest on large farms (₹ 894567), followed by medium (₹ 460280) and small farms (₹ 314992) with an average of ₹ 554165 as against ₹ 425093, ₹ 341233, and ₹ 258914 on the said non-contract broiler farms, respectively with an overall average of ₹ 341772. Table 3 reveals that in overall, the investment on equipment (64.72%) was the major component of capital investment, followed by investment on buildings (34.56%) and electricity fittings (0.72%). Some of the contract and non–contract broiler farmers across different categories made investments on buildings while some had broiler farms on rent. All non-contract large farmers operated on rented farms and did not have any fixed investment on buildings and electrical fittings, while contract large

Table 3 Fixed capital investment pattern on broiler farms in Ludhiana (₹/farm)

Sl. No.	Investment	Contract farmers				Non-contract farmers			
		Farm size category							
		Small	Medium	Large	Overall	Small	Medium	Large	Overall
1	Value of building*	78750	106000	381429	191500	81429	55000	-	45000
		(25.00)	(23.03)	(42.64)	(34.56)	(31.45)	(16.12)		(13.17)
2	Equipment	234717	352280	504852	358655	175986	285067	425093	295897
		(74.52)	(76.54)	(56.44)	(64.72)	(67.97)	(83.54)	(100)	(86.6)
3	Electricity fittings	1525	2000	8286	4010	1500	1167	-	875
		(0.48)	(0.43)	(0.93)	(0.72)	(0.58)	(0.34)		(0.3)
4	Total fixed investment	314992	460280	894567	554165	258914	341233	425093	341772
		(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
5	Per bird total fixed investment	14.71	13.27	16.09	15.11	18.78	8.07	4.53	6.78

*Note** includes feed store, office, and labour room values
Source Field survey data

farmers had the highest (42.64%) proportion of capital investment on buildings, followed by small (25%) and medium (23.03%) farms.

The investment was incurred on equipments such as feeders, drinkers, brooders, tarpaulins, water tanks for water supply to chicks through drinkers, etc. On contract farms, the large farms had the highest per bird fixed capital investment of ₹ 16.1, followed by the small (₹ 14.7) and medium (₹ 13.3) farms with an overall average of Rs. 15.1. Across non-contract farms, small farms had the highest per-bird total capital investment of ₹ 18.8, followed by medium (₹ 8.1) and large (₹ 4.5) farms with an overall average of ₹ 6.8 (Table 3).

Cost of production and net returns under contract and non-contract broiler farming

Fixed costs on contract and non-contract broiler farms

The details about the fixed costs on contract and non-contract broiler farms are presented in Table 4. The total fixed cost on contract broiler farms was in the following order: small < medium < large farms. The total fixed cost on non-contract broiler farms also showed the same pattern. The share of rent in the total fixed cost was largest of medium (54.97%), followed by small (53.53 %) and large (39.2 %) farmers. The depreciation on buildings on large, small and medium farms revealed a similar pattern on contract and non-contract broiler farms. It is a natural phenomenon, large farms means big shed. On non-contract farms, the rental value of shed was found higher on large farms (₹ 180000), followed by medium (₹ 105000) and small (₹ 54000) farms. Across non-contract farms, depreciation on buildings was the highest on small (₹ 4028.6), followed by medium (₹ 2750) farms. The large farms did not have their own buildings and they operated on rented farms. The interest on fixed capital investment was the highest component of fixed cost after rental value of shed on both contract and non-contract broiler farms. The per bird total fixed cost was found higher on contract farms because they had more depreciation expenses on buildings and equipments as compared to non-contract farms.

Variable costs on contract and non-contract broiler farms

The component-wise variable costs on different categories of contract and non-contract broiler farms have been presented in Table 5. The contract farmer who actually reared chicks incurred expenditure on labour, litter material, disinfectants, electricity and miscellaneous items. The company provided the day-old chicks, feed, medicines, vaccines and regular supervision for rearing the broiler chicks. The total variable cost on a contract broiler farm increased with increase in farm-size. However, the per bird total cost revealed an inverse relation with boiler farm-size, being highest on small farm. The labour costs accounted for the major share of the total variable costs and varied from 42.9 per cent to 50.7 per cent on small to large

Table 4 Fixed costs on broiler farms in Ludhiana (₹/farm/annum)

Sl. No.	Particulars	Contract farms				Non-contract farms			
		Small	Medium	Large	Overall	Small	Medium	Large	Overall
		Farm size category							
1	Rental value of shed	48000 (53.53)	70800 (54.97)	75429 (39.25)	63300 (46.78)	54000 (59.66)	105000 (70.23)	180000 (77.91)	113400 (72.88)
2	Depreciation on fixed assets								
a.	Buildings	3225 (3.60)	4300 (3.34)	14286 (7.43)	7365 (5.44)	4029 (4.45)	2750 (1.84)	-	2235 (1.44)
b.	Equipment & electricity fitting	3795 (4.23)	3074 (2.39)	4043 (2.10)	3702 (2.74)	4003 (4.42)	4219 (2.82)	4282 (1.85)	4166 (2.68)
3	Interest on fixed investment @11 per cent	34650 (38.64)	50631 (39.31)	98402 (51.21)	60958 (45.05)	28481 (31.47)	37536 (25.11)	46760 (20.24)	35795 (23.00)
4	Total fixed cost	89669 (100)	128805 (100)	192160 (100)	135325 (100)	90512 (100)	149505 (100)	231042 (100)	155596 (100)
5	Per bird total fixed cost	4.19	3.71	3.46	3.69	6.57	3.53	2.47	3.11

Note Figures within parentheses indicate the percentages to their respective totals.
Source Field survey data

farms. The cost of the litter material was the next major component of total variable cost which, on an average, accounted for 31.4 per cent of the total variable costs on contract farms. The other expenses were electricity charges, miscellaneous charges and interest on the working capital and these accounted for 8.1 per cent on small, 6.3 per cent on medium and 5.2 per cent on large farms of the total variable cost.

On non-contract broiler farms, the total variable costs depicted the same pattern as observed in the case of contract boiler farms, viz. Large > Medium > Small farms. The major variable costs incurred by non-contract broiler farms in rearing chicks were costs on feed day-old chicks, labour, disinfectants, medicine/vaccine, electricity, and some miscellaneous expenses, litter material, veterinary services. The expenditure on feed was the major component of total variable costs accounting for its 68.7 per cent. Shaikh and Zala (2011) have also reported the cost of feed to be the major item among variable costs.

Another major component of variable costs was the cost of day-old chicks, which overall accounted for 17.42 per cent of the total variable costs. The stock of poultry birds is an asset, but as the flock's size changes rapidly, it was not considered as fixed capital. The interest for the investment on poultry birds (charged @ 11 %) on small, medium, and large non-contract farms was estimated at 1.9 per cent, whereas these costs were considered nil for contract farmers as the chicks were provided by the company. Similarly, non-contract farmers had to spent a considerable amount on medicines and veterinary services, which were free for contract farmers being provided by the company.

The per bird total variable cost provided a more precise estimate on contract and non-contract broiler farms. In terms of farm-size, both contract and non-contract broiler farms depicted a similar pattern for per-bird total variable cost, Small > Medium > Large farms. The higher per-bird variable cost on non-contract farms as compared to contract farms, was due to their major share of expenses on feed and day-old chicks which together accounted for overall about 86 per cent of the total variable costs. On contract farms, day-old chicks and feed along with medicines/vaccination were provided by the company. In both contract and non-contact farming systems, an inverse relationship between variable costs and farm size has been observed. The large farms had lower variable costs per bird due to the availability of economies of scale on these farms (Singh et al., 2010: Balamurugan and Manoharan, 2013).

Table 5 Variable costs on broiler farms in Ludhiana (₹/farm/annum)

Sl. No.	Particulars	Contract farms				Non-contract farms			
		Small	Medium	Large	Overall	Small	Medium	Large	Overall
		Farm size category							
1	Day-old chick	-	-	-	-	390714 (16.99)	1109583 (16.60)	2391429 (17.84)	1306625 (17.42)
2	Labour cost	69000 (42.89)	122400 (48.65)	188571 (50.68)	124200 (48.24)	102857 (4.47)	392000 (5.86)	630857 (4.71)	374400 (4.99)
3	Feed cost	-	-	-	-	1583186 (68.84)	4597808 (68.77)	9195129 (68.61)	5151752 (68.68)
4	Disinfectants	1610 (1.00)	1950 (0.77)	2443 (0.65)	1986 (0.77)	1170 (0.05)	1942 (0.03)	2457 (0.02)	1852 (0.02)
5	Medicines	-	-	-	-	5079 (0.22)	5867 (0.09)	9461 (0.09)	6849 (0.09)
6	Electricity charges	14250 (8.86)	17760 (7.06)	30000 (8.06)	20640 (8.02)	11486 (0.50)	20600 (0.31)	45257 (0.35)	26040 (0.35)
7	Miscellaneous charges	12611 (7.84)	18480 (7.35)	18780 (5.05)	16237 (6.31)	15853 (0.69)	20994 (0.31)	25782 (0.28)	20871 (0.28)
8	Litter material	55000 (34.19)	77880 (30.95)	112857 (30.33)	80970 (31.45)	46629 (2.03)	125200 (1.87)	273929 (2.00)	149755 (2.00)
9	Veterinary services	-	-	-	-	2600 (0.11)	5042 (0.08)	5164 (0.06)	4230 (0.06)
10	Interest on investment on birds	-	-	-	-	42979 (1.87)	122054 (1.83)	263057 (1.92)	143729 (1.92)
11	Interest on working capital @11 % for half period	8386 (5.21)	13116 (5.21)	19396 (5.21)	13422 (5.21)	97287 (4.23)	284320 (4.25)	560342 (4.21)	315466 (4.21)
12	Total variable cost	160857 (100.00)	251586 (100.00)	372047 (100.00)	257456 (100.00)	2299839 (100.00)	6685410 (100.00)	13402863 (100.00)	7501568 (100.00)
13	Per bird total variable cost	7.52	7.24	6.68	7.01	166.80	158.07	142.70	148.87

Note Figures within parentheses indicate the percentages to their respective totals. *Miscellaneous charges include: oil & white washing.
Source: Field survey data

Returns on contract and non-contract broiler farms

The details on cost of production and returns from contract and non-contract broiler farming systems per annum across different sizes of broiler farms have been presented in Table 6. It reveals that the total cost of broiler production on small, medium and large contract farms was ₹ 250525, ₹ 380390 and ₹ 564207, respectively with the overall value of ₹ 392780. On non-contract farms, the cost of production depicted a similar pattern: Small > Medium > Large farms. Overall, the share of fixed and variable costs in total costs was 34.4 per cent and 65.5 per cent, respectively on contract farms, whereas on non-contract farms, the share of variable costs was very high (97.1%).

On contract farms, per bird total cost was ₹ 11.71, ₹ 10.90, and ₹ 10.10 for small, medium, and large farms, respectively, with an overall average of ₹ 10.70, while on non-contract farms, this total cost worked out to be ₹ 173, ₹ 162 and ₹ 145, respectively, with an overall average cost of ₹ 151. The total fixed cost and total variable costs per bird showed a decreasing trend as farm size increased on both contract and non-contract broiler farms.

Table 6 Returns on broiler farms in Ludhiana (₹/annum)

Sl. No.	Particulars	Contract farms				Non-contract farms			
		Small	Medium	Large	Overall	Small	Medium	Large	Overall
		Farm size category							
		Per farm							
1	Returns from								
	Incentives on broilers/returns from broilers	411385 (76.6)	707500 (83.36)	1016736 (84.0)	697286 (81.1)	2595643 (96.9)	7774583 (97.8)	16447000 (97.7)	8997300 (97.6)
	Sale of empty gunny bags	59356 (11.0)	51180 (6.0)	77529 (6.41)	63672 (7.5)	24911 (0.9)	39425 (0.5)	103714 (0.6)	56846 (0.6)
	Sale of poultry manure	66250 (12.3)	90000 (10.6)	116143 (9.6)	89650 (10.54)	56629 (2.1)	135200 (1.7)	283929 (1.7)	159755 (1.7)
	Gross returns	536991 (100)	848680 (100)	1210407 (100)	850609 (100)	2677182 (100)	7949208 (100)	16834643 (100)	9213901 (100)
2	Total cost	250526	380391	564207	392781	2390351	6834915	13633905	7657164
	(a) Fixed cost	89669	128805	192160	135325	90512	149505	231042	155596
	(b) Variable cost	160857	251586	372047	257456	2299839	6685410	13402863	7501569
3	Returns over variable cost	376134	597094	838360	593153	377343	1263798	3431780	1712332
4	Net returns	286465	468289	646200	457828	286831	1114293	3200737	1556737
		Per bird returns							
1	Returns from								
	Incentives on broilers/ returns from broilers	19.20	20.40	18.30	19.00	188.20	183.80	175.10	178.60
	Sale of empty gunny bags	2.80	1.50	1.40	1.70	1.80	0.90	1.10	1.10
	Sale of poultry manure	3.10	2.60	2.10	2.40	4.10	3.20	3.00	3.20
	Gross returns	25.1	24.50	21.8	23.20	194.20	187.90	179.20	182.80
2	Total fixed cost	4.20	3.70	3.50	3.70	6.57	3.50	2.50	3.10
3	Total variable cost	7.50	7.20	6.70	7.00	166.80	158.00	142.70	148.90
4	Total cost (Rs /bird)	11.70	10.90	10.10	10.70	173.30	161.60	145.20	151.10
5	Live weight per bird	2.10	2.10	1.90	2.00	2.10	2.10	1.80	1.90
6	Total cost per kg of live weight	5.60	5.10	5.20	5.30	81.40	76.20	79.30	79.10
7	Net returns per bird	13.40	13.50	11.60	12.50	20.80	26.30	34.10	30.90
8	Net returns per kg of live weight	6.37	6.34	6.03	6.07	9.76	12.42	18.61	16.25

Source Field survey data

The average weight of a bird, overall, was estimated to be more (2.02 kg) on contract farms than on non-contract farms (1.9 kg). Overall, the total cost per kg of live weight on contact and non- contract farms came out to be ₹ 5.30 and ₹ 79.10, respectively. The results revealed an inverse relationship between per bird total cost and farm size. The large farms could get benefits from the bulk purchases and thus economized on costs.

In contract farming, the gross returns per farm were highest on large farms (₹ 1210407), followed by medium (₹ 848680) and small (₹ 536991) farms. The incentives from rearing of broilers were earned highest by large (₹ 1016735, 84%), followed by medium (₹ 707500, 83.4%) and small (₹ 411385, 76.6%) farms with an overall average of ₹ 697286.50 (82%). The returns from sale of empty gunny bags and poultry manure overall were ₹ 63672.50 (7.5 %) and ₹ 89650 (10.5%), respectively in contract broiler farms, but were very low 0.6% and 1.7%, respectively in non-contract farming.

In non-contract farming, the gross returns per farm were highest on large (₹ 16834642), followed by medium (₹ 7949208) and small (₹ 2677182) farms. On farms of different sizes, the returns from the sale of broilers varied from 96.9 per cent to 97.7 per cent of the total gross returns. Khan and Babu (2004) had also observed that per cent returns from the sale of broilers constituted the major share in total receipts.

On contract farms the per bird incentives for broilers was ₹ 19.20 on small farms followed by ₹ 20.40 on medium and ₹ 18.30 large farms, with an overall incentive of ₹ 19.00. Due to the average weight of broilers being higher on medium contract farms than on small and large farms, returns from sale of broiler were highest on medium farms, followed by small farms and large farms. Among non-contract farmers, the per bird returns from the sale of broiler was highest (₹ 188) on small farms, followed by medium (₹ 184) and large (₹ 175) farms, with an overall average of ₹ 179. The per bird net returns were estimated to be the highest (₹ 13.50) on medium farms, followed by small (₹ 13.40) and large (₹ 11.60) farms, with an overall average of ₹ 12.50 on contract farms. On non-contract farms, the per bird net return increased with farm size, i.e. ₹ 20.80, ₹ 26.30 and ₹ 34.10 on small, medium and large farms. Overall, the net returns per bird as well as per kg of live weight were higher on the non-contract than contract farms because the non-contract farmers received the prevailing market price for their output whereas the growing/rearing charges were paid to contract farmers according to the live weight of the birds, which was predetermined in the contract agreement, and the contract farming had a cap or income limitation. The contract farmers had to merely raise the birds and faced less risk because the company provided the inputs and purchased the produce. A non-contract farmer, meanwhile, had to deal with every risk possible, from purchasing of inputs, vaccination to selling in markets.

Production efficiency of contract and non-contract broiler farms

The feed conversion ratio, meat feed price ratio, and benefit-cost ratio for contract and non-contract broiler farming are presented in Table 7. In contract farms, the average feed conversion ratio was 1.20 with 1.22, 1.18 and 1.15 on small, medium, and large farms, respectively while on non-contract farms, the feed conversion ratio was 1.26, 1.19 and 1.15 on the corresponding farms with an overall average of 1.26. Table 7 also shows that the feed conversion ratio decreased as farm size increased. The better the production efficiency, the lower the feed conversion ratio value. The overall per-bird value of live weight was ₹ 19.00 on contract and ₹ 178.60 non-contract farms.

On contract farms, the meat feed price ratio was estimated to be 0.16, 0.18, and 0.19 for small, medium, and large farms, respectively, with an overall average value of 0.19. On non-contract farms, the ratio was estimated to be 1.64, 1.69, and 1.79 for small, medium, and large farms, respectively, with an overall average value of 1.75. Therefore, when farm size increased, the meat feed price ratio increased which shows that the higher the meat feed price ratio, higher will be the efficiency. Due to the lesser value of feed consumed per bird, the large farms had a higher meat feed price ratio. Across non-contract farms, a reduction in the value of feed consumed per bird was due to the bulk purchases of feed ingredients, etc. The overall benefit-cost ratio was found 2.17 for contract farms and 1.20 for non-contract farms, showing that the production of meat is economically viable. Kumar and Rai (2006) had also reported similar findings.

Table 7 Production efficiency on broiler farms in Ludhiana, Punjab

Sl. No.	Particulars	Contract farms				Non-contract farms			
		Small	Medium	Large	Overall	Small	Medium	Large	Overall
		Farm size category							
1	Feed (kg/bird)	2.56	2.52	2.21	2.43	2.69	2.53	2.1	2.4
2	Live weight per bird	2.1	2.13	1.93	2.02	2.13	2.12	1.83	1.9
3	Feed conversion ratio (1÷2)	1.22	1.18	1.15	1.20	1.26	1.19	1.15	1.20
4	Value of live weight (₹/bird)	19.2	20.4	18.3	19.0	188.2	183.8	175.1	178.6
5	Value of live weight (₹/kg)	9.15	9.57	9.48	9.41	88.38	86.70	95.69	93.98
6	Value of feed (₹/bird)	114.8	108.7	97.9	102.2	114.8	108.7	97.9	102.2
7	Meat feed price ratio (4÷6)	0.16	0.18	0.19	0.19	1.64	1.69	1.79	1.75
8	Benefit-cost ratio	2.14	2.23	2.15	2.17	1.19	1.16	1.23	1.20

Source: Field survey data

Conclusion and policy implications

The study has reported the economic performance of broiler farming on contract and non-contract farming. It has found that the total cost per-farm as well as per-bird is less on contract than non-contract farms. The per-bird gross returns on contract and non-contract farms have been found to be ₹ 23.18 and ₹ 182.86, respectively. The per-farm and per-bird net returns over the variable costs have been recorded higher on non-contract farms and the net returns per kg of live weight are also similar. It is because non-contract farmers receive the prevailing market price for their output, whereas the growing/rearing charges are paid to the contract farmers according to the live weight of the birds, which is pre-determined in the contract agreement, and the contract farming has a cap or income limitation. In both the categories of farms, as farm size increases, the feed conversion ratio decreases, which shows that large farms are more efficient as lower the feed conversion ratio, higher the efficiency. From small to large farms in both categories, the meat-feed price ratio has been found increasing. The benefit-cost ratio is observed was higher on contract compared to non-contract farms. The study has brought out that broilers production in contract farms is feasible to those farmers who lack adequate funds to meet huge variable costs. Therefore, the study has suggested to opt for contract broiler farming rather than leaving the broiler farms empty. Although, broiler farming has been a profitable venture in the Ludhiana district of Punjab, there is much scope of reducing production cost and boosting profitability through educating farmers on adoption of scientific modern technologies.

References

Anonymous 2020. Economic Survey 2019-20. Agriculture and Farm Management. Department of Economic Affairs, Government of India, New Delhi.

Anonymous 2022. National action plan for egg and poultry, Department of Animal Husbandry, Dairying and Fisheries, Government of India.

BAHS (Basic Animal Husbandry Statistics) 2019. Department of Animal Husbandry, Dairying and Fisheries, Government of India.

BAHS (Basic Animal Husbandry Statistics) 2023. Department of Animal Husbandry, Dairying and Fisheries, Government of India.

Balamurugan, V. and Manoharan, M. 2013. Cost and benefit of investment in integrated broiler farming A case study. Int. J. Curr. Res. Aca. Rew, 2(4), pp.114-123.

Chatterjee, R. N., and Rajkumar, U. 2015. An overview of poultry production in India. Indian Journal of Animal Health, 54(2): 89-108.

Dahake V. V., Mankawade K. R., and Deshmukh V. A. 2016. Economic analysis of broiler production in Wardha district. Agriculture Update 11: 277-82.

Goel, R. and Toor, J.S. 2023. Mortality of chickens in broiler poultry farms in Punjab: a garrett ranking technique based analysis. Journal of Food, Agriculture & Environment, 21(1), pp.54-57.

Kalamkar, S. S. (2012). Inputs and services delivery system under contract farming: A case of broiler farming. Agricultural Economics Research Review, 25(conf), 515-521.

Khan, H. S. S., and Babu, K. S. 2004. Cost and returns in broiler production: A case study of Bellary district. Indian Journal of Agricultural Marketing, 18, 191.

Kolluri G., Tyagi J. S., and Sasidhar P. V. K. 2021. Indian poultry industry vis-à-vis coronavirus disease 2019. A situation analysis report. Poult Sci 100: 1-5.

Kumar A. M. and Torane S. R. 2019. Financial feasibility of broiler production in case of non-contract and contract farms. Econ Aff 64: 395-400.

Kumar, B. G., and Rai, R. B. 2006 Economic status of poultry farming enterprises in Andaman and Nicobar Islands. Agriculture Economic Research Review, 19, 377-386.

Mallick, P., Muduli, K., Biswal, J. N., and Pumwa, J. 2020. Broiler poultry feed cost optimization using linear programming technique. Journal of Operations and Strategic Planning, *3*(1), 31-57.

Poultry Trends. 2023. Poultry sector in India witnessing a robust growth. Retrieved December 25, 2024, from https://www.poultrytrends.in/poultry-sector-in-india-witnessing-a-robust-growth/#:~:text=Broiler%20meat%20production%20in%20the,126.53%20billion%20in%202021%2D22.

SAPPLPP. 2009. Vertical Integration at Suguna Poultry Farms - A critical look at pro-poor livelihood issues, Case Study SAGP 12, South Asia Pro Poor Livestock Policy Programme, A joint initiative of NDDB and FAO.

Satapathy, D., Sharma, A., Paswan, J. K., Sarkar, S., and Varun, T. K. 2017. Economic broiler farming: scope and limitations. Indian Farmers, 4(5), 393-405.

Shaikh, A. S., and Zala, Y. C. 2011. Production performance and economic appraisal of broiler farms in Anand district of Gujarat. Agricultural Economics Research Reviews, 24: 317-323.

Singh V. P., Sharma V. K., Sidhu M. S., and Kingra H. S. 2010. Broiler production in Punjab: An economic analysis. Agric Econ Res Rev 23: 315-24.

Singh, S., and Kaur, P. 2016. Price spread and marketing efficiency in the marketing of broilers in Ludhiana district of Punjab. Indian Journal of Economics and Development*,* 12(1a): 117-122.

Singh, A. K., Sagar, M. P., Pratap, J., and Chaturvedani, A. K. 2018a. Production and profitability under contract and non-contract broiler farming systems in Eastern Plain Zone of Uttar Pradesh, India. International Journal of Current Microbiology and Applied Sciences, 7(8), 2624-2631.

Singh, A. K., Sagar, M. P., Pratap, J., and Chaturvedani, A. K. 2018b. Contract broiler farming system in eastern plain zone of Uttar Pradesh. The Pharma Innovation Journal, 7(7), 807-810.

Tripathy A., Bardhan D., Kumar S., Kumar S., Singh S. R. K., Khan R., and Dora D. S. 2022. Value chain analysis of Kadaknath chicken in Madhya Pradesh and Chhattisgarh. Agric Econ Res Rev 35: 135-50.

Vijayakumar, E.P., and Damodaran, K. 2015. Economics of poultry farming: A critical review. International Journal of Economic and Business Review, 3(8), 63-67.

Wongnaa, C. A., Mbroh, J., Mabe, F. N., Abokyi, E., Debrah, R., Dzaka, E., and Poku, F. A. 2023. Profitability and choice of commercially prepared feed and farmers' own prepared feed among poultry producers in Ghana. Journal of Agriculture and Food Research, 12, 1-13.

Received 2 November 2023 Accepted 18 November 2024

Agricultural Economics Research Review 2024, 37 (2), 195-211
DOI: 10.5958/0974-0279.2024.00014.2

Intercropping and management of production risks: Evidence from semiarid regions of India

Hardeep Singh[1]* and Poonam Rani[2]

[1]Department of Humanities and Social Sciences, Indian Institute of Technology, Jammu, Jammu and Kashmir–181221, India
[2]Department of Economics, Akal University, Bathinda, Punjab–151302, India

*Corresponding author: hardeep.singh@iitjammu.ac.in

Abstract The study has examined the impact of mixed/intercropping systems on the risk profiles of agricultural households. It has used plot-level panel data of agricultural households collected and administered by the International Crops Research Institute for the Semi-arid tropics for the period 2010 to 2014. Using Antle's (1983) framework and CRE (Correlated Random Effect) model, it has found that mixed cropping increases household risk exposure when there are no restrictions placed on crop combinations. However, imposing restrictions on crop combinations can help mitigate these risks. The empirical evidence in the study has highlighted that selecting the right crop combinations can enhance crop yields and reduce the risk exposure of agricultural households. Additionally, the findings support the use of conservation agricultural practices to reduce the exploitation of natural resources while stabilizing crop yields.

Keywords Mixed-cropping, central moments, conservation agriculture, semiarid tropics

JEL codes O13, Q10, Q16

Introduction

The food insecurity is a critical global challenge affecting many countries. Food and Agriculture Organization (FAO) has focused on four dimensions of food security, viz. availability, accessibility, utilization, and stability of the consumption basket[1]. However, millions of people are facing the problem of food unavailability, especially in the Global South (Giuseppe, 2015). The agricultural households, especially in the developing countries, are facing these challenges to a larger extent as the majority of these households depend upon rainfed agriculture for their livelihoods. Additionally, these households lack financial resources, good institutional structure, and adequate market infrastructure adding to their challenges (Kumar and Parikh, 2001; Di Falco et al., 2011; Fahad and Wang, 2018). Smallholding size of the plots further culminates the problem (Kirwan and Roberts, 2016). Moreover, it is well-reported that global agriculture is facing continuous threats from weather shocks, pursuing conventional agricultural practices, and continuous depletion of natural resources (Rosenzweig and Binswanger, 1993; Shiferaw and Bantilan, 2004; McLaughlin and Kinzelback, 2015). Numerous studies have documented that the threats from climate-related changes would increase in the near future and might affect the agricultural economy, especially in the developing countries (Morton, 2007; Nelson et al., 2010; Porter et al., 2015). In light of this looming crisis, the conservation agriculture emerges as a panacea to protect agricultural households from the income shocks associated with these environmental upheavals and to provide adequate food availability. The conservation agriculture is characterized by a farming system that advocates minimum soil

[1]https://www.fao.org/conservation-agriculture/en/

disturbance, maintaining perpetual soil cover, and pursuing multiple cropping systems (Gonzalez-Sanchez and Basch, 2017; Acevedo et al., 2020).

Mixed/inter-cropping system, one of the conservation agricultural practices, has been largely followed by farmers to reduce the weather and price risks (Lemken et al., 2017; Wang et al., 2015; Arslan et al., 2015). In a mixed cropping setup, farmers go for two or more crops simultaneously on the same plot in a particular season where one crop is considered a major crop, and the other, a minor crop. It is to be noted that these crops need not be grown at the same time; however, they must be grown together for a specific period of time (Government of India, 2013; Jalilian et al., 2017). Several studies have explored the impact of mixed cropping on different aspects associated with agricultural households. These studies have claimed that pursuing mixed cropping helps in managing pests (Pan and Qin, 2014); needs fewer resources (Vrignon-Brenas et al., 2016); stabilizes the income during drought-like situations (Wang et al., 2015); protects the soil and water resources (Betencourt et al., 2012; Neill and Lee, 2001); helps in optimally utilizing the rainwater (Solanki et al., 2011); increases labour productivity (Hong et al., 2019); and ensures higher stable yields throughout the year (Raseduzzaman and Jensen, 2017).

Nevertheless, studies exploring the impacts of mixed cropping have particularly focused on outcomes like average crop yields, productivity, or income (Hong et al., 2020; Hong et al., 2019; Arslan et al., 2015; Wezel et al., 2014; Agegnehu et al., 2006; Hauggaard-Nielsen et al., 2009; Abalu, 1976). However, to fully understand how pursuing conservation agricultural practices influences the risk exposure of the farmers, one must go beyond simple averages. This makes the case for studying the relationship between mixed cropping and higher moments of crop yields. In the development economics literature, a few studies have focused on the influence of pursuing different conservation strategies on risk exposure to the farmers (Kumar et al., 2020; Issahaku and Abdulai, 2020; Teklewold and Mekonnen, 2020; Chavas and Di Falco, 2012; Di Falco and Chavas, 2006; 2009). For instance, Di Falco and Chavas (2009) investigated the impact of crop genetic diversity on mean, variance, and skewness for wheat crop yield using farm-level data from Sicily (Italy). Using a flexible-based moment approach, they found that crop genetic diversity helps increase crop yields and reduces risk exposure. However, it could reduce variance only if pesticide-use is low. A similar study of barley crops in the highlands of Ethiopia found that crop genetic diversity increases farm productivity (Chavas and Di Falco, 2012). Additionally, increasing biodiversity might increase variance but help reduce downside risk exposure to the farmers, and the result is stronger for the less fertile soils. However, neither study directly focused on intercropping. In a similar study, Teklewold and Mekonnen (2020) explored the effects of different combinations of climate-smart agricultural practices (CSA), including agriculture water management, improved crop seeds, and inorganic fertilizer for maize, wheat, teff, barley, and legume crops on risk exposure to the agricultural households considering five regional states of the Ethiopian part of the Blue Nile Basin. Using a multinomial treatment effects approach, the study found that adopting CSA practices is a risk-reducing strategy for agri-households.

Furthermore, using data from 1204 plots in the semiarid tropics of India, Kumar et al. (2020) have assessed the impact of soil and water conservation strategies on farm crop productivity and risk exposure. Utilizing a moment-based approach, the findings suggested that soil bunding helps increase crop yields while reducing crop yield variability. Additionally, soil bunding reduces the chances of downside risk or probability of crop failure. Issahaku and Abdulai (2020) also explored the influence of crop choice, soil and water conservation practices on crop revenue, and exposure to risks (skewness). Employing a multinomial endogenous switching regression framework, the study found that adopting conservation agricultural practices increases crop revenues and reduces riskiness in crop yields. The study also found that factors including access to weather information, education level of household-head, and access to agri-extension services increase the likelihood of adopting conservation practices. However, these studies did not focus on adopting mixed cropping while examining the impact of conservation practices on the risk exposure of households. It is also to be noted that these studies have focused only on the crop yield for main crops while examining the influence of conservation practices on crop yields, ignoring the yields obtained from minor crops. Ignoring the minor crops while examining the impacts of intercropping might lead to misleading results as it could understate or overstate the agricultural revenue obtained by an agricultural household. Additionally, these studies have mostly considered a particular crop combination that might stabilize crop yields or even reduce the risk exposure of agricultural households.

A significant observation is that mixed crops can compete with or complement each other to reduce or increase crop yields. Increasing crop yields through mixed cropping would require choosing an appropriate combination of crops that might help increase farmers' resilience against weather shocks. The farmers sometimes mix a minor crop to provide appropriate nutrients to the major crop, or they might choose a combination that helps retain the productivity of the natural resources (Junior et al., 2023). In these circumstances, the farmers might receive less crop revenue per hectare by not harming the natural resources. In this study, we have examined the influence of mixed cropping on the risk profile of agricultural households. In our study, we have looked at the influence of mixed cropping on the risk profile of the farmers without conditioning on any particular combination of crops followed by a household. Later, we extended our analysis to particular crop combinations across different seasons that were widely followed in the selected regions. We have restricted our analysis to the risk profile of the agri-households only. We have not looked at the role of mixed cropping in preserving natural resources.

Using plot-level panel data from some semiarid regions of India, we have examined the impact of pursuing different crop combinations on the same plot and in the same season on the risk profile of agricultural households. To determine risk profile, the study has focused on first four central moments of the crop yields: mean, variance, skewness, and kurtosis. Most of the studies focus on mean and variance to determine the variability of crop yields. However, variance does not indicate crop yields' downside and upside risks. Skewness provides information about these risks, where an increase in skewness reflects a decline in downside risk to the farmers. In contrast, higher kurtosis reflects increased infrequent deviations in crop yields.

Some specificities of this study are: (i) the analysis is not restricted to particular crop combinations as has been followed in the previous studies, (ii) it provides some empirical evidence stating that mixed cropping does not always lead to increased crop yields, it might also decrease crop yields, and (iii) a plot-level analysis, which was lacking in the literature, has been performed. Even though Arslan et al. (2015) have done a plot-level analysis to explore the adaptation role of intercropping against weather shocks, they have not considered the risk profile of the households.

Data

The study has used the data from the Village Dynamics in South Asia (VDSA) panel survey collected and administered by the International Crops Research Institute for Semi-Arid Tropics (ICRISAT). The survey was designed (i) to examine the social and economic changes accruing over time in the household economies of the semi-arid tropics of South Asia, and (ii) to improve the availability of reliable, high-frequency time series data at the household, individual, and field levels in purposefully selected villages within the South Asia's semi-arid and tropical regions. For the survey, rural households were selected in India and Bangladesh's poverty-ridden, semi-arid, and humid tropics. Based on several relevant variables, the VDSA survey collected detailed information about the agricultural households continuously for the period 2010-2014 across 30 villages spread over 15 districts across 8 states, namely Andhra Pradesh (4 villages), Maharashtra (4 villages), Gujarat (4 villages), Karnataka (4 villages), Madhya Pradesh (2 villages), Bihar (4 villages), Jharkhand (4 villages), and Odisha (4 villages). The villages were selected purposefully based on key criteria derived from an analysis of the taluka-level information. These villages represented populations from six agroecological regions in India vulnerable to significant geographic poverty traps. Apart from six villages, a monthly survey of 40 households was conducted in each village. Table 1 provides the list of districts, villages, and number of sampled households. A detailed questionnaire was prepared to collect the database from each household, where information was recorded in different modules, viz. households' cropping patterns, inputs used for cultivation purposes, demography, endowment, livestock activities, and employment, among others. It may be noted that the nature of panel data was unbalanced. Most of the selected households in these

Table 1 Description of selected districts, villages and households

Country/region	State	District	Villages	No. of households
Semi-arid Tropics (SAT) India	Andhra Pradesh	Mahbubnagar	Aurepalle, Dokur	70, 50
		Prakasam	JC Agraharam, Pamidipadu	40, 40
	Maharashtra	Akola	Kanzara, Kinkhed	62, 52
		Solapur	Kalman, Shirapur	61, 89
	Karnataka	Bijapur	Kapanimbargi, Markabbinahalli	40, 40
		Tumkur	Belladamadugu, Tharati	40, 40
	Gujarat	Junagadh	Karamdichingariya, Makhiyala	40, 40
		Panchmahal	Babrol, Chatha	40, 40
	Madhya Pradesh	Raisen	Papda, Rampura Kalan	40, 40
East India	Bihar	Patna	Arap, Bhagakole	40, 40
		Darbhanga	Inai, Susari	40, 40
	Odisha	Dhenkanal	Sogar, Chandrasekharpur	40, 40
		Bolangir	Anlatunga, Villaikani	40, 40
	Jharkhand	Ranchi	Dubaliya, Hesapiri	40, 40
		Dumka	Dumariya, Durgapur	40, 40

Source ICRISAT-VDSA.
https://vdsa.icrisat.org/vdsa-desgImplementation.aspx

semiarid regions wait for the monsoon to start their agricultural activities. If the households do not receive sufficient rainfall, they tend to keep their land fallow for that season. A significant portion of the households remarked that they had to remove their crop from the field immediately after sowing for several reasons, including floods, lack of sufficient rainfall, pest attacks, and unavailability of fertilizers and pesticides at the right time. Further, the migration and non-responses from some households contributed to a higher attrition rate within the sample, making it challenging to construct balanced panel data.

This survey describes an agricultural household's cropping patterns on a particular plot and in a specific season. Leveraging this data, we employed the information to determine our intercropping variable. Given the definition of mixed cropping, this database provided an edge by providing such detailed information. Considering the agricultural input and output modules of the ICRISAT-VDSA database, we have constructed a mixed cropping variable as a categorical variable, taking value 1 if the farmers cultivate more than one crop on a specific plot during a particular season and zero otherwise.

Descriptive Statistics

To determine the impacts of mixed cropping on the risk exposure to agricultural households, we have considered crop revenue per hectare as the dependent variable. In the mixed cropping set-up, the farmers grow different crops, which vary in units, making it difficult to determine the agricultural productivity. The VDSA survey provided information about each crop's quantity and price, making it easier to determine agricultural productivity in terms of revenue. However, there was a large variation in the reported agricultural revenue as some farmers reported lower crop yields because of lack of sufficient rainfall and attack of pests. Additionally, the farmers grow various crops, leading to variations in final crop yields that fetch different prices in the market. To reduce this variation in the dependent variable, we have used the natural logarithm of agricultural productivity in value terms. Similarly, we found large variations in the expenditure incurred by agricultural households. To control for the effect of outliers on our dependent variable, we also considered expenditure incurred for agricultural activities in logarithmic form. Figure 1 depicts the kernel density of the logarithm of crop revenue per hectare. It is evident that the distribution is more of leptokurtic

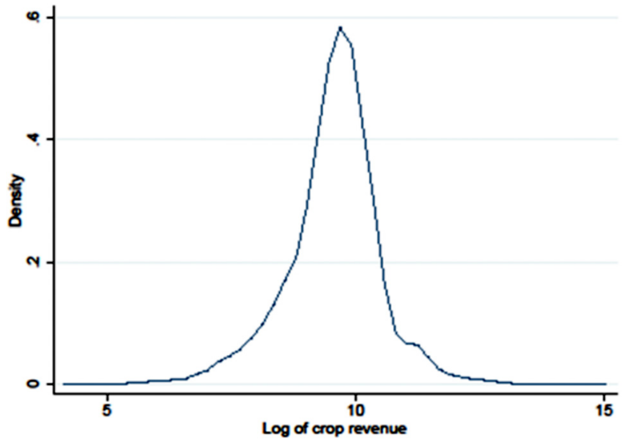

Figure 1 Kernel density of log of crop revenue

(higher kurtosis) and is skewed towards both tails. In Figure 2, we have presented the returns from adopting a mixed cropping system and those of not adopting the system. It is to be noted that the results are presented without restricting the crop combination. It can be observed from Figure 2 that the average crop yields were lower for mixed cropping plots compared to the ones that did not adopt the cropping pattern. However, higher crop yields required choosing an appropriate mixed crop combination. Additionally, the mixed crops might compete with each other, leading to an overall reduction in crop yields, or it might assist in reducing the variability of the crop yields or in mitigating the downside risks associated with the crop yields (Arslan et al., 2015; Di Falco and Chavas, 2009).

The distribution of adoption of mixed cropping across different farm classes has been shown in Table 2. As we move from marginal to large landholding farmers, we see a noticeable decline in the percentages of farmers opting for mixed cropping. Table 3 presents the descriptive statistics of the variables utilized in the analysis. On average, 19 per cent of the farmers had embraced mixed cropping in their agricultural system. The average area owned by an agricultural household was 1 hectare, with an average of 0.5 hectares being irrigated. The average age of the farmer was 51 years, and they had received 6 years of schooling. On average, a household comprised 6 members, including children and the elderly. It is to be noted that the markets were a bit far from the villagers, which might increase their transportation costs. The average distance of the market from the village was 10 km. It was also observed that a significant proportion of the farmers was involved in agricultural-related organizations, with approximately 33 per cent being members. Table 4 shows the intercropping variable's adoption probabilities and the

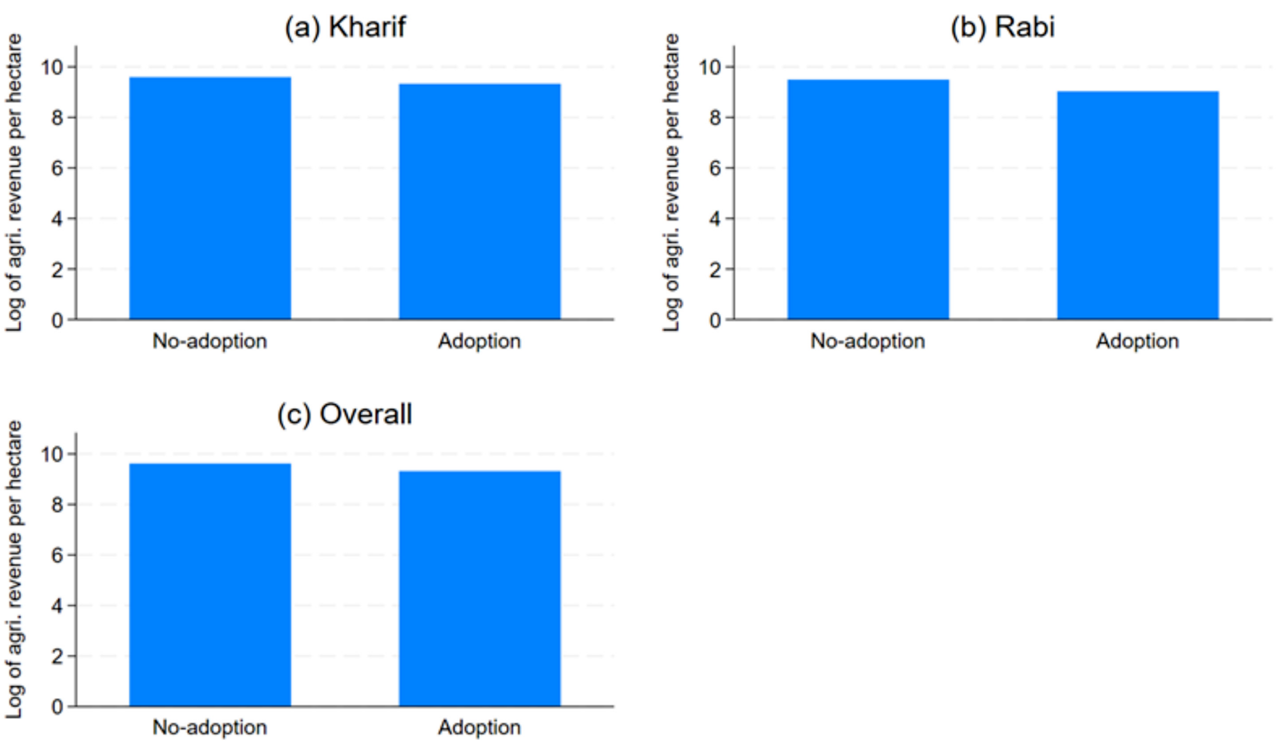

Figure 2 Returns from adoption of mixed cropping system

Table 2 Percentage of farmers adopting mixed cropping across different farm categories

Adoption of mixed crop (0/1)	Farm Size				
	Marginal (<1 ha)	Small (1-2 ha)	Semi-medium (2-4 ha)	Medium (4-10 ha)	Large (>10 ha)
No	74.88	87.31	88.22	90.66	90.3
Yes	25.12	12.69	11.78	9.34	9.7

Table 3 Descriptive statistics of agri-household characteristics

Variable	Units of measurement	Observations	Mean	Std. Dev.
Log of crop revenue	Agricultural revenue (₹/ha)	23,805	9.55	0.95
Adoption of mixed cropping	= 1 if yes and 0, otherwise	26,640	0.19	0.4
log of area	ha	25,861	0.57	0.5
Irrigated area	ha	26,640	0.54	1.21
Per capita non-farm income	Off-farm income (₹/ha)	21,684	4.74	0.65
Gender				
Female	=1 if female	26,503	0.04	0.2
Male	=1 if male	26,503	0.96	0.21
Age of household-head	Years	26,466	51.44	12.75
Level of education	Schooling Years	26,411	6.11	4.91
Dependency ratio	Ratio of dependent members over total members	26,460	0.64	0.65
Household size	Number	26,636	6.34	3.17
Part of any organization	=1 if yes and 0 otherwise	26,636	0.33	0.47
Market distance	km	26,638	10.51	6.29
log of wage cost	Wage cost (₹/ha)	24,884	7.61	1.35
log of material cost	Material cost (₹/ha)	24,435	7.7	1.5

Table 4 Descriptive statistics of choice and impact variables: 2010, 2012, 2014

Variables	Year					
	2010		2012		2014	
	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters
Choice variables						
Mixed cropping	0.26	0.74	0.18	0.82	0.14	0.86
Impact variables						
Crop yields	9.09	9.32	9.45	9.67	9.6	9.82
Central moments						
First moment (mean)	-0.09	-0.11	0.13	0.05	0.17	0.06
Second moment (variance)	0.83	0.42	0.7	0.36	0.54	0.34
Third moment (skewness)	-0.57	-0.37	-0.11	0.06	0.26	0.06
Fourth moment (kurtosis)	3.03	1.22	2.08	1.69	1.29	0.86

Note The table represents the statistics for the choice and impact variables considered in the study. Mixed cropping has been represented as a categorical variable taking value 1 if the household was growing mixed cropping and 0 otherwise. Crop yields are measured as agricultural revenue per hectare. First, second, third and fourth moments represent the first four central moments viz., mean, variance, skewness, and kurtosis of the crop yield production function.

outcome variables' average level for the years 2010, 2012, and 2014 without conditioning on the crop combination. The outcome variable was the crop yield measured in agricultural income per hectare. We have shown the changes in the choice and outcome variables over time. It was noted that the farmers adopting the mixed cropping system have declined over the time. However, crop yields in value terms for both groups had slightly improved over the same time.

Empirical strategy

We have modelled the first four central moments of the agricultural revenue per hectare as a function of household-level variables, including the adoption of intercropping. We have followed the moment-based approach developed by Antle (1983). This approach helps us to evaluate the mean, variance, skewness, and kurtosis of the farm returns conditional on a number of factors (Kim and Chavas, 2003; Antle, 1983). To assess farmers' risk exposure, we defined the stochastic production function as per Equation (1):

$$y = g(W, V) \quad \ldots(1)$$

where, y is the crop yield (revenue in value terms per hectare), W consists of farm and farmer level factors; and V is a vector of variables that a farmer cannot control for. To determine the influence of inputs on the probability distribution of $g(W,V)$, Antle (1983) had developed a model where the probability distribution of $g(W,V)$ was modelled as a unique function of its inputs. Let us consider the econometric specification (2):

$$g(W, V) = g_1(w, \varnothing) + \varepsilon \quad \ldots(2)$$

Where, $g_1(w, f) = E[g(W,V)]$ is the mean of $g(W,V)$, and $\varepsilon = g(W,V) - g_1(w, \varnothing)$ is a random variable with mean 0. Following Di Falco and Chavas (2009) and Antle (1983), the higher-order moments of $g(W,V)$ can be derived as per Equation (3):

$$E\{[g(W,V) - g_1(w, \varnothing)]^k / w\} = g_k(w, \varnothing_k) \; k = 2,3,4 \quad \ldots(3)$$

Equations (2) and (3) provide us with the moments of the distribution of $g(W,V)$, where it consists of the second $g_2(w, \varnothing_2)$, so on.

Given the above theoretical framework, the production function can be defined using the following reduced-form regression Equation (4):

$$y_{hvt} = \alpha + \beta.INTC_{hvt} + \delta.W_{hvt} + \varepsilon_{hvt} \quad \ldots(4)$$

Where, y_{hvt} represents the agricultural revenue per hectare obtained by the household h residing in village v and in year t. W_{hvt} represents the explanatory variables shown in Table 2 that we have taken into consideration for our analysis purposes. $INTC_{hvt}$ represents the status of the adoption of a mixed cropping system. β is the main parameter that informs us about the impact of adoption of mixed cropping on the mean crop yield. Equation (4) models the first central moment of the production function. Following Di Falco and Chavas (2009) and Antle (1983), the higher-order moments can be represented as per Equation (5):

$$\widehat{\varepsilon_{hvt}^{k}} = \alpha^k + \beta^k.INTC_{hvt}^k + \delta^k.W_{hvt}^k + \mu_{hvt}^k \quad \ldots(5)$$

Where, all the variables are defined as before and k = 2,3, … …, K indexes the higher-order moments of the production function. However, for our analysis purposes, we have only focused on the first four central moments of the production function, viz., mean, variance, skewness, and kurtosis.

Some potential econometric challenges are likely to arise while running this reduced-form regression equation. The adoption of mixed cropping is a choice variable that depends upon the farmer's own characteristics, and these characteristics might further influence crop productivity. The endogeneity of the mixed cropping variable may violate the independence assumption of ordinary least squares between the error-term and the right-hand side variables. Additionally, the farmers who go for these cropping systems might have unobserved factors that influence their productivity levels (Mundlak, 2001). Following Arslan et al., (2015), we have limited data spanning over 5 years for which we could consider explanatory variables to be approximately exogenous. Furthermore, there might be some time-invariant unobservable factors that might be correlated with the crop yield.

Given the short panel and our interest in time-invariant heterogeneity, we have followed a Chamberlin-like correction to the random effect model to estimate a Correlated Random Effects (CRE) model (Arslan et al., 2015). The CRE model helps in modelling the time-invariant unobservable and other explanatory variables using a Chamberlain-like framework assuming $v_h/W_{hvt} \sim N(\vartheta + \overline{W_{hvt}}\epsilon, \sigma_b^2)^2$, where, σ_b^2 is the variance of b_h while performing $v_h = \omega + \overline{W_{hvt}}\epsilon + b_h$, and $\overline{W_{hvt}} = T^{-1}\sum_{t=1}^{T} W_{hvt}$ is the 1 × K vector of the time averages of all time-varying explanatory variables. While performing the analysis, we have incorporated the time averages of all the time-varying variables in Equations (4) and (5), which helped us to get rid of the biases that might influence our results. Here, we had assumed that there existed some dependency between v_h and W_{hvt}.

Empirical results

Table 5 shows the estimates derived using Equations (4) and (5), where we have modelled the first four central moments of the crop yield as a function of several explanatory variables, including the adoption of mixed cropping. While performing this regression, we have attempted to control for the biases that might arise in different ways. For instance, different crops differ in their productivity. Additionally, from the mixed cropping perspective, crops might compete or complement each other. We have included crop-fixed effects in our analysis to control for such factors. Further, some changes might occur over time, influencing our outcome of the interest variable. For example, technological changes over time can lead to changes in the cropping system being followed by the farmers. To control for such factors, we have considered time-fixed effects. Inherent characteristics of the villages also influence our interest variables. The characteristics of the prevailing natural resources, including soil and water, might differ across different regions. We have addressed these differences by adding fixed effects for the village. From Table 5, our key variable of interest is adoption of a mixed cropping system. Column 2 of Table 5 shows the impact of mixed cropping on the mean crop yield. In this specification, we have not restricted the crop combinations being followed by an agricultural household. The coefficient associated with mixed cropping is negative and statistically significant, implying that, on an average, the adoption of mixed cropping yields lower crop revenue per hectare. This result contradicts the observation found in the literature. However, it is plausible that growing crops simultaneously on the same land might compete for the same resources, further leading to an overall reduction in agricultural revenue. Additionally, studies have shown that adopting conservation practices provides limited yield effects or sometimes even declines the yields (Kitonyo et al., 2018; Corbeels et al., 2014; Rosenstock et al., 2014).

The interest of this study was to examine the influence of mixed cropping on risk exposure in agricultural households. Therefore, we have moved to variance, skewness, and kurtosis of the crop yields. Column 3 of Table 5 shows the results for the variance in crop yields. The coefficient associated with the variance is positive and statistically significant, implying that pursuing mixed cropping might lead to an increase in crop yield variability. If the crops do not help each other for their growth, the variance in the overall revenue obtained by an agricultural household might increase. The increasing variance will increase the risks to agricultural households for achieving a stable income. However, variance does not distinguish between the upside and downside risks associated with crop yields. Therefore, we have extended our analysis to the skewness and kurtosis of the production function. The coefficient associated with the skewness (Column 4, Table 5) is negative but statistically insignificant, implying that adopting mixed cropping might not influence the downside or upside risks. However, going a step further, we found that mixed cropping increased the kurtosis of the crop yields (Column 5, Table 5). The increasing kurtosis implies that there exists large infrequent deviations in the crop yields or that there exist more observations at the either extreme than the thin tails of the normal distribution. A rational and well-informed farmer always prefers to be positively skewed, with a lower possibility for significant changes in yield distribution (Teklewold and Mekonnen, 2020). Di Falco and Chavas (2009), while exploring the impact of oncrop biodiversity on the risk exposure to households, found that oncrop biodiversity leads to an increase in the variance of crop yields while increasing the skewness. From these results, it can be observed that mixed cropping might lead to increased risk exposure in agricultural households.

It is well known that agricultural activities in India are carried over different seasons in a year. In the VDSA-ICRISAT database used in this study, households were found to carry out cultivation across five seasons, viz. kharif, rabi, summer, annual, and perennial. However, most households perform these activities during the kharif and rabi seasons only. Across India, kharif and

Table 5 Estimates from Equations (4) and (5) on four central moments of crop yield

Variables	(1) Mean	(2) Variance	(3) Skewness	(4) Kurtosis
Adoption of mixed crop (0/1)	-0.2861***	0.2088***	-0.1686	1.0974***
	(0.0228)	(0.0355)	(0.1094)	(0.3639)
Area under cultivation	-0.8931***	0.1703***	-0.3087**	0.7577**
	(0.0268)	(0.0413)	(0.121)	(0.363)
Area under irrigation	0.0617***	-0.0188**	0.0268	-0.1287**
	(0.0063)	(0.0079)	(0.0217)	(0.0589)
Gender (=1 if Male)	-0.0519*	-0.0890*	-0.014	-0.7199
	(0.028)	(0.0462)	(0.1417)	(0.4676)
Age of household-head	0.0205***	-0.004	0.0059	-0.0419
	(0.0026)	(0.0035)	(0.0102)	(0.0351)
Years of education	0.0299***	0.027	0.0061	0.2064
	(0.0112)	(0.0166)	(0.0459)	(0.1289)
Per capita non-farm income	0.0394***	-0.003	-0.0475	-0.0022
	(0.0098)	(0.015)	(0.0471)	(0.168)
Dependency ratio	0.0093	-0.0215	-0.0714	-0.3388
	(0.0176)	(0.0261)	(0.0847)	(0.3223)
Household size	0.0082	0.0235**	0.0093	0.2676**
	(0.0069)	(0.0105)	(0.0322)	(0.1178)
Part of any organisation (0/1)	0.0894***	-0.0237	-0.0988	-0.1272
	(0.014)	(0.0217)	(0.0703)	(0.2699)
Market distance	0.0025	-0.0019	0.0257***	0.0045
	(0.0017)	(0.0025)	(0.0088)	(0.0339)
Wage cost	0.2247***	-0.0805***	0.1820***	-0.3018
	(0.012)	(0.0204)	(0.064)	(0.2176)
Material cost	0.1636***	-0.025	-0.0189	0.0077
	(0.01)	(0.0168)	(0.0543)	(0.1995)
Constant	7.0371***	1.1213***	-0.9406	3.9723*
	(0.1081)	(0.1762)	(0.5838)	(2.3056)
Observations	17,926	17,926	17,926	17,926
R-squared	0.4758	0.0789	0.0125	0.0158
Crop fixed effects	Yes	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Note ***, **, and * represent the significance level at 1%, 5%, and 10% levels, respectively.

rabi are also prominent seasons during which cultivation is done. Therefore, to further extend our analysis, we have carried the analysis across the kharif and rabi seasons separately.

Table 6 shows the estimates of four central moments for the kharif season. Here also, we have not restricted our analysis to a particular combination of crops. It can be observed that the coefficients associated with the mean, variance, and kurtosis depict the same signs with the same statistical significance as observed in Table 5. Further, it is to be noted that the coefficient associated with the skewness is found to be negative and statistically significant, implying that adoption of mixed cropping might lead to an increase in downside

Table 6 Estimates from Equations (4) and (5) for kharif season on four central moments of crop yield

Variables	(1) Mean	(2) Variance	(3) Skewness	(4) Kurtosis
Adoption of mixed crop (0/1)	-0.1797***	0.2069***	-0.2730**	1.0971**
	(0.0281)	(0.0431)	(0.1364)	(0.4642)
Area under cultivation	-0.8068***	0.1866***	-0.5288***	0.8045
	(0.0338)	(0.0531)	(0.1609)	(0.5157)
Area under irrigation	0.0400***	0.0146	-0.0007	-0.0351
	(0.0110)	(0.0111)	(0.0288)	(0.0746)
Gender (=1 if Male)	-0.0107	-0.0781	0.2011	-0.4949
	(0.0330)	(0.0504)	(0.1454)	(0.4726)
Age of household-head	-0.0030	-0.0018	-0.0074	-0.0430
	(0.0032)	(0.0041)	(0.0115)	(0.0443)
Years of education	-0.0175	0.0136	-0.0288	0.0689
	(0.0132)	(0.0154)	(0.0390)	(0.1154)
Per capita non-farm income	-0.0288**	0.0379*	-0.0764	0.0828
	(0.0130)	(0.0202)	(0.0609)	(0.2046)
Dependency ratio	0.0073	-0.0432	-0.0415	-0.3373
	(0.0214)	(0.0329)	(0.1071)	(0.4175)
Household size	-0.0031	0.0318**	0.0209	0.3179*
	(0.0092)	(0.0134)	(0.0435)	(0.1731)
Part of any organisation (0/1)	0.0204	-0.0157	-0.0914	-0.4882
	(0.0183)	(0.0277)	(0.0869)	(0.3229)
Market distance	0.0051**	0.0015	0.0287**	0.0458
	(0.0023)	(0.0038)	(0.0130)	(0.0494)
Wage cost	0.2511***	-0.1397***	0.2583***	-0.5818*
	(0.0168)	(0.0292)	(0.0920)	(0.3106)
Material cost	0.0818***	-0.0030	0.0307	0.1415
	(0.0132)	(0.0236)	(0.0794)	(0.3000)
Constant	7.4178***	1.3661***	-1.6817**	4.8361
	(0.1469)	(0.2476)	(0.8207)	(3.2107)
Observations	11,499	11,499	11,499	11,499
R-squared	0.4719	0.0757	0.0151	0.0148
Crop fixed effects	Yes	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Note ***, **, and * represent the significance level at 1%, 5%, and 10%, respectively.

risks associated with crop yields. It is plausible if the combinations followed by an agricultural household compete with each other. In this case, the crops might utilize nutrients from each other, increasing the risk of crop failure for a household. Additionally, several studies have shown that the likelihood of crop failure might increase in this setup because of the prevalence of short-term pest infestation problems (ECAF, 2001). Lithourgidis et al. (2011) have stated that yields obtained from mixed cropping setup depend upon the chosen crop combination, management practices, and the prevailing environmental conditions. A competition for resources, including light, water, and nutrients among different mixed crops, might reduce crop yields and increase the risk of crop failure (Olowe and Adeyemo, 2009; Cenpukdee and Fukai, 1992).

A similar exercise was performed for the rabi season, the results of which are shown in Table 7. The results of the rabi season show that adopting mixed cropping might lead to a lower mean and higher variance for crop revenue per hectare. However, the coefficients corresponding to skewness and kurtosis are insignificant. It is interesting to note that the results are stronger for the kharif season than rabi season. This is plausible because most agricultural activities are performed during the kharif season due to the region's dependence on rainfall. It is well documented that most of the rainfall in India is received during the kharif season. In the dry or rabi season, households sometimes leave their land fallow because of water shortage.

The study has signified that adopting mixed cropping might increase risk exposure to agricultural households. However, we do not claim that promoting mixed

Table 7 Estimates from Equations (4) and (5) for rabi season on four central moments of crop yield

Variables	(1) Mean	(2) Variance	(3) Skewness	(4) Kurtosis
Adoption of mixed crop (0/1)	-0.2797***	0.2262***	0.2652	1.1363
	(0.0443)	(0.0679)	(0.2081)	(0.7032)
Area under cultivation	-0.9843***	0.2604***	-0.0651	0.5290
	(0.0501)	(0.0725)	(0.2133)	(0.6561)
Area under irrigation	0.0780***	-0.0465***	0.0456	-0.2463**
	(0.0097)	(0.0135)	(0.0397)	(0.1120)
Gender (=1 if Male)	-0.0625	-0.0905	-0.3227	-0.6753
	(0.0464)	(0.0776)	(0.2286)	(0.6940)
Age of household-head	0.0013	0.0044	0.0073	0.0156
	(0.0039)	(0.0054)	(0.0163)	(0.0533)
Years of education	0.0036	0.0342	0.1078	0.3120
	(0.0179)	(0.0322)	(0.1076)	(0.3540)
Per capita non-farm income	-0.0115	-0.0247	-0.0779	-0.1767
	(0.0150)	(0.0222)	(0.0728)	(0.2662)
Dependency ratio	-0.0374	-0.0153	-0.1242	-0.1955
	(0.0238)	(0.0363)	(0.1223)	(0.4585)
Household size	0.0121	0.0112	-0.0174	0.1097
	(0.0095)	(0.0145)	(0.0375)	(0.1012)
Part of any organisation (0/1)	0.0876***	-0.0042	-0.0727	0.4405
	(0.0209)	(0.0345)	(0.1167)	(0.4407)
Market distance	-0.0112***	-0.0035	0.0160	-0.0674
	(0.0026)	(0.0037)	(0.0136)	(0.0559)
Wage cost	0.1658***	-0.0302	0.1290	0.0943
	(0.0195)	(0.0312)	(0.0965)	(0.2972)
Material cost	0.1973***	-0.0710**	-0.0653	-0.2582
	(0.0194)	(0.0276)	(0.0729)	(0.1974)
Constant	7.2927***	1.0121***	-0.4685	2.7036
	(0.1713)	(0.2429)	(0.6866)	(1.9733)
Observations	6,417	6,417	6,417	6,417
R-squared	0.5847	0.1186	0.0268	0.0456
Crop Fixed Effects	Yes	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes

Note ***, **, and * represent the significance level at 1%, 5%, and 10% levels respectively.

cropping will increase the vulnerability of agricultural households. Since mixed cropping involves growing two or more crops simultaneously on the same land, therefore, choosing the appropriate combination of crops becomes necessary. Sometimes, pursuing such a cropping system might not benefit the farmers in terms of higher yields (Cenpukdee and Fukai, 1992), but it helps them protect the fertility of the natural resources. There is no consensus among the researchers on this debate. Keeping this argument in mind, we have extended our analysis by choosing the appropriate combination of crops across both seasons. We have selected 'pigeon peas and soybeans' for the kharif season, and 'lentils and mustard' for the rabi season. These two crop combinations were widely followed across different villages in the mixed crop set-up. The results of this exercise are shown in Tables 8 and 9.

Table 8 Estimates on four central moments from Equations (4) and (5) for kharif season for 'pigeon peas and soybeans'

Variables	(1) Mean	(2) Variance	(3) Skewness	(4) Kurtosis
Adoption of mixed crop (0/1)	0.1881***	-0.1231**	0.1301	-0.5433*
	(0.0438)	(0.0534)	(0.1285)	(0.3164)
Area under cultivation	-0.7455***	0.1004	-0.2291	0.8651
	(0.0591)	(0.0849)	(0.2304)	(0.6183)
Area under irrigation	0.0418**	0.0186	0.0025	-0.0029
	(0.0198)	(0.0170)	(0.0348)	(0.0687)
Gender (=1 if Male)	0.1901	-0.1995	-0.0868	-0.1125
	(0.1259)	(0.1493)	(0.3429)	(0.6796)
Age of household-head	-0.0037	-0.0104	0.0286	-0.1164*
	(0.0083)	(0.0111)	(0.0263)	(0.0657)
Years of education	-0.0725	-0.0364	0.0443	-0.2719
	(0.0454)	(0.0559)	(0.1191)	(0.2428)
Per capita non-farm income	0.0043	0.1208**	-0.1831	0.4050
	(0.0357)	(0.0491)	(0.1240)	(0.3167)
Dependency ratio	0.0661	0.0109	0.2198	-0.5145
	(0.0812)	(0.0856)	(0.2246)	(0.5307)
Household size	-0.0335	0.0244	-0.0509	0.0689
	(0.0286)	(0.0285)	(0.0764)	(0.1428)
Part of any organisation (0/1)	0.0791*	0.0241	0.0760	0.2028
	(0.0425)	(0.0511)	(0.1258)	(0.2799)
Market distance	-0.0050	0.0127	-0.0266	0.1259
	(0.0048)	(0.0086)	(0.0321)	(0.1165)
Wage cost	0.3076***	-0.1519**	0.3528**	-0.9252*
	(0.0440)	(0.0651)	(0.1781)	(0.4746)
Material cost	0.0432	0.0536	-0.2348	0.4046
	(0.0391)	(0.0561)	(0.1608)	(0.4253)
Constant	6.2937***	1.8667***	-2.8890	7.0254
	(0.4372)	(0.6795)	(1.8811)	(5.0222)
Observations	1,804	1,804	1,804	1,804
R-squared	0.4702	0.1404	0.0243	0.0545
Year Fixed Effects	Yes	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes	Yes

Note ***, **, and * represent the significance level at 1%, 5%, and 10% levels respectively.

Table 9 Estimates on four central moments from Equations (4) and (5) for rabi season for 'lentils and mustard'

Variables	(1) Mean	(2) Variance	(3) Skewness	(4) Kurtosis
Adoption of mixed crop (0/1)	0.2399***	-0.1621	0.2701	0.0137
	(0.0856)	(0.1013)	(0.2479)	(0.5674)
Area under cultivation	-0.8910**	-0.2254	-1.5189	-1.1522
	(0.4352)	(0.6433)	(1.4928)	(3.2844)
Area under irrigation	0.0482*	-0.0239	-0.0059	-0.1511
	(0.0261)	(0.0318)	(0.0691)	(0.1502)
Gender (=1 if Male)	-0.1818	-0.4483	-0.9656	-1.6131
	(0.2237)	(0.2981)	(0.7492)	(1.5257)
Age of household-head	-0.0026	0.0027	-0.0205	-0.0132
	(0.0169)	(0.0140)	(0.0311)	(0.0469)
Years of education	-0.0047	0.0326	0.0997	-0.1220
	(0.1009)	(0.0570)	(0.1138)	(0.2485)
Per capita non-farm income	-0.0321	0.0169	0.1042	-0.1167
	(0.0694)	(0.0985)	(0.2114)	(0.5343)
Dependency ratio	-0.1504	-0.0000	-0.3916*	-0.1631
	(0.0921)	(0.0998)	(0.2355)	(0.4413)
Household size	-0.0317	0.0334	-0.0662	0.1442
	(0.0490)	(0.0503)	(0.1303)	(0.2812)
Part of any organisation (0/1)	0.1302	-0.0105	0.0702	0.1194
	(0.0819)	(0.1031)	(0.2330)	(0.4996)
Market distance	-0.0613***	0.0244	0.0199	0.0399
	(0.0171)	(0.0222)	(0.0534)	(0.1241)
Wage cost	0.0899	-0.0663	-0.0005	-0.0939
	(0.0848)	(0.0915)	(0.2078)	(0.4213)
Material cost	-0.0208	0.0913	0.0205	0.4162
	(0.0739)	(0.0900)	(0.2087)	(0.4353)
Constant	8.1387***	-0.1556	0.7862	-3.4991
	(0.6671)	(0.8396)	(1.9753)	(4.4699)
Observations	492	492	492	492
R-squared	0.3531	0.1368	0.0768	0.1096
Year Fixed Effects	Yes	Yes	Yes	Yes
Village Fixed Effects	Yes	Yes	Yes	Yes

Note ***, **, and * represent the significance level at 1%, 5%, and 10% levels respectively.

Table 8 shows the results for the kharif season. It can be observed that for the selected crop combination, mixed cropping might increase mean crop yield and help reduce the variance. These results closely corroborate the previous studies, in which it was found that conservation agricultural practices help increase crop productivity and stabilize crop yields (Di Falco and Chavas, 2009; Agegnehu et al., 2008). Moving on to the higher-order moments of the crop yields, we find that the coefficient associated with the skewness is positive but insignificant. However, the impacts of mixed cropping on kurtosis are negative and weakly significant, implying that mixed cropping helps reduce the infrequent deviations in crop yields. These results comply with the previous studies where it has been found that farmers adopt those practices that help reduce the risk of losses (Kumar et al., 2020; Teklewold and Mekonnen, 2020).

A similar exercise was carried out for the rabi season of lentil and mustard crop combination, the results of which have been shown in Table 9. However, we find the results significant for the rabi season for only the coefficient associated with the mean crop yield. The coefficient is positive and statistically significant, implying that mixed cropping might increase the crop yield.

Conclusions and policy implications

The study is focused on intercropping/mixed cropping which is one of the conservation strategies widely used to increase and stabilize crop yields. In this study, the impacts of mixed cropping have been examined on the risk exposure to agricultural households. The study initially did not focus on any particular combination of crops, but later, to corroborate with the previous literature, an appropriate combination of crops was selected from different seasons. For this analysis, a plot-level panel database collected by the International Crops Research Institute of Semi-arid Crops from some semi-arid villages of India has been utilized. In the study, Antle's (1983) and Correlated Random Effects models have been used as these help in controlling for biases that might influence the results.

Utilizing an unbalanced panel database from Semi-arid regions of India, the study has found that pursuing mixed cropping might increase the risk exposure to the agricultural households when it was not conditioned on any particular combination of crops. On selecting an appropriate combination of crops across both rabi and kharif seasons, the study has revealed that it might help reduce the risk exposure to agricultural households. It may be concluded from the study that it is not always the case that pursuing mixed cropping would increase and stabilize crop yields. It might help natural resources in retaining their productivity. To increase and stabilize crop yields, the farmers need to select an appropriate combination of crops.

The study holds some practical policy implications. This study can enlighten the policymakers in promoting cropping systems that help the farmers achieve higher yields while reducing crop-yield risk exposure. The study has also suggested that careful selection of crop combinations is essential, as not all combination yield the same results. Developing seeds for intercropping systems that complement each other to enhance revenue and improve soil nutrients would support the goals of food security and natural resource conservation. To achieve the desired results, the policymakers should provide information about suitable crop combinations, nutrient requirements, and sowing and harvesting periods.

Limitations

This study had a few limitations also. It focused only on the Semi-arid regions of India and therefore the results might not have an external validity. Secondly, crop combinations were selected across the rabi and kharif seasons only. Changing the cropping combination might lead to different results. Lastly, it was focused only on mixed cropping to examine its impact on agricultural households' risk exposure. Future studies can extend this analysis by incorporating conservation technologies such as minimum soil disturbance, permanent soil, and species diversification.

References

Abalu, G. O. 1976. A note on crop mixtures under indigenous conditions in northern Nigeria. *The Journal of Development Studies*, *12*(3), 212-220. *https://doi.org/10.1080/00220387608421577*

Acevedo, S., Mrkaic, M., Novta, N., Pugacheva, E., and Topalova, P. 2020. The effects of weather shocks on economic activity: What are the channels of impact? *Journal of Macroeconomics*, *65*, 103207. *https://doi.org/10.1016/j.jmacro.2020.103207*

Agegnehu, G., Ghizaw, A., and Sinebo, W. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *European Journal of agronomy*, *25*(3), 202-207. *https://doi.org/10.1016/j.eja.2006.05.002*

Agegnehu, G., Ghizaw, A., and Sinebo, W. (2008). Yield potential and land-use efficiency of wheat and faba bean mixed intercropping. *Agronomy for sustainable development*, *28*, 257-263. *https://doi.org/10.1051/agro:2008012*

Antle, J. M. (1983). Testing the stochastic structure of production: A flexible moment-based approach. *Journal of Business & Economic Statistics*, *1*(3), 192-201. *https://doi.org/10.2307/1391337*

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., and Kokwe, M. 2015. Climate smart agriculture? Assessing the adaptation implications in Zambia. *Journal of Agricultural Economics*, *66*(3), 753-780. *https://doi.org/10.1111/1477-9552.12107*

Betencourt, E., Duputel, M., Colomb, B., Desclaux, D., and Hinsinger, P. 2012. Intercropping promotes the ability of durum wheat and chickpea to increase rhizosphere phosphorus availability in a low P soil. *Soil biology and Biochemistry*, *46*, 181-190. *https://doi.org/10.1016/j.soilbio.2011.11.015*

Chavas, J. P., and Di Falco, S. (2012). On the role of risk versus economies of scope in farm diversification with an application to Ethiopian farms. *Journal of agricultural economics*, *63*(1), 25-55. *https://doi.org/10.1111/j.1477-9552.2011.00319.x*

Cenpukdee, U., and Fukai, S. (1992). Cassava/legume intercropping with contrasting cassava cultivars. 2. Selection criteria for cassava genotypes in intercropping with two contrasting legume crops. *Field Crops Research*, *29*(2), 135-149. *https://doi.org/10.1016/0378-4290(92)90083-L*

Corbeels, M., De Graaff, J., Ndah, T. H., Penot, E., Baudron, F., Naudin, K., and Adolwa, I. S. (2014). Understanding the impact and adoption of conservation agriculture in Africa: A multi-scale analysis. *Agriculture, Ecosystems & Environment*, *187*, 155-170. *https://doi.org/10.1016/j.agee.2013.10.011*

Di Falco, S., and Chavas, J. P. (2006). Crop genetic diversity, farm productivity and the management of environmental risk in rainfed agriculture. *European review of agricultural economics*, *33*(3), 289-314. *https://doi.org/10.1093/eurrag/jbl016*

Di Falco, S., and Chavas, J. P. 2009. On crop biodiversity, risk exposure, and food security in the highlands of Ethiopia. *American Journal of Agricultural Economics*, *91*(3), 599-611. *https://doi.org/10.1111/j.1467-8276.2009.01265.x*

Di Falco, S., Veronesi, M., and Yesuf, M. 2011. Does adaptation to climate change provide food security? A micro perspective from Ethiopia. *American journal of agricultural economics*, *93*(3), 829-846. *https://doi.org/10.1093/ajae/aar006*

ECAF. (2001). Conservation agriculture in Europe. *http://www.ecaf.org/English/First.htm*

Fahad, S., and Wang, J. 2018. Farmers' risk perception, vulnerability, and adaptation to climate change in rural Pakistan. *Land use policy*, *79*, 301-309. *https://doi.org/10.1016/j.landusepol.2018.08.018*

Fustec, J., Lesuffleur, F., Mahieu, S., and Cliquet, J. B. (2010). Nitrogen rhizodeposition of legumes. A review. *Agronomy for sustainable development*, *30*, 57-66. *https://doi.org/10.1051/agro/2009003*

Giuseppe, F. 2015. Global strategic framework for food security & Nutrition-CFS 2014 report. *https://www.fao.org/cfs/policy-products/gsf/en/*

Gonzalez-Sanchez, E.J., and G. Basch. 2017. Conservation agriculture: Making climate change mitigation and adaptation real in Europe. European Conservation Agriculture Federation (ECAF). *https://climate-adapt.eea.europa.eu/en/metadata/publications/conservation-agriculture-making-climate-change-mitigation-and-adaptation-real-in-europe*

Government of India. 2013. Some aspects of farming in India. Ministry of Statistics and Programme Implementation. National Sample Survey Office. Report No. 573(70/33/2). *https://www.mospi.gov.in/sites/default/files/publication_reports/NSS_Report_573_16feb16.pdf*

Hauggaard-Nielsen, H., Gooding, M., Ambus, P., Corre-Hellou, G., Crozat, Y., Dahlmann, C., Dibet, A., von Fragstein, P., Pristeri, A., Monti, M., and Jensen, E. S. 2009. Pea–barley intercropping for efficient symbiotic N2-fixation, soil N acquisition and use of other nutrients in European organic cropping systems. *Field Crops Research*, *113*(1), 64-71. *https://doi.org/10.1016/j.fcr.2009.04.009*

Hong, Y., Heerink, N., and van der Werf, W. 2020. Farm size and smallholders' use of intercropping in Northwest China. *Land Use Policy*, *99*, 105004. *https://doi.org/10.1016/j.landusepol.2020.105004*

Hong, Y., Heerink, N., Zhao, M., and van der Werf, W. 2019. Intercropping contributes to a higher technical efficiency in smallholder farming: Evidence from a case study in Gaotai County, China. *Agricultural Systems*, *173*, 317-324. *https://doi.org/10.1016/j.agsy.2019.03.007*

Issahaku, G., and Abdulai, A. (2020). Adoption of climate smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana. *Australian Journal of Agricultural and Resource Economics*, *64*(2), 396-420. *https://doi.org/10.1111/1467-8489.12357*

Jalilian, J., Najafabadi, A., and Zardashti, M. R. 2017. Intercropping patterns and different farming systems affect the yield and yield components of safflower and bitter vetch. *Journal of Plant Interactions*, *12*(1), 92-99. *https://doi.org/10.1080/17429145.2017.1294712*

Junior, G. D. N. A., de Morais, J. E. F., Neto, A. J. S., de Souza, L. S. B., Alves, C. P., da Silva, G. Í. N., Leite, R. M. C., da Silva, M. J., Jardim, A. M. R. F., Montenegro, A. A. A., and da Silva, T. G. F. 2023. Use of intercropping and mulch to improve the water and natural resources use efficiencies of forage cactus and millet production in a semiarid region. *Field Crops Research*, *304*, 109171. *https://doi.org/10.1016/j.fcr.2023.109171*

Kirwan, B. E., and Roberts, M. J. 2016. Who really benefits from agricultural subsidies? Evidence from field level data. *American journal of agricultural economics*, *98*(4), 1095-1113. *https://doi.org/10.1093/ajae/aaw022*

Kim, K., and Chavas, J. P. (2003). Technological change and risk management: An application to the economics of corn production. *Agricultural economics*, *29*(2), 125-142. *https://doi.org/10.1111/j.1574-0862.2003.tb00152.x*

Kitonyo, O. M., Sadras, V. O., Zhou, Y., and Denton, M. D. (2018). Nitrogen fertilization modifies maize yield response to tillage and stubble in a sub-humid tropical environment. *Field Crops Research*, *223*, 113-124. *https://doi.org/10.1016/j.fcr.2018.03.024*

Kumar, K. K., and Parikh, J. 2001. Indian agriculture and climate sensitivity. *Global environmental change*, *11*(2), 147-154. *https://doi.org/10.1016/S0959-3780(01)00004-8*

Kumar, S., Singh, D. R., Singh, A., Singh, N. P., and Jha, G. K. (2020). Does adoption of soil and water conservation practice enhance productivity and reduce risk exposure? Empirical evidence from semi-arid tropics (SAT), India. *Sustainability*, *12*(17), 6965. *https://doi.org/10.3390/su12176965*

Lemken, D., Spiller, A., and von Meyer-Höfer, M. 2017. The case of legume-cereal crop mixtures in modern agriculture and the transtheoretical model of gradual adoption. *Ecological Economics*, *137*, 20-28. *https://doi.org/10.1016/j.ecolecon.2017.02.021*

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., and Vlachostergios, D. 0. (2011). Annual intercrops: An alternative pathway for sustainable agriculture. *Australian journal of crop science*, *5*(4), 396-410.

McLaughlin, D., and Kinzelbach, W. 2015. Food security and sustainable resource management. *Water Resources Research*, *51*(7), 4966-4985. *https://doi.org/10.1002/2015WR017053*

Morton, J. F. 2007. The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the national academy of sciences*, *104*(50), 19680-19685. *https://doi.org/10.1073/pnas.0701855104*

Mundlak, Y. (2001). Production and supply. *Handbook of agricultural economics*, *1*, 3-85. *https://doi.org/10.1016/S1574-0072(01)10004-6*

Neill, S. P., and Lee, D. R. 2001. Explaining the adoption and disadoption of sustainable agriculture: The case of cover crops in northern Honduras. *Economic development and cultural change*, *49*(4), 793-820. *https://doi.org/10.1086/452525*

Nelson, G. C., Rosegrant, M. W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T. B., Ringler, C., and You, L. 2010. *Food security, farming, and climate change to 2050: Scenarios, results, policy options* (Vol. 172). International Food Policy Research Institute *http://dx.doi.org/10.2499/9780896291867*

Olowe, V. I. O., and Adeyemo, A. Y. (2009). Enhanced crop productivity and compatibility through intercropping of sesame and sunflower varieties. *Annals of Applied Biology*, *155*(2), 285-291. *https://doi.org/10.1111/j.1744-7348.2009.00340.x*

Pan, P., and Qin, Y. 2014. Genotypic diversity of soybean in mixed cropping can affect the populations of insect pests and their natural enemies. *International Journal of Pest Management*, *60*(4), 287-292. *https://doi.org/10.1080/09670874.2014.974725*

Porter, J. J., Demeritt, D., and Dessai, S. 2015. The right stuff? Informing adaptation to climate change in British local government. *Global Environmental Change*, *35*, 411-422. *https://doi.org/10.1016/j.gloenvcha.2015.10.004*

Rahman, M. R., Shi, Z. H., and Chongfa, C. (2009). Soil erosion hazard evaluation—an integrated use of remote sensing, GIS and statistical approaches with biophysical parameters towards management strategies. *Ecological Modelling*, *220*(13-14), 1724-1734. *https://doi.org/10.1016/j.ecolmodel.2009.04.004*

Raseduzzaman, M. D., and Jensen, E. S. 2017. Does intercropping enhance yield stability in arable crop production? A meta-analysis. *European Journal of Agronomy*, *91*, 25-33. *https://doi.org/10.1016/j.eja.2017.09.009*

Rosenzweig, M. R., and Binswanger, H. P. (1993). Wealth, weather risk and the composition and profitability of agricultural investments. *The economic journal*, *103*(416), 56-78. *https://doi.org/10.2307/2234337*

Rosenstock, T. S., Mpanda, M., Rioux, J., Aynekulu, E., Kimaro, A. A., Neufeldt, H., Shepherd, K.D., and Luedeling, E. (2014). Targeting conservation agriculture in the context of livelihoods and landscapes. *Agriculture, Ecosystems & Environment*, *187*, 47-51. *https://doi.org/10.1016/j.agee.2013.11.011*

Shiferaw, B., and Bantilan, M. C. S. 2004. Agriculture, rural poverty and natural resource management in less favored environments: Revisiting challenges and conceptual issues. *Food, Agriculture and Environment*, *2*(1), 328-339. *https://oar.icrisat.org/1278/*

Solanki, N. S., Singh, D., and Sumeria, H. K. 2011. Resources utilization in maize (Zea mays)-based intercropping system under rainfed condition. *The Indian Journal of Agricultural Sciences*, *81*(6). *https://epubs.icar.org.in/index.php/IJAgS/article/view/6572*

Teklewold, H., and Mekonnen, A. 2020. Weather at different growth stages, multiple practices and risk exposures: Panel data evidence from Ethiopia. *Climate Change Economics*, *11*(02), 2050009.*https://doi.org/10.1142/S2010007820500098*

Vrignon-Brenas, S., Celette, F., Piquet-Pissaloux, A., Jeuffroy, M. H., and David, C. 2016. Early assessment of ecological services provided by forage legumes in relay intercropping. *European Journal of Agronomy*, *75*, 89-98. *https://doi.org/10.1016/j.gfs.2014.02.002*

Wang, Z., Zhao, X., Wu, P., and Chen, X. 2015. Effects of water limitation on yield advantage and water use in wheat (Triticum aestivum L.)/maize (Zea mays L.) strip intercropping. *European Journal of Agronomy*, *71*, 149-159.*https://doi.org/10.1016/j.eja.2015.09.007*

Wezel, A., Casagrande, M., Celette, F., Vian, J. F., Ferrer, A., and Peigné, J. 2014. Agroecological practices for sustainable agriculture. A review. *Agronomy for sustainable development*, *34*(1), 1-20. *https://doi.org/10.1142/q0088*

Zougmoré, R., Guillobez, S., Kambou, N. F., and Son, G. (2000). Runoff and sorghum performance as affected by the spacing of stone lines in the semiarid Sahelian zone. *Soil and Tillage Research*, *56*(3-4), 175-183. *https://doi.org/10.1016/S0167-1987(00)00137-9*

Received 6 June 2024 Accepted 30 December 2024

Agricultural Economics Research Review 2024, 37 (2), 213-226
DOI: 10.5958/0974-0279.2024.00015.9

Consumption of functional dairy foods in Northern Tamil Nadu: Pattern and key drivers

Dhasarathan M, Subhasis Mandal, Biswajit Sen, and Ajmer Singh*

Division of Dairy Economics, Statistics and Management,
ICAR-National Dairy Research Institute, Karnal, Haryana–132001, India

*Corresponding author: ajmerskundu@gmail.com

Abstract The study conducted in the northern parts of Tamil Nadu has analysed the consumers' consumption pattern and the factors moderating consumption of functional dairy foods (FDFs) based on the data collected from 220 respondents (160 consumers and 60 sale points). The study has used tabular and frequency analyses for consumption pattern and double-hurdle model along with tobit model (for comparison) for factors moderating consumption analysis. It has found that 84 per cent of respondents were aware of FDF foods, with television advertisements being their primary source of information. The average monthly per capita consumption was 3.6 litres in terms of milk equivalent quantity which was 33.43 per cent of the total per capita milk availability in Tamil Nadu. The FDFs are still in the early stages of adoption, with fortified milk showing the highest potential. It has also found that factors like income, price, occupation, dietary habits, family size and location significantly influence the consumption expenditure on FDFs. Addressing these factors could facilitate broader adoption and integration of FDFs into consumers' diets.

Keywords Functional dairy foods, double-hurdle model, tobit model, probiotic foods, fortified foods, Tamil Nadu, consumption pattern

JEL codes D10, J10, M30, Q18

Introduction

Now-a-days, the food serves purposes beyond hunger satisfaction and provision of essential nutrients; it is also designed to prevent nutrition-related diseases and enhance physical and mental well-being of consumers. The evolving dietary patterns, rise in the per capita availability of milk, expansion in the demography of individuals with elevated income levels and the increasing awareness among Indian consumers have led to the diversification of the dairy sector. The consumers now look beyond basic products such as pouched milk and occasional butter or cheese spreads, prompting a growing emphasis on value addition in dairy products. This shift has fostered the development of a functional dairy food industry in the country.

The functional foods (sometimes referred to as physiologically functional foods, nutraceuticals, designer foods or pharmafoods) are those food items or food components that enhance healthcare by regulating or influencing certain physiological processes, besides ensuring the essential nutrition to human beings (Grujiæ and Grujèiæ, 2023). The term 'functional food' was introduced in Japan in the mid-1980s for food products fortified with special constituents that produce advantageous physiological effects (Robu *et al*., 2022). In 1994 the Institute of Medicine's Food and Nutrition Board defined functional food as: "Any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains".

The dairy industry plays a significant role in the development of functional foods. The functional dairy products primarily originate from milk that has been adequately shown to positively impact one or more specific functions in the body. This goes beyond basic nutritional effects, significantly improving health and well-being, and/or lowering the risk of diseases (Rani *et al*., 2022). Now a days, consumers focus on nutritional content and health benefits of functional dairy foods, including vitamin/mineral enriched milk, milk containing omega-3 fatty acids, probiotic cheese or yogurt, and low-fat milk products (Peng *et al*., 2006). Several studies have demonstrated various health benefits of these products, including a reduced risk of hypertension (Alonso *et al*., 2005; Toledo *et al*., 2009), *Diabetes mellitus* (Liu *et al*., 2006), and coronary heart diseases (Hu *et al*., 1999). Globally, the functional dairy food market, valued at USD 44 billion, is projected to experience a Compound Annual Growth Rate (CAGR) of 4.5 per cent from 2023 to 2033, potentially reaching USD 67.1 billion by 2033 (Choudhury, 2023). In India, the functional dairy food market is anticipated to grow at a rate of 5.7 per cent from 2022 to 2032 (Shireen and Aneesh, 2021). However, studies on the consumer awareness and consumption habits towards functional dairy foods are extremely uncommon in India and virtually absent in Tamil Nadu. Therefore, the present study was undertaken to explore the level of awareness, current consumption patterns and key factors moderating the consumption of functional dairy foods in the northern part of Tamil Nadu state.

Data and Methodology

The study was conducted in the northern part of Tamil Nadu due to the region's concentration of dairy industries and its well-developed dairy supply chain infrastructure. For this study, both Chennai and Salem districts were purposively selected. As a metropolitan city, Chennai has a well-established awareness of health considerations among consumers, along with a strong supply network for functional dairy foods. The Salem district, leads in average daily milk sales (1.86 LLPD (lakh litres per day)) among district unions and ranked first in daily milk procurement (5.13 LLPD) by the district cooperative milk producers' union for the year 2021-2022 (Animal Husbandry, Dairying, Fisheries and Fishermen Welfare Department, 2022). The study is based on both primary and secondary data. The primary data were collected by direct personnel interview method using a well-developed and pre-tested structured interview schedule. A total of 160 respondents were selected randomly from different purchase locations equally in both the districts' urban/semi-urban and rural areas. The supply chain intermediaries (60 sale points equally in both districts' urban/semi-urban and rural areas) were also selected using random sampling method. The sale of functional dairy foods (agencies, quantities, prices) from sellers were also collected using semi-structured interview schedule. The secondary data on information about functional dairy foods, market players and different products details, etc., were collected from various published articles and websites.

The analytical tools used in the study were tabular and frequency analyses for consumption pattern as well as awareness and double-hurdle model for factors influencing consumption expenditure on various functional dairy foods. The entire sample of households was stratified into three distinct income groups using a cumulative square root frequency approach (Dalenius and Hodges, 1957).

Double-Hurdle Model

For this study, the double-hurdle model was preferred over the tobit model due to the latter's inherent assumptions about the nature of zero expenditures. The tobit model assumes that zero consumption arises solely from corner solutions — economic decisions in which certain exogenous factors lead to non-consumption. However, this framework does not account for situations where zero expenditures result from factors unrelated to economic constraints, such as infrequency of purchase, social or psychological preferences, or ethical considerations (Deaton and Irish, 1984; Jones, 1989). For instance, vegetarians abstain from meat for reasons other than price, and many non-smokers would refrain from smoking even if tobacco were free (Atkinson, Gomulka, and Stern, 1990; Garcia and Labeaga, 1996). Given this limitation, the double-hurdle model offers a more flexible approach by allowing for two distinct processes that can result in zero expenditures. First, it models the consumer's discrete decision to participate in the market, and second, it analyzes the continuous decision regarding the quantity to purchase.

The Hurdle models (Cragg,1971) are characterized by the relationship as per Equation (1)

$$y_i = s_i h_i^* \quad \ldots(1)$$

where, y_i is the observed value of the dependent variable which is per capita consumption expenditure on functional dairy foods (₹/day).

The selection variable, s_i, is 1 if the dependent variable is not bounded and 0, otherwise. In the Cragg model, the lower limit that binds the dependent variable is 0 and the selection model is shown in Equation (2)

$$s_i = \begin{cases} 1 & if z_i\gamma + D_i\delta + \varepsilon_i > 0 \\ 0 & otherwise \end{cases} \quad \ldots(2)$$

where z_i and D_i are vectors of explanatory variables and dummy explanatory variables, respectively as follows: z_1 = Family size (No.), z_2 = log of monthly family income (₹), D_1 = Occupation of household head (0= Business, 1= Salaried employment, 2= Self-employment), D_2 = Area of household location (0= Rural, 1= Urban/Semi-urban), D_3 = District of household location (0= Chennai, 1= Salem), D_4 = Food habit (0= non-vegetarian, 1= vegetarian), γ and δ are vectors of coefficients of z_i and D_i, respectively and ε_i is the standard normal error-term.

The continuous latent variable h_i^* is observed only if s_i = 1. The outcome model can be either the linear model or the exponential model, as proposed in Cragg model (1971) and is shown in Equation (3)

$$h_i^* = x_i\beta + \vartheta_i \quad \text{(linear)}$$

$$h_i^* = \exp\ (x_i\beta + \vartheta_i) \quad \text{(exponential)} \quad \ldots(3)$$

where x_i is the vector of explanatory variables as follows: x_1 = log of monthly family income (₹), x_2 = log of monthly food expenditure (₹), x_3 = log of monthly non-food expenditure (₹), x_4 = Price of functional dairy foods (₹), β is a vector of coefficients of x_i and ϑ_i is the error-term and $\vartheta_i \sim N(0, \sigma^2)$. For the linear model, ϑ_i has the truncated normal distribution with lower truncation point $x_i\beta$. For the exponential model, ϑ_i has the normal distribution.

Results and Discussions

A. Distribution of consumers by income groups

The family income typically plays a crucial role in shaping the consumers' expenditure on functional dairy foods. The average monthly household income was ₹ 90,775. The classification of households into various income groups is presented in Table 1. These income groups are significantly different from one another at $p < 0.05$.

B. Awareness status and sources of information for functional dairy foods

The Evaluation of consumers' awareness on functional dairy foods was crucial, as it plays a key role in positioning these products successfully in the Indian functional food market. The awareness status of consumers for functional dairy foods across income groups has been shown in Figure 1. It was found that 84 per cent respondents were aware about the functional dairy foods, and only 16 per cent were unaware. In that 84 per cent aware respondents, only 8 per cent respondents were aware about the functional dairy food (FDF) before explaining the term and 76 per cent became aware after explaining the term.

Table 1 Distribution of sample households by income class

Income Groups	Income (₹ /month)	Average family income (₹ /month)	No. of households
Group 1	Up to 74,000	49,846 [a]	78 (48.75)
Group 2	74,000 to 1,54,000	98,333 [b]	60 (37.50)
Group 3	1,54,000 to 4,00,000	2,15,273 [c]	22 (13.75)
Total			160 (100)

Figures within the parentheses indicate percentages of total respondents in the respective columns
(The values with different superscripts indicate the significant difference at P<0.05)
Source: Authors' calculations

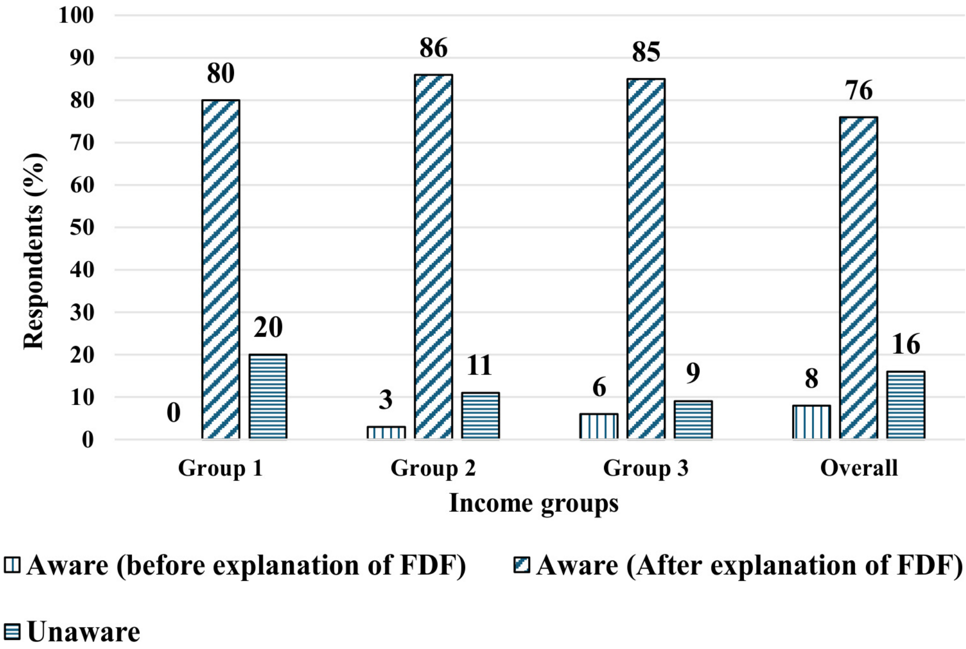

Figure 1 Awareness status of consumers for functional dairy foods
Source Authors' calculations

The various sources of information about functional dairy foods have been shown in Figure 2. The analysis of the results indicates that the primary source of information for consumers about functional dairy foods was electronic television advertisements, accounting for nearly 38.75 per cent. After electronic television advertisement, social media was secondary source of information which made up to 21.88 per cent. Newspapers contributed the least, with just 10 per cent of consumers citing them as their source of information.

C. Sources of purchase and usage frequency of functional dairy foods

The analysis of purchase sources for functional dairy foods was essential for identifying the locations where consumers showed a greater preference for buying

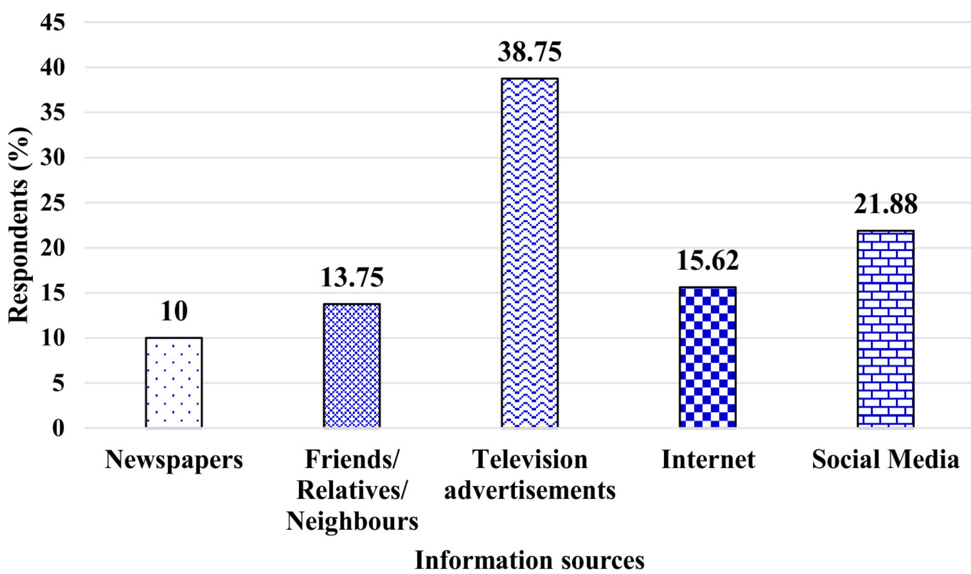

Figure 2 Sources of information about functional dairy foods
Source Authors' calculations

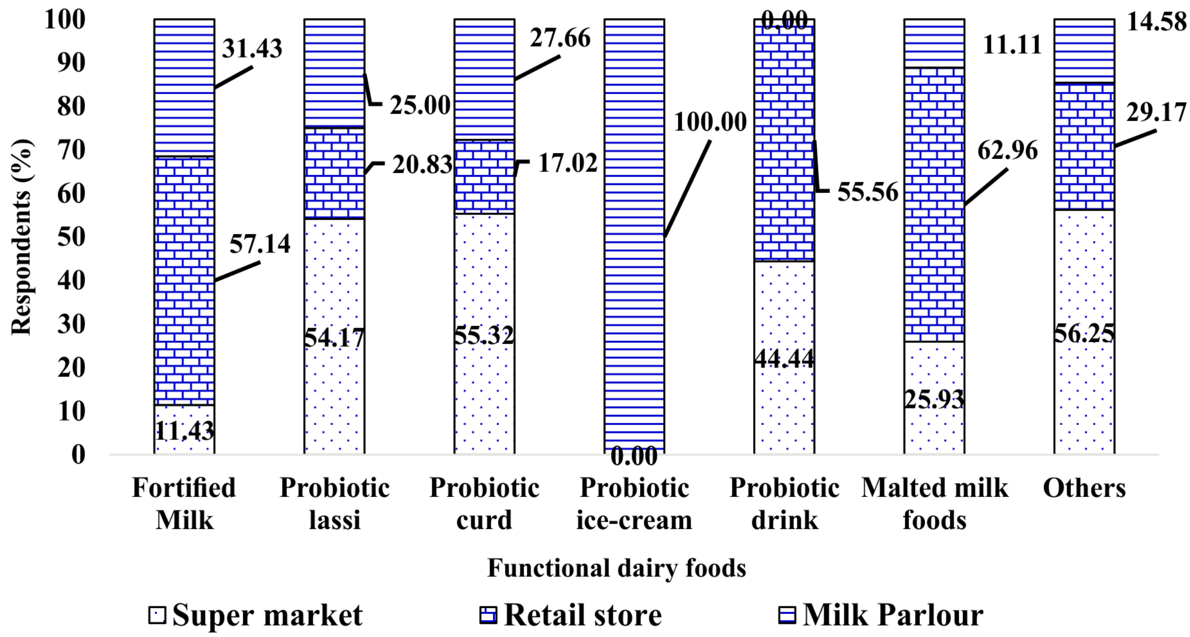

Figure 3 Sources for purchase of functional dairy foods
Source Authors' calculations

these products. The various sources for purchase of different functional dairy foods have been shown in Figure 3.

Fortified milk: It was found that the majority of consumers purchased fortified milk from the retail shops (57.14%), followed by milk parlours (31.43%) and supermarkets (11.43%). Thus, consumers gave maximum importance to retail shops which were usually in close vicinity of households which made it convenient for consumers to purchase the product.

Probiotic food items: For the purchase of probiotic lassi of various brands, majority of consumers opted for supermarkets (54.17%), followed by milk parlours (25%) and retail stores (20.83%). The reason for purchase from supermarkets was better availability of probiotics there as compared to other locations. A similar pattern was observed for the purchase of probiotic curd of various brands. The milk parlours were exclusively chosen for purchasing probiotic ice-cream (100%) because local retail stores and supermarkets offer a wide variety of regular ice creams. The probiotic ice cream was available only in certain areas of Chennai and Salem, specifically at Mercelys ice cream parlour and in ice cream parlours having Mercelys probiotic ice-cream within large malls.

For probiotic drinks, such as Yakult, the retail stores had a slightly higher share (55.56%) compared to supermarkets (44.44%). This was because Yakult, a popular probiotic drink brand, was commonly found in medium-sized retail shops as well as supermarkets. For malted milk foods, retail stores had a higher share (62.96%) compared to supermarkets (25.93%). This was because malted milk foods were commonly found in retail shops as well as supermarkets in sachets, bottles and tetra packs. Other functional dairy foods such as fruit yoghurt, sugar-free desserts, low-calorie products, etc., were predominantly bought from the supermarkets (56.25%) because these products are not commonly purchased by most people, leading local retail shops to not stock them.

The frequency for consumption of various functional dairy foods has been presented in Figure 4. The study has revealed that 22.86 per cent consumers rarely consumed the fortified milk, while 65.71 per cent consumers used fortified milk on daily basis. Most of the respondents reported that the additional vitamins indicated on the milk packet provide them confidence that it will help-improve their health. However, the probiotic lassi was rarely consumed by 100 per cent consumers, because most people do not drink lassi on regular basis.

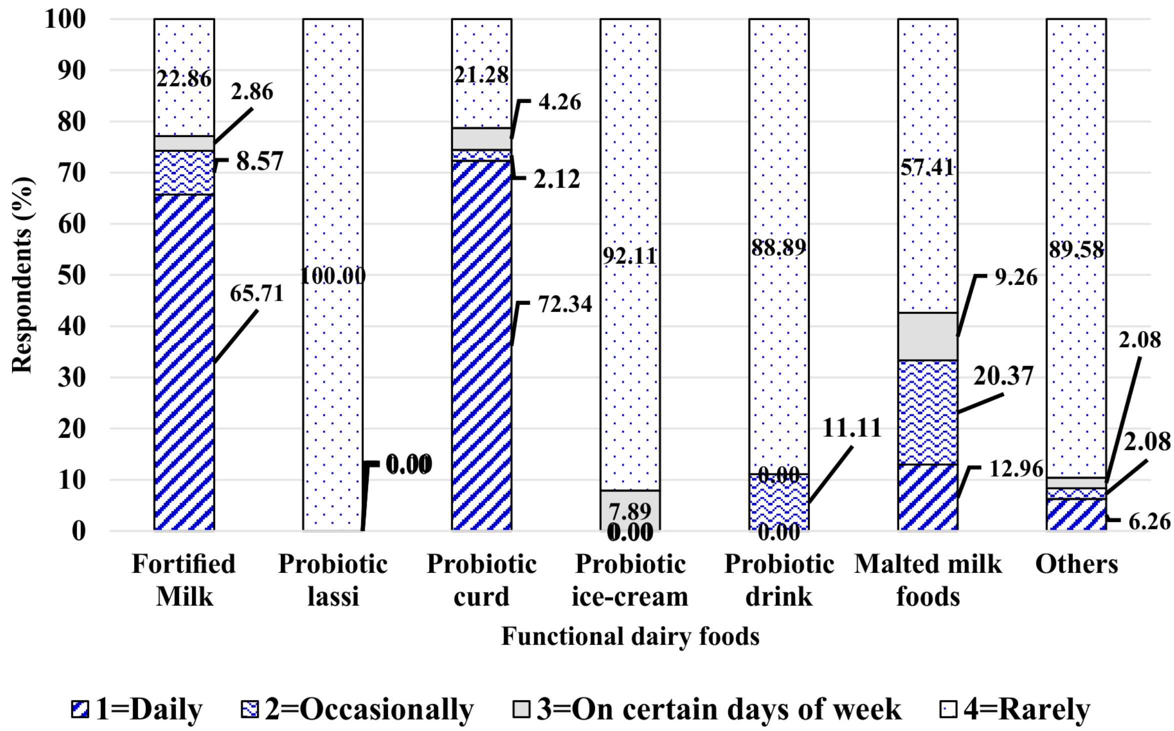

Figure 4 Frequency of consumption of functional dairy foods
Source Authors' calculations

It was found that (i) 21.28 per cent consumers rarely consumed the probiotic curd, (ii) around 2.12 per cent consumers consumed probiotic curd occasionally, (iii) 72.34 per cent consumers used probiotic curd on daily basis, and (iv) 92.11 per cent consumers took probiotic ice-cream rarely. The analysis of frequency of consumption of probiotic drink showed that most of the consumers rarely used the probiotic drink (88.89%), followed by occasionally (11.11%). The consumption of malted milk foods and other functional dairy products was infrequent, with 57.41% and 89.48% of respondents consuming them rarely. Ultimately, the results reveal that functional dairy foods are consumed rarely or on occasional basis.

D. Consumption pattern of functional dairy foods

The study of consumption pattern of households for the functional dairy foods has a prime importance in order to expand the market in Tamil Nadu as well as in India. Table 2 represents the number of consumers consuming the different functional dairy foods in their income group category.

It was found that the consumption of fortified milk, probiotic lassi, probiotic curd, malted milk foods and other functional dairy foods was highest in Income Group 3, and probiotic ice cream was in Income Group 2. The consumption of probiotic drink has been found consistently low across all groups.

The average monthly per-capita consumption of milk and functional dairy foods by sample households are shown in Table 3. It can be seen that the average monthly per-capita consumption of functional dairy foods was 4.23 kg, after converting all products to a common unit using specific gravity, and 3.6 litres in terms of milk equivalent quantity* (MEQ). When compared with the average monthly per-capita milk availability of 10.77 litres (BAHS, 2023) in Tamil Nadu, the functional dairy foods accounted for 33.43% of the total per-capita milk availability.

The average monthly per-capita consumption expenditure on milk and functional dairy foods by sample households has been depicted in Table 4. It is seen that the average monthly per-capita expenditure on functional dairy foods was ₹ 363.83.

Table 2 Distribution of consumers across income groups based on consumption of functional dairy foods

Products	Income Group 1 (n=78)	Income Group 2 (n=60)	Income Group 3 (n=22)	Overall (n=160)
Fortified milk	10 (12.82)	14 (23.33)	11 (50.00)	35 (21.88)
Probiotic lassi	8 (10.26)	10 (16.66)	6 (27.27)	24 (15.00)
Probiotic curd	16 (20.51)	20 (33.33)	11 (50.00)	47 (29.38)
Probiotic ice-cream	11 (14.10)	20 (33.33)	7 (31.82)	38 (23.75)
Probiotic drink	8 (10.26)	3 (5.00)	4 (18.18)	15 (9.38)
Malted milk foods	22 (28.20)	23 (38.33)	9 (40.91)	54 (33.75)
Others	20 (25.64)	19 (31.67)	9 (40.91)	48 (30.00)

Figures within the parentheses indicate percentages of total respondents (n) in the respective columns
Source Authors' calculations

Table 3 Average monthly per-capita consumption of milk and functional dairy foods by sample households in Tamil Nadu

Products	Income Group 1 (n=78)	Income Group 2 (n=60)	Income Group 3 (n=22)	Overall (n=160)
Milk (l)	10.11	10.17	6.18	9.56
Functional dairy foods				
Fortified milk (l)	1.24	3.02	6.41	2.68
Probiotic lassi (l)	0.35	0.54	0.94	0.51
Probiotic curd (kg)	0.28	0.47	0.69	0.41
Probiotic ice-cream (l)	0.26	0.49	0.42	0.37
Probiotic drink (l)	0.03	0.02	0.04	0.03
Malted milk foods (kg)	0.08	0.14	0.14	0.11
Total (kg)	2.30	4.81	8.89	4.23
Total (MEQ*)	2.21	4.32	6.27	3.60

Source Authors' calculations

E. Determinants of consumption expenditure

The present study aimed to identify the factors that influence per-capita consumption expenditure on functional dairy foods. Before applying the double hurdle model, a histogram with a kernel density (kdensity) overlay was employed to visually assess the distribution of the dependent variable (consumption expenditure). This initial step was crucial for detecting the shape of the data distribution, identifying any skewness or potential outliers.

The distribution of various dependent variables used in the double-hurdle model has been shown in Figures 5 (a-f). There is a spike near zero expenditure in all the histograms. This indicates that a significant proportion of the sample did not spend anything on the functional dairy foods. The presence of zero expenditures justified

Table 4 Average monthly per-capita expenditure on milk and functional dairy foods by sample households (in ₹)

Products	Income Group 1 (n=78)	Income Group 2 (n=60)	Income Group 3 (n=22)	Overall (n=160)
Milk	505.25	575.61	323.79	505.26
Functional dairy foods				
Fortified milk	54.41	133.58	282.11	118.01
Probiotic lassi	6.40	71.73	124.60	67.57
Probiotic curd	34.69	58.27	86.01	51.20
Probiotic ice-cream	44.20	83.30	71.40	63.11
Probiotic drink	8.96	4.44	11.26	7.61
Malted milk foods	30.09	80.31	79.48	56.33
Total	178.75	431.63	654.86	363.83

Source Authors' calculations

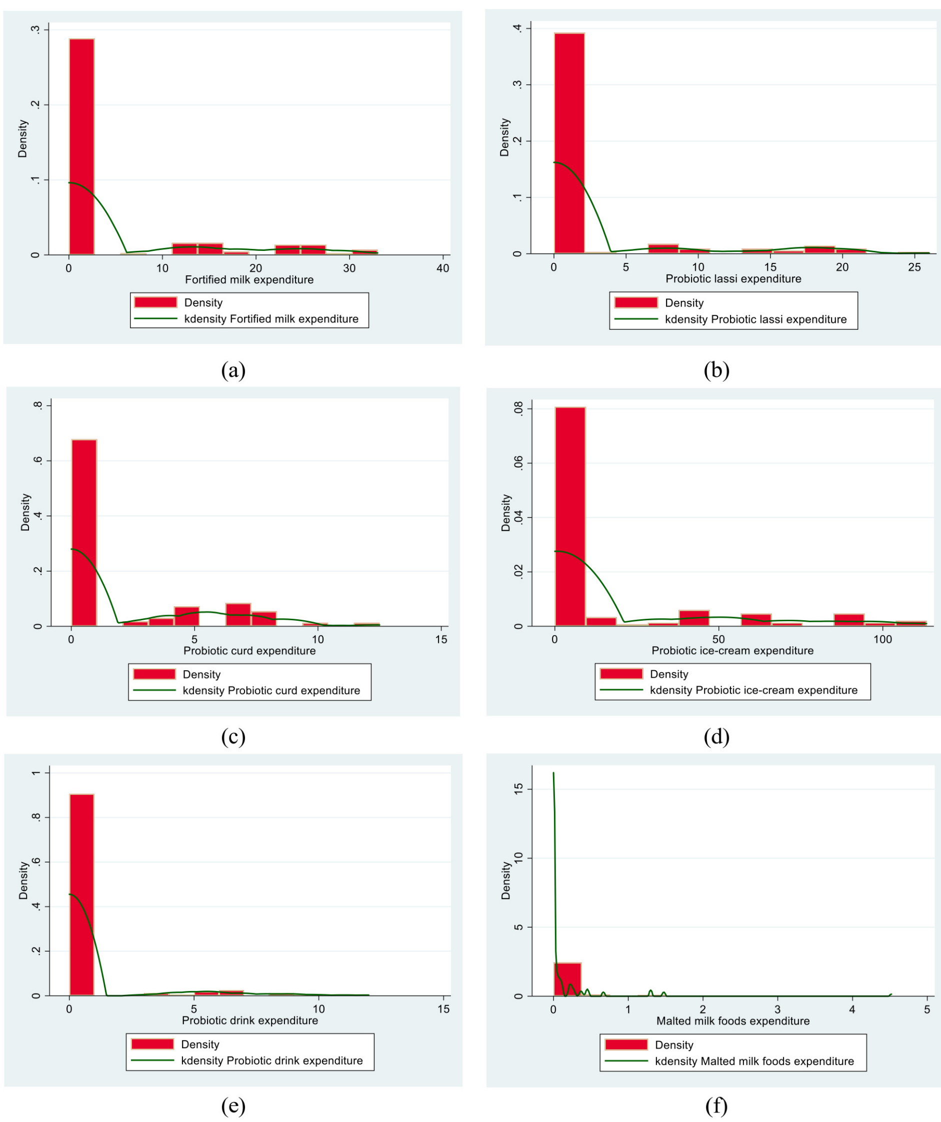

Figure 5 Histogram with kernel density estimate (Kdensity) overlay of various dependent variables used in the double-hurdle model

Source Authors' calculations

the use of a double-hurdle model, which is designed to handle situations where a proportion of the population has zero expenditure and the rest have positive expenditures. So, the factors determining per-capita consumption expenditure on functional dairy foods was analysed using Cragg double-hurdle model as well as tobit model for comparison and the results are presented in Tables 5 and 6.

Table 5 Factors influencing per-capita expenditure on functional dairy foods by double-hurdle model

Variables	(1) Per capita fortified milk expenditure (₹/day)		(2) Per capita probiotic lassi expenditure (₹/day)		(3) Per capita probiotic curd expenditure (₹/day)	
	Outcome equation	Selection equation	Outcome equation	Selection equation	Outcome equation	Selection equation
Family size		-0.252		0.244*		-0.113
		(0.154)		(0.142)		(0.144)
Occupation dummy (Base= Business)						
Salaried employment		-0.075		-0.617*		0.012
		(0.307)		(0.335)		(0.305)
Self-employment		-0.231		-0.784*		0.315
		(0.388)		(0.413)		(0.358)
Area dummy (Base = Rural)						
Urban/ Semi-urban		0.780***		-0.026		1.200***
		(0.299)		(0.284)		(0.289)
District fixed effect = Yes (Base= Chennai (d_0))						
Salem (d_1)		-0.438*		-0.487*		-0.333
		(0.258)		(0.282)		(0.241)
Food habit dummy (Base= non-vegetarian)						
Vegetarian		-0.161		0.671**		0.249
		(0.296)		(0.291)		(0.268)
Monthly family income	-0.727	0.681***	-0.475	0.126	-0.880	0.591**
	(1.951)	(0.249)	(2.172)	(0.274)	(0.736)	(0.236)
Monthly food expenditure	4.017		7.061		-0.515	
	(4.104)		(4.805)		(1.516)	
Monthly non-food expenditure	-0.618		5.418		2.076*	
	(2.857)		(3.951)		(1.083)	
Price	-0.712***		-0.716***		-0.219***	
	(0.087)		(0.210)		(0.065)	
Constant	32.547	-7.766***	-14.237	-2.996	25.786	-7.643***
	(43.757)	(2.858)	(68.155)	(3.148)	(16.018)	(2.720)
log sigma	1.417***		1.458***		0.684***	
	(0.123)		(0.154)		(0.108)	
Model adequacy check						
Observations (No.)	35	160	24	160	47	160
Pseudo R^2	0.1852		0.1288		0.1280	

Note: Standard errors within the parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Contd…

Variables	(4) Per capita probiotic ice-cream expenditure (₹/day)		(5) Per capita probiotic drink expenditure (₹/day)		(6) Per capita malted milk food expenditure (₹/day)	
	Outcome equation	Selection equation	Outcome equation	Selection equation	Outcome equation	Selection equation
Family size		-0.414**		-0.195		0.013
		(0.203)		(0.212)		(0.117)
Occupation dummy (Base= Business)						
Salaried employment		0.273		0.387		-0.290
		(0.378)		(0.447)		(0.295)
Self-employment		0.316		-0.055		-0.110
		(0.506)		(0.560)		(0.345)
Area dummy (Base = Rural)						
Urban/ Semi-urban		0.141		0.305		0.808***
		(0.315)		(0.344)		(0.237)
District fixed effect = Yes (Base= Chennai (d_0))						
Salem (d_1)		-5.800		-0.633*		0.646***
		(177.523)		(0.341)		(0.237)
Food habit dummy (Base= non-vegetarian)						
Vegetarian		0.255		0.713**		-0.037
		(0.328)		(0.315)		(0.256)
Monthly family income	-2.640	0.756**	1.002	0.079	0.374	0.410*
	(11.878)	(0.309)	(1.399)	(0.308)	(0.424)	(0.223)
Monthly food expenditure	-15.181		-0.441		0.366	
	(26.569)		(3.514)		(0.668)	
Monthly non-food expenditure	-7.332		-0.269		0.204	
	(17.364)		(2.288)		(0.457)	
Price	-0.677**		-0.066**		0.000	
	(0.289)		(0.030)		(0.001)	
Constant	531.699**	-7.423**	18.935	-1.876	-11.937*	-5.799**
	(265.325)	(3.498)	(37.017)	(3.563)	(6.868)	(2.581)
log sigma	3.340***		0.644***		0.281***	
	(0.140)		(0.188)		(0.090)	
Model adequacy check						
Observations (No.)	38	160	15	160	54	160
Pseudo R^2	0.1527		0.1358		0.3281	

Note Standard errors within the parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculations

In double-hurdle model, the outcome equation was modelled linearly for all functional dairy foods, except malted milk foods, for which exponential model was used as it provided the best fit. The double-hurdle model has provided valuable insights into the factors influencing the selection and expenditure decisions for various functional dairy products. It has revealed that fortified milk, the selection-decision was significantly influenced by area, district and income, while per-capita expenditure was affected only by 'price'. These results suggest that people residing in urban or semi-urban areas and having higher incomes are more likely to

Table 6 Factors influencing the per-capita expenditure on functional dairy foods by tobit model

Variables	(1) Per capita fortified milk expenditure (₹/day)	(2) Per capita probiotic lassi expenditure (₹/day)	(3) Per capita probiotic curd expenditure (₹/day)	(4) Per capita probiotic ice-cream expenditure (₹/day)	(5) Per capita probiotic drink expenditure (₹/day)	(6) Per capita malted milk food expenditure (₹/day)
Family size	4.388**	-1.443	-0.639*	-16.551*	-0.995	-0.020
	(1.922)	(1.505)	(0.374)	(9.950)	(0.650)	(0.119)
Occupation dummy (Base= Business)						
Salaried employment	4.907	-6.889**	1.915***	16.432	10.363***	-0.166
	(3.230)	(2.966)	(0.725)	(13.252)	(1.994)	(0.221)
Self-employment	2.054	-0.694	1.815*	3.746	5.686***	-0.277
	(4.942)	(4.046)	(0.926)	(16.916)	(2.151)	(0.279)
Area dummy (Base = Rural)						
Urban/ Semi-urban	1.873	2.628	-1.664*	24.126**	3.265***	-0.107
	(3.535)	(2.452)	(0.945)	(10.701)	(1.200)	(0.205)
District fixed effect = Yes (Base= Chennai (d_0))						
Salem (d_1)	-15.356***	1.398	-1.798***	-94.199	2.772*	0.346*
	(3.331)	(2.327)	(0.624)	(2,957.771)	(1.489)	(0.189)
Food habit dummy (Base= non-vegetarian)						
Vegetarian	8.055**	5.783**	1.203**	-6.550	-6.457***	0.356*
	(3.250)	(2.405)	(0.601)	(9.973)	(0.982)	(0.197)
Monthly family income	4.674	-2.661	-0.100	16.177	3.564***	-0.292
	(3.370)	(2.926)	(0.744)	(12.427)	(1.023)	(0.246)
Monthly food expenditure	-17.937**	21.622**	-2.374	-7.656	6.311**	0.742*
	(8.415)	(9.385)	(1.587)	(34.733)	(2.915)	(0.441)
Monthly non-food expenditure	4.141	-0.544	2.072*	-17.585	6.294***	0.054
	(4.774)	(4.454)	(1.080)	(16.982)	(2.303)	(0.296)
Price	0.703***	0.244***	0.110***	0.380***	0.090***	0.003***
	(0.085)	(0.047)	(0.014)	(0.059)	(0.013)	(0.000)
Constant	36.299	-186.872**	-1.807	41.638	-187.265***	-5.421
	(79.714)	(81.825)	(16.294)	(298.378)	(45.770)	(4.037)
Model adequacy check						
Observations (No.)	160	160	160	160	160	160
Pseudo R^2	0.3974	0.5261	0.5591	0.3451	0.7635	0.3563

Note Standard errors within the parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source Authors' calculations

consume in the fortified milk products compared to the rural residents. The district fixed effect has indicated lower participation in Salem than Chennai. Additionally, an increase in the price of fortified milk would lead to a reduction in per-capita expenditure.

In the case of probiotic lassi, the factors family size, occupation, district and food habits significantly influenced the selection-decision, while price was the sole determinant of per-capita expenditure. An increase in family size by one member positively influenced market participation, potentially due to the ease of availability of probiotic lassi at a small price difference from regular lassi, encouraging consumers to switch to a nutritionally superior product option. It was also found that salaried or self-employment people were less likely to participate compared to those in business. The district effect has shown a lower participation in Salem than Chennai, and vegetarians demonstrated a higher likelihood of consumption than non-vegetarians. As expected, an increase in price reduced the per-capita expenditure on probiotic lassi.

For probiotic curd, the selection-decision was significantly affected by the factors area and income, while monthly non-food expenditure and price factors influenced the per-capita expenditure. The respondents from urban or semi-urban areas and those with higher incomes were more inclined to participate in the probiotic curd market than rural residents. The price increase led to a decline in per-capita expenditure. Conversely, higher monthly non-food expenditure was associated with increased per-capita expenditure on probiotic curd. This pattern suggests that the households with higher non-food expenditure likely have greater disposable income, enabling them to allocate more resources to premium products like probiotic curd. This could indicate that probiotic curd is perceived as a higher-value or non-essential product that wealthier households are more likely to purchase, even as they spend more on non-food items.

For probiotic ice cream, the factors family size and income were significant determinants of the selection-decision, while price influenced the per-capita expenditure. The larger families were less likely to participate in the probiotic ice cream market, possibly due to budget constraints, while the higher-income households were more likely to participate. Any Price increase reduced the per-capita expenditure on probiotic ice cream. In the case of probiotic drinks, district and food habits significantly affected the selection-decision, with price influencing per-capita expenditure. The participants in Salem district were less likely to participate than those in Chennai district, and the vegetarian participants have revealed a higher likelihood of participation than non-vegetarians. As with other products, the price increase reduced the per-capita expenditure.

Finally, for malted milk foods, the factors area, district, and income significantly influenced the selection-decision. The urban and semi-urban residents, as well as higher-income households, were more likely to participate in the malted milk foods market than rural residents. Interestingly, the district fixed effect has revealed that respondents in the Salem district were more likely to participate than those in Chennai.

F. Comparative Analysis of results from tobit and Double-Hurdle Models

The results of tobit analysis have provided a contrasting perspective on the factors influencing the consumption of functional dairy foods. Notably, the tobit model has suggested that an increase in the price of various functional dairy foods would lead to an increase in the consumption expenditure—a counterintuitive finding that is inconsistent with the economic theory. This inconsistency is particularly evident when a comparison is made with the double-hurdle model results, which showed price increases leading to reduced consumption expenditures across all product categories.

The tobit model has also indicated contradictory findings regarding consumer characteristics. For instance, vegetarians were found less likely to participate in the probiotic drink market, contrary to the double-hurdle model findings, which revealed that vegetarians tend to participate more. However, some results from the tobit model aligned also with the double-hurdle model. For example, the respondents in the Salem district were less likely to participate in the fortified milk market and were more likely to participate in the malted milk food market. Additionally, family size negatively influenced participation in the probiotic ice cream market, and non-food expenditure positively impacted probiotic curd consumption expenditure, which are findings consistent with the double-hurdle model.

The contrasting results highlight the limitations of the tobit model in this context. The tobit specification assumes a single decision-making process, failing to account for situations where certain variables influence the selection decision (whether to participate) but not the outcome decision (how much to consume), or vice versa. For instance, variables such as occupation and food habits significantly influenced selection decisions but had minimal impact on outcome decisions. The double-hurdle model addresses this limitation by separately modelling the selection and outcome processes, thus providing more accurate and meaningful insights into the determinants of functional dairy food consumption.

Conclusions and Policy Implications

The study revealed the consumption patterns and key factors influencing the consumption of functional dairy foods in northern Tamil Nadu. Notably, it found a high level of awareness (84%) about functional dairy products among the participants. However, despite this high awareness, the information asymmetry limits the consumers' ability to fully increase their consumption. This highlights the need to educate the public on the specific health benefits of these products. Currently, the fortified milk has been found to be the most consumed functional dairy product in the region. The expanding consumer knowledge about the health advantages of other functional dairy products could promote a more diversified consumption pattern.

Also, improvements in the distribution networks are essential to enhance the accessibility of functional dairy products, ensuring their availability in both supermarkets and local retail shops. This would facilitate easier access for consumers and potentially increase purchase rates. Additionally, as consumer decisions are increasingly shaped by digital platforms such as social media and the Internet, there is a growing need to focus on digital marketing strategies to further boost awareness and sales.

It has observed that income, price, occupation, dietary habits, family size and location are the factors which influences consumption of functional dairy foods. The urban residents, individuals with higher incomes and vegetarians have been found to be more likely to spend on these products. Addressing these factors through targeted marketing and distribution efforts could help in promoting the wider adoption of functional dairy foods.

Acknowledgement

This paper is part of the study conducted for the first author's (Dhasarathan M) master degree programme in Agricultural Economics at the ICAR-National Dairy Research Institute, Karnal, Haryana. The dissertation, titled 'Consumption Pattern and Demand Analysis of Functional Dairy Foods in Tamil Nadu,' was completed in 2024.

References

Alonso, A, Beunza, J J, Delgado-Rodriguez, M, Martinez, J A, & Martinez Gonzalez, M A. 2005. Low-fat dairy consumption and reduced risk of hypertension: The Seguimiento Universidad de Navarra (SUN) cohort. *American Journal of Clinical Nutrition* 8: 972-979. https://doi.org/10.1093/ajcn/82.5.972

Animal Husbandry, Dairying, Fisheries and Fishermen Welfare Department, Government of Tamil Nadu. 2022. Dairy development. https://cms.tn.gov.in/sites/default/files/documents/dairy_e_pn_2022_23.pdf

Atkinson, A B, Gomulka, J and Stern, N H. 1990. Spending on Alcohol: Evidence from the Family Expenditure Survey 1970-1983. *The Economic Journal* 100: 808-27. https://doi.org/10.2307/2233660

Basic Animal Husbandry Statistics, Department of Animal Husbandry & Dairying, Ministry of Fisheries, Animal Husbandry & Dairying, Government of India. 2023. New Delhi. https://dahd.nic.in/sites/default/filess/BAHS2023.pdf

Choudhury, N R. 2023. Market Survey on Functional Dairy Products Market. Future Market Insights. https://www.futuremarketinsights.com/reports/functional-dairy-products-market

Cragg, J G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica* 39(5): 829–844. https://doi.org/10.2307/1909582

Dalenius, T and Hodges, J L. 1957. Minimum Variance Stratification. *Journal of the American Statistical Association* 54(285): 88–101. https://doi.org/10.2307/2282141

Deaton, A S and Irish, M. 1984. Statistical Models for Zero Expenditures in Household Budgets. *Journal of Public Economics* 23: 59-80. https://doi.org/10.1016/0047-2727(84)90067-7

Garcia, J and Labeaga, J M. 1996. Alternative Approaches to Modelling Zero Expenditures: An Application to Spanish Demand for Tobacco. *Oxford Bulletin of Economics and Statistics* 58(3): 489-503. https://EconPapers.repec.org/RePEc:bla:obuest:v:58:y:1996:i:3:p:489-506

Grujiæ, S and Grujèiæ, M. 2023. Factors affecting consumer preference for healthy diet and functional foods. *Foods and Raw Materials* 11(2): 259–271. https://jfrm.ru/files/archive/23/Gruji%C4%87.pdf

Hu, F B, Stampfer, M J, Manson, J E, Ascherio, A, Colditz, G A, Speizer, F E. 1999. Dietary saturated fats and their food sources in relation to the risk of coronary heart disease in women. *American Journal of Clinical Nutrition* 70: 1001-1008. https://doi.org/10.1093/ajcn/70.6.1001

Jones, A M. 1989. A Double-hurdle Model of Cigarette Consumption. *Journal of Applied Econometrics* 4(1): 23-39. http://www.jstor.org/stable/2096488

Liu, S, Choi, H K, Ford, E, Song, Y, Klevak, A, Buring, J E. 2006. A prospective study of dairy intake and the risk of type 2 diabetes in women. *Diabetes Care* 29: 1579-1584. https://doi.org/10.2337/dc06-0256

Peng, Y, West, G E, & Wang, C. 2006. Consumer attitudes and acceptance of CLA enriched dairy products. *Canadian Journal of Agricultural Economics* 54(4): 663-684. https://doi.org/10.1111/j.1744-7976.2006.00072.x

Rani, D A, Virginia, P and Sana, A. 2022. Fortified Food Consumption and Awareness in Indian Market. *International Journal of Research in Engineering and Science* 10(5): 1-3. https://www.ijres.org/papers/Volume-10/Issue-5/Ser-3/A10050103.pdf

Robu, E, Sergheeva, E, and Popovici, C. 2022. Functional foods: A study of consumer perception and preferences in the Republic of Moldova. In *New Trends on Sensing-Monitoring-Telediagnosis for Life Sciences* (p. 51). Chisinau, Republic of Moldova. http://repository.utm.md/bitstream/handle/5014/21657/Conf-MTFI-2022-p51.pdf?sequence=1

Shireen, A, and Aneesh, M. 2021. Knowledge and consumption of probiotics and prebiotics in India: A narrative review. *International Journal of Community Medicine and Public Health* 8(10): 5119-5126. https://doi.org/10.18203/2394-6040.ijcmph20213823

Thomas, P R and Earl, R. (eds). 1994. *Opportunities in the Nutrition and Food Sciences: Research Challenges and the Next Generation of Investigators.* (p. 109). Committee on opportunities in the nutrition and food sciences, Food and nutrition board, Institute of Medicine, The National Academies Press, Washington, D.C. https://nap.nationalacademies.org/read/2133/chapter/1

Toledo, E, Delgado-Rodriguez, M, Estruch, R, Salas-Salvado, J, Corella, D, Gomez Gracia, E. 2009. Low-fat dairy products and blood pressure: Follow-up of 2290 older persons at high cardiovascular risk participating in the PREDIMED study. *British Journal of Nutrition* 101: 59-67. https://doi.org/10.1017/S0007114508981496

Received 17 October 2024 Accepted 5 December 2024

Appendix

Table A1 Major functional dairy product categories available in Tamil Nadu

Product categories
Fortified milk (fortified with Vitamin A & D)
Probiotic lassi of various flavours
Probiotic curd
Probiotic ice-cream of various flavours
Probiotic drink
Malted milk foods
Others include Fruit/probiotic yoghurt of various flavours, Fruit lassi of various flavours, Fortified lassi, Sugar free desserts, Low-calorie products such as low-fat cream, etc.

Source: Based on data collected by authors and may not be a complete listing.

Agricultural Economics Research Review 2024, 37 (2), 227-235
DOI: 10.5958/0974-0279.2024.00016.5

Determinants of India's processed food exports in post-reforms era

Charu Singh* and Meenu

Department of Economics, Panjab University, Chandigarh – 160014, India

*Corresponding author: charu.kalsy@gmail.com

Abstract The paper has analysed the determinants of India's processed food exports, for which there is a massive potential for further growth. Providing an overview of India's processed food exports, it has examined its determinants to the global markets using principal component analysis. It has shown that the most important determinant of India's processed food exports is the country's resource endowment. The results for other factors such as inflation, real effective exchange rate, trade openness index, GDP, etc. have been found varied. The study has suggested the development of secondary agriculture, i.e., conversion of agricultural produce and residue into high-value products through processing.

Keywords Processed Food, Exports, India, Determinants, Principal Component Analysis

JEL codes F1, Q17

Introduction

According to the Ministry of Food Processing Industries (MoFPI), New Delhi, food processing is the transformation of raw agricultural and allied sector products at the primary, secondary, or tertiary levels. The primary processing involves basic tasks such as cleaning, sorting, and grading items like fruits, vegetables, milk, meat, and fish. The secondary processing adds significant value to these primary products, such as converting milk into condensed milk. The tertiary processing is oriented towards retailing and marketing. Thus, any alteration in raw agricultural produce is classified as processed food.

For an economy like India where most of the population is still dependent on the primary sector, the food processing sector, also referred to as secondary agriculture sector, continues to be a crucial sector in the path to development. As per Athukorala and Sen (1998), labour-surplus developing economies especially benefit from the food processing sector due to its strong positive effect on employment generation, among other things.

The goal to end hunger globally and achieve food security can be achieved with the help of insights into the international trade of food. The world market has seen a considerable structural change in the trade of food during the past few decades, wherein the share of export of traditional food has been gradually declining and that of processed food has been increasing (Jongwanich 2009; Majumdar 2013). In the post-reforms era, India's export of raw agricultural produce has also declined continually, in line with the course of the development of an economy. Keeping in mind the share of the population employed in the primary sector and the increasing demand for processed food in the world, it becomes essential to focus on the export of value-added or processed agricultural produce from India. With this background, the present paper is an attempt to evaluate the determinants of India's processed food exports.

India's processed food exports: An overview

The MoFPI follows the ITC (HS) classification, as defined by the World Customs Organization, for processed food products, which aligns with Chapters

Table 1 HS Codes for India's Processed Food Exports Basket

HS Code	Export Commodity
02	Meat and edible meat offal
03	Fish and crustaceans, mollusks and other aquatic invertebrates
04	Dairy produce; birds' eggs; natural honey; edible prod. Of animal origin, not elsewhere specified or included
07	Edible vegetables and certain roots and tubers
08	Edible fruit and nuts; peel or citrus fruit or melons
09	Coffee, tea, mate and spices
10	Cereals
11	Products of the milling industry; malt; starches; insulin; wheat gluten
12	Oil seeds and olea fruits; misc. Grains, seeds and fruit; industrial or medicinal plants; straw and fodder
13	Lac; gums, resins and other vegetable saps and extracts
15	Animal or vegetable fats and oils and their cleavage products; pre. Edible fats; animal or vegetable waxex
16	Preparations of meat, of fish or of crustaceans, mollusks or other aquatic invertebrates
17	Sugars and sugar confectionary
18	Cocoa and cocoa preparations
19	Preparations of cereals, flour, starch or milk; pastry cooks products
20	Preparations of vegetables, fruit, nuts or other parts of plants
21	Miscellaneous edible preparations

Source Ministry of Food Processing Industries

10 and 11 of the National Industrial Classification (NIC)-2008. This study considers these categories at the 2-digit level of the ITC (HS) classification:

The opening of Indian economy with the economic reforms of 1991 flourished the country's export sector. In the post-reforms era, India's exports have increased in both absolute and relative terms. Table 2 shows the changes in the share of India's total exports as a percentage of its GDP and that of India's processed food exports as a share of its total exports.

The share of India's total exports in its GDP increased gradually till 2012-13 before the sector was affected due to various external shocks such as the Eurozone debt crisis, trade wars, etc. The share has been fairly stable during the past few years of the study.

During most part of the 1990s, India's processed food exports enjoyed a share of over a 15 per cent in its total exports, after which it started declining as the other sectors took off in the early-2000s. During the last decade of the study period (2011-12 to 2021-22), however, the share has stabilized within the range of about 9.6 per cent to almost 15.5 per cent as a share of India's total exports.

The analysis of India's processed food exports reveals notable structural shifts in the shares of categories of India's processed food exports. Certain categories, such as HS Codes 10 and 03, consistently maintained high shares throughout the study period, while others experienced significant changes. For example, the share of HS Code 02 rose from 3.44% in the 1991-92 to 2000-01 period to 11.54% between 2011-12 and 2019-20. Although HS Code 09 was among the categories with high shares across all sub-periods, its share gradually declined over time. Similarly, HS Code 23 experienced a marked decrease in its share throughout the study period. Table 3 shows the average shares of all the categories of processed food exports over the study period and sub-periods.

Review of Literature

The share of processed food in non-manufacturing exports of developing countries has increased considerably during the past few decades, owing to the change in consumers' food habits (Athukorala and Sen 1998). India, despite being a leading food producer, processes a very small percentage of its food *vis-à-vis* its counterparts, but has still witnessed impressive

Table 2 Overview of India's Overall and Processed Food Exports Scenario

Year	Share of Total Exports in GDP (%)	Share of Processed Food Exports in Total Exports (%)	Year	Share of Total Exports in GDP (%)	Share of Processed Food Exports in Total Exports (%)
1991-92	7.19	16.07	2007-08	15.17	9.99
1992-93	7.96	16.80	2008-09	13.17	7.78
1993-94	8.05	15.83	2009-10	13.15	8.30
1994-95	8.80	19.00	2010-11	16.54	9.60
1995-96	8.52	18.86	2011-12	15.84	12.69
1996-97	8.37	17.91	2012-13	18.13	11.91
1997-98	7.88	17.72	2013-14	15.57	11.96
1998-99	8.05	14.84	2014-15	12.57	11.58
1999-00	9.04	13.20	2015-16	11.37	11.28
2000-01	9.04	13.70	2016-17	11.10	11.76
2001-02	9.73	12.98	2017-18	11.93	10.61
2002-03	9.77	11.26	2018-19	11.26	10.47
2003-04	10.70	10.55	2019-20	10.50	12.84
2004-05	12.23	9.25	2020-21	9.21	15.42
2005-06	12.89	8.74	2021-22	12.58	12.02
2006-07	11.99	9.32			

Source Authors' calculations

Table 3 Category-wise Average Shares of India's Processed Food Exports

HS Code	1991-92 to 2019-20 (%)	1991-92 to 2000-01 (%)	2001-02 to 2010-11 (%)	2011-12 to 2019-20 (%)
02	7.09	3.44	6.74	11.54
03	16.50	20.57	13.59	15.23
04	1.08	0.48	1.59	1.18
07	3.78	3.22	4.74	3.34
08	7.35	9.85	7.41	4.49
09	11.9	16.39	10.29	8.87
10	19.43	15.43	20.16	23.08
11	0.68	0.62	0.60	0.84
12	4.85	4.27	5.17	5.13
13	4.25	3.62	3.84	5.40
15	3.78	3.56	4.09	3.69
16	0.79	0.08	1.27	1.03
17	3.97	2.28	4.92	4.79
18	0.18	0.04	0.09	0.43
19	1.06	0.57	1.18	1.46
20	1.22	0.75	1.41	1.54
21	1.81	1.79	1.74	1.93
22	0.67	0.43	0.62	0.99
23	9.55	12.60	10.56	5.05

Source Authors' calculations

growth in its processed food exports sector (Majumdar 2013; Devi 2014).

There are several internal and external factors that influence India's export sector in general. After the mid-20th century, economies started opening doors to international trade, resulting in a vast change in the world economy. Studies show that while openness to trade has increased exports from the developing countries, the share of exports based on the primary sector has gone down over time, while that of merchandise and services sectors has increased (Veeramani 2007).

Another factor that influences the extent of exports is the 'resource endowment' of a country. Alkhteeb and Sultan (2019) have found that India's agricultural exports are positively influenced by the country's agricultural production, while other resource endowments like labour and land (i.e., farm size) are insignificant factors (Narayan and Bhattacharya 2019).

There is a mixed evidence about the influence of domestic prices or inflation on the exports from India. For manufacturing exports across developing nations, inflation seems to affect exports negatively (Sumiyati 2020). On the other hand, for Azerbaijan's agricultural exports, inflation has been found to be an insignificant determinant (Nifiyev 2020). Further, India's black pepper exports were significantly influenced by the domestic as well as export prices positively (Pushia 2020).

The shift from unprocessed primary products to processed foods in the global agri-food trade is linked to economic advancement, as seen in Sri Lanka and other Asian countries, with export success influenced by world demand growth, resource endowment, and supportive policies for global integration (Athukorala et al. 2024). Further, Suanin (2023) has found that compliance with international food safety standards boosts the processed food exports from developing countries, especially to the USA and other developing markets, with limited impact on the EU exports.

Research gaps and objective

Very little attempt has been made to understand the determinants of India's processed food exports, especially using secondary data from the Ministry of Food Processing Industries (MoFPI), Government of India. The present study attempts to bridge this gap by analysing the determinants of India's processed food exports to the global markets in the post-reforms era.

Hypothesis

The following hypothesis was constructed to test for the present study:

H_0: There is no significant relation between India's Processed Food exports and any of the determinants.

H_1: At least one of the determinants is significant in explaining variability in India's Processed Food exports.

Data sources and methodology

The paper has used secondary data collected from the following data sources:

- World Integrated Trade Solutions (WITS) database
- Handbook of Statistics on the Indian Economy, Reserve Bank of India
- Database on Indian economy, Reserve Bank of India
- World Development Indicators, World Bank.

The paper has analysed the determinants of exports of processed food from India to the world during the period 1991-92 to 2019-20. For this purpose, the paper has taken into consideration some variables that can potentially have a significant impact on India's processed food exports, which are shown in the model (1):

$$Ex_{it} = f(GDP_{it}, REER_{it}, RE_{it}, WM_{it}, OPEN_{it}, P_{it}) \quad \ldots(1)$$

where Ex_{it} is India's Processed Food Exports, GDP_{it} is India's Gross Domestic Product, $REER_{it}$ is Real Effective Exchange Rate (REER), RE_{it} is India's agricultural resource endowment, WM_{it} is the world market for Processed Food, $OPEN_{it}$ is India's openness to trade, and P_{it} is price level or inflation.

The following steps were undertaken to evaluate the determinants of India's processed food exports:

Step 1. To identify the appropriate model for the given dataset, multicollinearity was checked using the Variance Inflation Factor (VIF), wherein high multicollinearity was confirmed for India's processed food exports to the world.

Table 4 Variance Inflation Factor

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
P	1.32E+10	196.2012	19.12437
OPEN	3.56E+10	53.03965	4.796302
WM	8.65E+13	67402.99	65.40961
GDP	3.72E+13	29495.12	41.72607
RE	43730317	416.7259	10.53856
REER	4.61E+10	968.042	4.247429
C	1.39E+16	25794.36	NA

Source Authors' calculations

Step 2. To combat the problem of multicollinearity the paper has used Principal Component Analysis (PCA), which helps in converting highly correlated data into uncorrelated factors. The PCA also helps to reduce the dimensionality of the data set while retaining as much information as possible, even though these two goals are conflicting (Ismail and Abdullah 2016).

Step 3. The relevant principal components (PCs) were selected using two methods. The first method involved selection of those PCs whose eigen values and percentage variance were more than the average eigen value and percentage respectively (Kaming et al. 1997; Chan and Park 2005). The second method for selecting relevant PCs was using the values of the cumulative variance percentage (CVP) as per Ismail and Abdullah (2016).

Step 4. Using the factor loadings of PCA analysis and mean-centred data, the principal component series (PC1, PC2, …, PCK) were computed.

Step 5. Finally, the principal components series were used in a linear regression model. This approach is known as Principal Component Regression (PCR), which is essentially a combination of PCA and multiple linear regression (Ismail and Abdullah 2016). The equation of a PCR model is given as follows:

$$Ex_{it} = \alpha_1 + \beta_1 PC_1 + \beta_2 PC_2 + \ldots + \beta_k PC_k + \varepsilon_{it}$$

where

Ex_{it} = Exports of India's processed food exports to the world

α_1 = Constant term

PC_k = Principal Components (uncorrelated independent variables)

β_k = Regression coefficients

ε_{it} = Random error

Determinants of India's processed food exports

Preparation of the dataset

The independent variables considered for the model, in line with literature review, exhibit the problem of multicollinearity. Table 4 shows the Variance Inflation Factor (VIF) results of the model used in the study. A VIF higher than 10 indicates that the variables are highly correlated. Here, the variables P, WM, GDP, and RE exhibit high correlation. The VIF greater than 4 implies that correlation exists to some extent but needs to be examined further, which is witnessed by the variables OPEN and REER. Therefore, the results of any model applied to this dataset would be unreliable.

To combat the problem of multicollinearity, the study has used Principal Component Analysis (PCA) which reduces the dataset into uncorrelated factors. The PCA results of India's processed food exports to the world are presented in Table 5.

The PCA results included as many dimensions/ components as the number of variables in the dataset.

Table 5 Principal Component Analysis of India's Processed Food Exports

	PC1	PC2	PC3	PC4	PC5	PC6
Standard deviation	0.2819	0.2185	0.0581	0.0287	0.0052	0.0000
Proportion of Variance	0.6046	0.3632	0.0257	0.0062	0.0002	0.0000
Cumulative Proportion	0.6046	0.9679	0.9935	0.9998	1.0000	1.0000

Source Authors' calculations.

PC1, PC2, …, PC6 are the principal components or dimensions obtained, which is equal to the number of variables in the dataset.

Table 6 Eigenvalues of Dimensions

	Eigenvalue Variance	Percentage	Cumulative Variance (%)
Dim.1	0.0795	60.46	60.46
Dim.2	0.0477	36.32	96.79
Dim.3	0.0034	2.57	99.36
Dim.4	0.0008	0.62	99.98
Dim.5	0.0000	0.02	100.0
Dim.6	0.0000	0.00	100.0
Averages	0.0219	16.67	-

Source Authors' calculations

For the present study, there were a total of six components/dimensions in the case of India's processed food exports to the global markets (PC1, PC2, …, PC6).

However, it must be noted that not all components are important for further analysis. There is no consensus about a specific method of selecting the relevant principal components (PCs) among researchers, although there are a few common practices followed for this purpose. The first method included those PCs whose eigen values and percentage variance were more than the average eigen value and percentage respectively (Kaming et al. 1997; Chan and Park 2005). The eigen values of the dataset are shown in Table 6.

Another common method for selecting the relevant PCs is studying the cumulative variance percentage (CVP) as per Ismail and Abdullah (2016). As can be seen in Table 6, the first two components account for 96.79 per cent of the variance in the dataset. This can also be depicted with the help of a Scree Plot (Figure 1), wherein the factors that have an insignificant contribution to the cumulative variance can be seen in an almost straight line. Therefore, for the analysis of India's processed food exports to the world, the study has considered the first two components, which explained most of the variation in the dataset, for further analysis.

Further, to ensure that all variables in the dataset are represented well by the chosen two PCs, the contribution of each variable was checked using Cos2 values of the first two PCs/dimensions. The higher the Cos2 value, the more is the contribution of a particular variable to the factor. Figure 2 shows that the variables that contribute most to the selected PCs are REER, OPEN, and P. Further, the contributions of WM and RE are nearly identical. The GDP contributes the least to the chosen components.

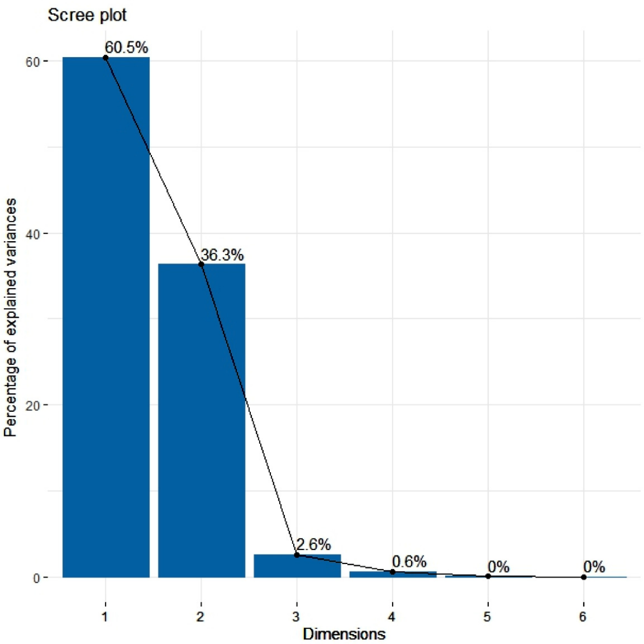

Figure 1 Scree Plot of PCs

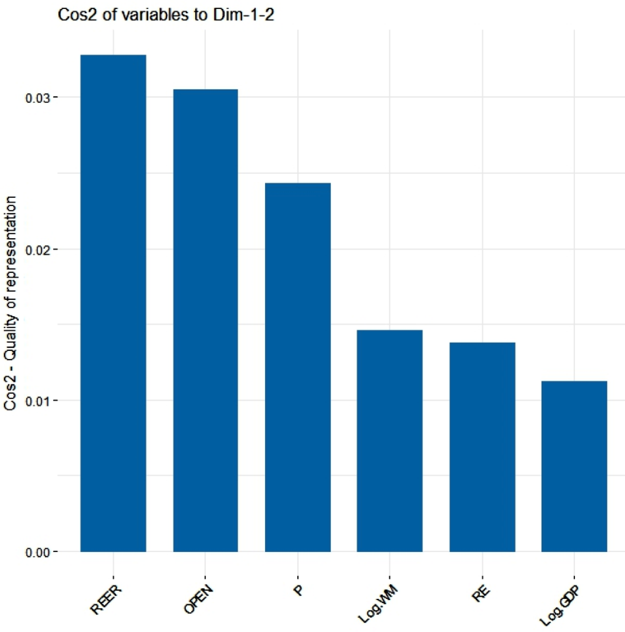

Figure 2 Contribution of Variables

Regression model estimation and results

The study has used the Principal Component Regression (PCR) model to analyse the determinants

Table 7 Determinants of India's Processed Food Exports

Variable	PC1	PC2
GDP	0.21308	0.39947
REER	-0.58777	0.33394
RE	-0.01771	0.53705
WM	0.35079	0.31659
OPEN	0.56392	-0.33153
P	0.40956	0.47994
Proportion of Variance	0.605	0.363
t-statistic	0.55445	11.6503
p-value	0.5840	0.0000
R^2	0.863588	
Adjusted R^2	0.853095	
F-statistic	82.29956	
Prob(F-statistic)	0.000000	

Source Authors' calculations

of India's processed food exports. For this purpose, a linear multiple regression model was run on the first two principal components selected in the preliminary analysis. The null hypothesis for this regression analysis was that all the factors considered (in the form of principal components) were not significant determinants of India's processed food exports to the world. The alternative hypothesis, in turn, was that at least one of them was significant in explaining the variations in India's processed food exports.

The results of the model are shown in Table 7. The PC1 was found as an insignificant factor in explaining the variance in India's processed food exports, while PC2 was positive and significant with p-value of 0.00. The R-squared value shows that about 86.36 per cent of the variation in India's processed food exports could be explained by the model, while the adjusted R-squared is about 85.31. The F-statistic is significant at a 1 per cent level of significance, implying that the null hypothesis can be rejected.

The factor loadings of PC2, which essentially describe the correlation of the component to the variables considered, are also given in Table 7. As can be seen from the Table, the PC2 exhibited the highest correlation with India's resource endowment (RE) or production of food grains, implying that India's processed food exports are significantly affected by the availability of raw materials in the country.

Next, the PC2 was also associated with the price level (P), which is the proxy for measuring inflation in India during the study period. The relationship between India's processed food exports and inflation has been found positive, which is in line with the available literature. As per theory, a country's inflation and exports should have a negative relationship, but a reasonable and stable inflation over a period acts as a catalyst for the growth of exports (Jacob et al. 2021).

Furthermore, PC2 was also positively correlated to India's GDP, implying that India's processed food exports are positively dependent on the country's GDP. The PC2 was weakly correlated with the other variables, viz. India's real effective exchange rate (REER), trade openness index (OPEN), and world's market demand for processed food (WM).

Conclusions and policy implications

The post-reforms era has seen remarkable changes in India's economy, especially in terms of trade. The Indian export sector has seen considerable growth in the past few decades, despite being vulnerable to international shocks. The importance of India's food processing exports is reinforced by the fact that the share of this category with respect to India's total exports was fairly stable, especially during the last decade of the study period (i.e., 2010-11 to 2019-20).

The study has shown that there is a significant relationship between the chosen determinants and India's processed food exports. The most significant factor in explaining India's processed food exports to the world was found to be the country's resource endowment (i.e., agricultural production). This provides robust statistical support for international trade theories and emphasizes the importance of secondary agriculture (i.e., conversion of agricultural produce and residue into high-value products through processing) along with primary agriculture for the Indian economy. Given the high domestic production of agricultural raw materials in India and relatively lower import dependence of the same, the food processing sector is of the essence in promoting farmers' income in the country.

The other important determinants were India's inflation level as well as GDP. While a reasonable and stable inflation rate over the long run acts as a catalyst for growth for an economy and its exports, there is also

Table 8 Expected Signs of the Variables

Variable	GDP_{it}	$REER_{it}$	RE_{it}	WM_{it}	OPENit	P_{it}
Expected Sign	+	-	+	+	+ or -	-

evidence in the literature that in the Indian context it is the rise in exports that has led to inflation and not vice-versa (Jacob et al. 2021; and Sahoo and Sethi 2020).

Appendix

Determinants: Rationale and Expected Signs

The variability in India's processed food exports can be explained by certain internal and external factors. The Gross Domestic Product (GDP) is a supply-side variable, that indicates the generation of a surplus in the country. The higher the GDP, the higher the possibility of exporting the surplus produced by the country (Sumiyati 2020). Therefore, India's processed food exports and its GDP are expected to have a positive relationship.

The real effective exchange rate (REER) is the nominal effective exchange rate adjusted for relative inflation. A lower exchange rate (or under-valued rupee) makes India's exports cheaper for foreign countries. Therefore, a negative relationship is expected between REER and exports.

The Resource Endowment (RE) for processed food exports is the agricultural production of the country, which provides the raw material for processing. Here, it is proxied by the Total Foodgrain Production over the study period. The expected sign of this determinant is positive since more agricultural production provides greater scope for processing.

The World Market (WM) is the world demand for processed food exports, proxied by the world export of processed food in a year. It is a demand-pull variable that can positively determine the exports of processed food from a country (Alkhteeb and Sultan 2019).

Openness to Trade (OPEN) shows a country's willingness to explore new markets (Athukorala and Sen 1998). However, it can also have a negative impact specifically on the primary sector exports because of their terms of trade disadvantage. Openness to Trade is calculated in accordance with WITS, World Bank methodology. The variable can take either a positive or negative value.

The price level or inflation (P), proxied by the Consumer Price Index, can theoretically impact exports negatively if it is too high (Narayan and Bhattacharya 2019). The expected sign of this variable, therefore, is negative.

References

Alkhteeb, T T and Z A Sultan. 2019. Determinants of India's agricultural export. *European Journal of Business and Management* 7(4): 53–63. https://www.researchgate.net/publication/332802024_Determinants_of_India's_Agricultural_Export

Athukorala, P C and K Sen. 1998. Processed food exports from developing countries: patterns and determinants. *Food Policy* 23(1): 41–54. https://doi.org/10.1016/S0306-9192(98)00019-0

Athukorala, P C, Weerahewa, J and Kandangama, N B. 2024. Exporting processed food: Sri Lanka's experience in the Asian context. Foreign Trade Review. https://doi.org/10.1177/00157325241283062

Chan, S and M Park. 2005. Project cost estimation using principal component regression. *Construction Management & Economics* 23: 295-304. https://doi.org/10.1080/01446190500039812

Devi, Kouru Uma. 2014. Trade performance of Indian processed foods in the international market. *Procedia - Social and Behavioral Sciences* 133: 84–92. https://doi.org/10.1016/j.sbspro.2014.04.172

Ismail, N A and S M Abdullah. 2016. Principal component regression with artificial neural network to improve prediction of electricity demand. *The International Arab Journal of Information Technology* 13 (1A): 196-202. https://www.researchgate.net/publication/297764886_Principal_component_regression_with_artificial_neural_network_to_improve_prediction_of_electricity_demand

Jacob, T, R Raphael and Ajina V S. 2021. Impact of exchange rate and inflation on the export performance of the Indian economy: An empirical analysis. *BIMTECH Business Perspectives* 3 (10): 1-13. https://api.semanticscholar.org/CorpusID:235818572

Jongwanich, Juthathip. 2009. The impact of food safety standards on processed food exports from developing countries. *Food Policy* 34 (5): 447-457. https://doi.org/10.1016/j.foodpol.2009.05.004

Kaming, P F, P O Olomolaiye, G D Holt and F C Harris. 1997. Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Construction Management and Economics* 15(1): 83–94. https://doi.org/10.1080/014461997373132

Majumdar, Kakali. 2013. Export performance of processed food in India. *Global Journal of Management and Business Studies* 3(3): 261–270. https://www.ripublication.com/gjmbs_spl/gjmbsv3n3spl_08.pdf

Ministry of Commerce, Government of India. Annual Reports (Various Issues). chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.commerce.gov.in/wp-content/uploads/2023/03/Annual-Report-FY-2022-23-DoC.pdf

Ministry of Finance, Government of India. Economic Survey (Various Issues). https://www.indiabudget.gov.in/economicsurvey/allpes.php

Ministry of Food Processing Industries, Government of India. Annual Reports (Various Issues). https://www.mofpi.gov.in/documents/reports/annual-report

Narayan, S and P Bhattacharya. 2019. Relative export competitiveness of agricultural commodities and its determinants: Some evidence from India. *World Development* 117: 29–47. https://doi.org/10.1016/j.worlddev.2018.12.013

Niftiyev, Ibrahim. 2020. Determinants of the agricultural exports in Azerbaijan. *SSRN Electronic Journal* September 2020. https://doi.org/10.2139/ssrn.3686701

Pushia, K P. 2020. Determinants of black pepper trade in India: A post globalisation scenario. *Agriculture Situation in India* 76 (March): 29-32. https://desagri.gov.in/wp-content/uploads/2021/04/March2020.pdf

Sahoo, M & N Sethi. 2020. The dynamic relationship between export, import and inflation: empirical evidence from India. *The Indian Economic Journal* 66 (21): 1-18. https://doi.org/10.1177/0019466220935552

Suanin, W. 2023. Processed food exports from developing countries: the effect of food safety compliance. *European Review of Agricultural Economics*, 50(2): 743–770. https://doi.org/10.1093/erae/jbac030

Sumiyati, E. E. 2020. Factors affecting manufacturing exports. *Journal of Economics, Business, & Accountancy Ventura* 23(2): 254–266. https://doi.org/10.14414/jebav.v23i2.2303

Veeramani, C. 2007. Industry-specific determinants of intra-industry trade in India. *Indian Economic Review, Department of Economics, Delhi School of Economics* 42(2): 211-229.

Received 2 August 2024 Accepted 2 December 2024

Agricultural Economics Research Review 2024, 37 (2), 237-247
DOI: 10.5958/0974-0279.2024.00017.1

Impact of PMKISAN Yojana on crop yield and income of farmers in Tamil Nadu, India

P Jagadeshwaran[1]*, K R Ashok[2], A Vidhyavathi[3], and M Prahadeeswaran[3]

[1]ICAR-Sugarcane Breeding Institute, Coimbatore, Tamil Nadu–641007, India
[2]Former Director, Centre for Agricultural and Rural Development Studies (CARDS), Tamil Nadu Agricultural University, Tamil Nadu–641003, India
[3]Department of Agricultural Economics, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu–641003, India

*Corresponding author: mailtojagadeshp@gmail.com

Abstract Agricultural subsidy and direct benefit transfer are pivotal policy instruments aimed at increasing adoption of modern technologies to enhance the income of small and marginal farmers. This study had analyzed the impact of Pradhan Mantri Kisan Samman Nidhi Yojana (PMKISAN) on crop yield and farm income in Tamil Nadu. Data were collected from 360 households, comprising both beneficiaries and non-beneficiaries and the impact was estimated using Propensity Score Matching (PSM). The findings indicate that PMKISAN was utilized maximum in crop production (55.60%), resulting in an income increase of Rs. 4831/ ha from paddy cultivation compared to non-beneficiaries. Challenges such as complexity in land records, lack of knowledge on e-KYC registration process, and access to credit facilities were identified as the factors affecting the participation. Addressing issues related to land records, ease of e-KYC registration and facilitation of address validation and payments/money transfers through involving of post offices can further increase the number of beneficiaries. Thus, PMKISAN assistance had a significant impact on increasing the farm income of small and marginal farmers.

Keywords PMKISAN, impact assessment, cash transfer, direct benefit transfer, and paddy

JEL codes Q120, Q140, Q180

Introduction

To improve crop productivity, development of improved technologies and their adoption by farmers is critical. In India, a higher income to the farmers is constrained by fragmented landholdings, predominance of small and marginal holdings, relatively high cost of inputs, and limited access to credit. With fragmented land area under cultivation, the small and marginal farmers find it difficult to invest in newer technologies (hybrid seeds, farm machineries, fertilizers, etc.,). The lack of credit and limited accessibility are the key factors behind low productivity in the country (Radhakrishna, 2020).

For agricultural development, provision of input subsidy and income support are pivotal. Realizing this fact, the Governments of India has launched a number of schemes with the objectives of providing input subsidy and income support to farmers and induce them to adopt modern technologies and thereby, reaping higher yield and income. The agricultural subsidy incentivizes the farmers to purchase inputs that they are unable to obtain at market rates (Karnik and Lalvani, 1996). The developing countries provide fertilizer and other input subsidies and consider those as pervasive policy instruments for agricultural development (World Bank, 2007). The agricultural support influences farmers' decision-making on crop choices, production practices, adoption of modern technologies and in reduction of production costs (Kumar *et al.,* 2011). The major schemes for the benefits of farmers are: Rashtriya Krishi Vikas Yojana

(RKVY), Pradhan Mantri Krishi Sinchai Yojana (PMKSY), Paramparagat Krishi Vikas Yojana (PKVY), Pradhan Mantri Fasal Bima Yojana (PMFBY), National Mission for Sustainable Agriculture (NMSA), National Food Security Mission (NFSM) and Pradhan Mantri Kisan Samman Nidhi Yojana (PMKISAN). Among the above schemes, PMKISAN Yojana is a Direct Cash Transfer scheme implemented in 2018. It aims at providing social security to the small and marginal farmers in the country through supplementing their financial needs in procuring various inputs like seeds, fertilizer, etc. and to protect them from usurious moneylenders for meeting such expenses. A sum of ₹ 6000 is given in three intervals in a year before the crop seasons (Kharif, Rabi and Summer) through Direct Benefit Transfer mode. This is to provide liquidity to the farm households for meeting their farm-related expenditures and helps boost demand in the rural economy.

Despite widespread provision of farm support as a policy option worldwide for enhancing farm income and higher agricultural production, there is an intense debate on these policies among policymakers, researchers and multilateral trade organisations about the usefulness of such schemes. In this context, this study has analyzed the impact of one of the biggest farm-support policies of Government of India, Pradhan Mantri Kisan Samman Nidhi Yojana (PMKISAN), which is being operated through Direct Cash Transfer, on crop yield and farmers' income.

Methodology

i) Study area

In 2022, the total number of farmers registered under the PMKISAN Yojana were 125 million. The highest number of beneficiaries was registered in the state of Uttar Pradesh, 26.11 lakhs, which is 20.82 per cent of the total beneficiaries, followed by Maharashtra (11.27 lakhs, 8.98%), Madhya Pradesh (8.88 lakhs, 7.08%) and Bihar (8.35 lakhs, 6.66%). The total number of beneficiaries in Tamil Nadu were 4.75 lakhs (3.79%). The percentage of total number of farmers over the total beneficiaries was calculated which could represent the number of farmers that need to be covered under this scheme. As shown in Table 1. the percentage of beneficiaries exceeds the total number of farmers in some states and Union Territories like Andaman and Nicobar Islands, Andhra Pradesh, Assam, Gujarat, Haryana, Manipur, Mizoram, Punjab, Uttar Pradesh and Uttarakhand. The families having joint ownership of land are also eligible for availing the scheme which could be the reason for this highest number. In Manipur the community ownership land was higher in number, whereas in states like Assam, Punjab and Haryana, there was the possibility of reverse tenancy, i.e., large farmers lease-in land of small and marginal farmers, who in turn become the landless labourers (Paramasivam, 2021). The UTs and states like Chandigarh (59.46%), Karnataka (53.28%), Bihar (50.25%), Kerala (44.27%), Tripura (42.66%), Puducherry (32.47%), Lakshadweep (26.86%), Sikkim (19.52%) and Goa (16.09%) have less than 60 per cent beneficiaries of the total operational landholdings. The reason could be incomplete digitisation of land records, and some farmers themselves might have not registered themselves in the scheme.

The study was conducted in state of Tamil Nadu using a multistage random sampling method to select the sample farmers. The districts of Dharmapuri, Thanjavur and Thoothukudi were randomly chosen, representing the North Western, East and Southern parts of the state. The sample adequately represented the geographic and socio-economic diversities of the state so as to provide an overall picture about the farm income. From each district, one block and from each block two villages were selected randomly. The beneficiaries and non-beneficiaries of PMKISAN were identified from each village. The total sample size was 360 households, of which 180 were beneficiaries and 180 were non-beneficiaries. The distribution of sample households is presented in Table 2.

ii) Data

Both primary and secondary data were collected related to the household characteristics, cropping pattern, landholding pattern, consumption expenditure, cost of cultivation, input use and farm income of PMKISAN beneficiaries and non-beneficiaries using the pre-tested interview schedule. The secondary data on subsidies, land-use pattern and crop-wise area coverage were collected from the Assistant Directorate of Agriculture and Horticulture in the respective blocks. The demographic details, agricultural landholdings, infrastructural details, etc. were collected from the District Statistical Handbook and District Census

Table 1 State-wise share of total beneficiaries in PMKISAN Yojana over potential farmers

State	Total No. of beneficiaries	Total No. of marginal and small farmers	Beneficiaries over marginal and small farmers (%)	Total No. of farmers	Ratio of beneficiaries in total farmers (%)
Andaman and Nicobar Islands	17287	7687	224.89	12105	142.81
Andhra Pradesh	5654077	7550285	74.89	3872720	146.00
Arunachal Pradesh	97320	51217	190.02	117208	83.03
Assam	3187456	2363333	134.87	2763199	115.35
Bihar	8358711	15914381	52.52	16634395	50.25
Chandigarh	465	619	75.12	782	59.46
Chhattisgarh	3862781	3313798	116.57	4275064	90.36
Delhi	17164	16925	101.41	21187	81.01
Goa	11439	67555	16.93	71106	16.09
Gujarat	6422871	3634615	176.71	5755642	111.59
Haryana	1956924	1116333	175.30	1638719	119.42
Himachal Pradesh	986004	885660	111.33	1032853	95.46
Jammu and Kashmir	1211475	1346875	89.95	1383621	87.56
Karnataka	5077565	6980864	72.74	9529289	53.28
Kerala	3690226	7514620	49.11	8336203	44.27
Lakshadweep	2619	9843	26.61	9749	26.86
Madhya Pradesh	8881953	7559215	117.50	11133893	79.77
Maharashtra	11271344	12155082	92.73	16871913	66.81
Manipur	477316	125442	380.51	150348	317.47
Meghalaya	198351	183016	108.38	255233	77.71
Mizoram	187664	72446	259.04	87668	214.06
Nagaland	207628	38001	546.38	214653	96.73
Odisha	3760292	4523930	83.12	5064234	74.25
Puducherry	11186	31746	35.24	34452	32.47
Punjab	2341709	361848	647.15	1132872	206.71
Rajasthan	7825342	4748245	164.80	8420796	92.93
Sikkim	13298	57061	23.30	68136	19.52
Tamil Nadu	4752765	7343548	64.72	7757670	61.27
Tripura	242270	552092	43.88	567909	42.66
Uttar Pradesh	26118219	22108231	118.14	24317794	107.40
Uttarakhand	932094	807881	115.38	849960	109.66
West Bengal	4822697	6968653	69.21	7362117	65.51

Source http://pmkisan.gov.in; http://agcensus.dacnet.nic.in/

Table 2 Distribution of Sample Households

Sl. No.	District	Block	PMKISAN	
			Beneficiary farmers	Non-Beneficiary farmers
1.	Dharmapuri	Pennagaram	60	60
2.	Thanjavur	Orthanadu	60	60
3.	Thoothukudi	Karunkulam	60	60
	Total sample		360	

Handbook. The list of PMKISAN beneficiaries was collected from the website: http://pmkisan.gov.in. The field survey was conducted during the year 2021-2022. The descriptive statistics were analysed to understand the behaviour of the demographic variables like age, education level, household size, farm income, consumption behaviour, expenditure on food and non-food items of rural households. The percentage analyses were also carried out to estimate the ratio of beneficiaries to total marginal and small farmers.

iii) Analytical tools

Estimation of impact of PMKISAN based on Propensity Score Matching

The Propensity Score Matching (PSM) is a quasi-experimental method in which the researchers use statistical techniques to construct an artificial control group by matching each benefitted unit with a non-benefitted unit of similar characteristics. In particular, the PSM computes the probability that a unit would enroll in a program based on observed characteristics. This is the propensity score. Then, PSM matches the benefitted units to non-benefitted units based on the propensity score. The PSM relies on the assumption that, conditional on some observable characteristics, non-benefitted units can be compared to benefitted units, as if the benefitted has been fully randomized. In this way, PSM seeks to mimic randomization to overcome the issues of selection bias that plague the non- experimental methods.

The basic evaluation problem comparing outcomes (Y) across the benefitted and non-benefitted individuals (i) can be represented by

$$Y_i = \propto X_i + \beta T_i + \varepsilon_i \qquad \ldots(1)$$

where *T*, is the dummy equal to 1 for those who get benefitted and 0 for those who do not get benefitted. *X* is the set of other observed characteristics of individual household and local environment, ε is the error-term reflecting unobserved characteristics that also affect the outcome variable (crop yield and farmers income). Equation (1) reflects an common approach used in impact evaluations, which is to measure the direct effect of the program (PMKISAN) on outcome variable (*Y*). The estimation problem is that treatment assignment is not often random because of the following reasons: a) purposive program placement and b) self-selection into the program. Programs are often implemented based on the need of the communities, while individuals may self-select into participations. Self-selection could be based on unobserved factors, which are captured in the error term of the estimating equation. Consequently, these unobserved factors may also correlate with the treatment variable T, which cannot be measured and could lead to selection bias i.e., cov (T, ε) ≠ 0. This correlation violates a key assumption of ordinary least squares (OLS): the independence of regressors from the disturbance term ε. Specifically, the correlation between T and ε introduces bias in the estimation equation, including the estimate of the program effect β.

Let Y_i represent the outcome for household i. For benefitted, the value of Y_i under treatment 'T' is represented as Y_i (1). For nonparticipants, Y_i can be represented as Y_i (0). Y_i (0) is used across non-benefitted households as a comparison outcome for benefitted outcomes Y_i (1), the average effect of the program is represented by Equation (2):

$$D = E(Y_i(1)/T_i = 1) - E(Y_i(0)/T_i = 0) \qquad \ldots(2)$$

The problem is that the treated and nontreated groups may not be similar prior to the intervention, so the expected difference between these groups may not be due entirely to program intervention. Equation (2) can be expressed as, Eq. (3)

$$D = E\left(\frac{Y_i(1)}{T_i} = 1\right) - E\left(\frac{Y_i(0)}{T_i} = 0\right) + E\left(\frac{Y_i(0)}{T_i} = 1\right) - E\left(\frac{Y_i(0)}{T_i} = 1\right) \qquad \ldots(3)$$

Here, $E(\frac{Y_i(0)}{T_i} = 1)$ represents the expected outcome for non-beneficiaries.

$$D = ATE + E\left(\frac{Y_i(0)}{T_i} = 1\right) - E(\frac{Y_i(0)}{T_i} = 0) \qquad \ldots(4)$$

$$D = ATE + B \qquad \ldots(5)$$

In Equations (4) and (5), ATE is the average treatment effect, $E\left(\frac{Y_i(1)}{T_i} = 1\right) - E\left(\frac{Y_i(0)}{T_i} = 1\right)$, which represents the average gain in outcomes of beneficiaries relative to non-beneficiaries.

Estimating the impact of PMKISAN using Propensity Score Matching involves three step: i) probit model was used to calculate the propensity score of the respondents ii) these propensity scores are used to match the beneficiaries and the non-beneficiaries through Nearest Neighbor Matching (NNM) iii) the impact of PMKISAN Yojana on crop yield and farm income was measured by estimating the difference between benefitted and non-benefitted groups.

Probit model

The factors influencing the adoption of PMKISAN Yojana were estimated using the probit model. The decision to adopt a new technology is a discrete choice of a farmer, and is assumed to be normally distributed. The Probit model is based on the cumulative normal distribution and utility theory or rational choice perspective on behaviour (Gujarathi, 2022), which assumes that individuals make decisions under certain factors. In this study, the adoption of PMKISAN Yojana was considered to be the dichotomous choice, where the net benefit obtained was higher by beneficiaries than non-beneficiaries. The difference between net benefits of beneficiaries and non-beneficiaries has been denoted as I*, such that I* > 0, indicating that net benefits are higher for beneficiaries than non-beneficiaries. Though, I* is not observable, it can be expressed as a function of observable elements in the following latent variables:

$$I_t^* = \beta Z_i + \mu_i \; I_i = I\,(I_i^* > 0)$$

where, I_i is the dependent variable that equals to 1 for beneficiaries households and is 0 for non-beneficiaries, β is a vector of parameter to be estimated. Z_i is a vector of household and plot-level characteristics and $\mu\text{-}_I$ is the error-term, which is assumed to be normally distributed.

The probability of being a beneficiary can be represented by Equation (6):

$$\Pr\,(Ii = 1) = \Pr\,(I_i^* > 0) = \Pr\,(\mu_i > -Z_i) = 1 - F\,(\beta Z_i) \quad \ldots(6)$$

Where, F is the cumulative distribution function of I_i.

The probability of adoption is estimated using the probit model and expressed as Equation (7):

$$\Pr\,(Y = 1) = \int_{-\infty}^{x\,\beta} \theta(t)dt = \Phi(x'\beta) = \Phi Zi* \quad \ldots(7)$$

where, Φ (x′β) is the cumulative density function, θ is the standard normal distribution, x′ is the vector of independent variable, β is a vector of coefficients to be estimated, and Zi* is the expected value of the latent variable.

It is assumed that Zi* is the vector of variables included in the model. The empirical model [Eq. (8)] used in the study is:

$$Y = a + \beta_1\,Age + \beta_2\,Sex + \beta_3\,Education + \beta_4\,Household\ size + \beta_5\,land\ holding\ size + \beta_6\,income + \beta_7\,farming\ experience + \beta_8\,type\ of\ land\ holding \quad \ldots(8)$$

The estimated β maximizes the likelihood function and is consistent, asymptotically normal and efficient. Rubin and Thomas (1996) had suggested to use all the covariates included in the model to predict the propensity score.

Results and discussion

Descriptive statistics

The descriptive statistics in Table 3 show that several characteristics of beneficiaries of PMKISAN significantly differ from the non-beneficiaries in terms of age, education level, income, experience and type of landholding, while the mean value of some characteristics like household size, landholding size and sex were found to be insignificantly different between the two groups. The average age of the farmers was 48.89 (47.21 ±11.73) years for non-beneficiaries and 47.71 (50.66 ±11.95) years for beneficiaries. It was found that the beneficiaries were more educated and more experienced than non-beneficiaries. The experience in terms of age was found to have a positive effect on the adoption of subsidy programme (Varma 2019). In case of landholding, about 92.78 per cent of PMKISAN beneficiaries had their own land and 7.22 per cent had both owned and leased-in lands, while among non-beneficiaries only 62.78 per cent had their owned land, 25.55 per cent had leased-in land and 11.67 per cent had both owned and leased-in lands.

Cost of paddy cultivation

The cost of paddy cultivation was calculated for both beneficiaries and non-beneficiaries of PMKISAN (Table 4). The cost met from PMKISAN Yojana help was excluded while calculating cost of cultivation for beneficiaries. The results indicate that the paddy yield was slightly higher for beneficiaries (47.50 q/ha) than non-beneficiaries (46.50 q/ha). The average cost of paddy cultivation of beneficiaries (₹ 64594/ha) was less than non-beneficiaries (₹ 67924/ha). Consequently, the average net returns were more among the

Table 3 Descriptive statistics of sample households

Variables	PMKISAN beneficiaries (n=180)		PMKISAN non-beneficiaries (n=180)		Combined Value (n=360)		t-test/ χ^2 test (p-value)
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	
Age (years)	50.66	11.95	47.21	11.73	48.89	11.94	0.075*
Education level (years of schooling)	7.18	3.49	6.08	3.21	6.65	3.39	0.041**
Household size (No.)	3.45	1.46	3.75	1.41	3.61	1.44	0.191
Landholding size (ha)	6.14	3.90	6.51	4.73	6.33	4.34	0.593
Income (₹)	37661	15152	47405	26307	42660	22043	0.005***
Farm experience (years)	26.89	17.15	23.43	17.51	25.11	17.37	0.021**
Sex[a]							
Male	144 (80)		152 (84.44)				0.668
Female	36 (20)		28 (15.56)				
Type of landholding[a]							
Owned	167 (92.78)		113 (62.78)				0.008**
Leased-in	-		46 (25.55)				
Both owned and leased-in	13 (7.22)		21 (11.67)				

[a] Proportion (per cent) of the sample. ***, ** and * denote significance at 1 per cent, 5 per cent and 10 per cent levels, respectively.

Table 4 Cost of paddy cultivation for beneficiaries and non-beneficiaries of PMKISAN Yojana

(₹/ha)

Particulars	PMKISAN Yojana	
	Beneficiaries*	Non-beneficiaries
Operational cost		
Seed	1450 (2.24)	1880 (2.77)
FYM	3200 (4.95)	3630 (5.34)
Fertilizers	6600 (10.22)	7060 (10.39)
Plant protection chemicals	2900 (4.49)	3507 (5.16)
Human labour	24850 (38.47)	25587 (37.67)
Machine labour	7500 (11.61)	8000 (11.78)
Interest on working capital	3487 (5.40)	3759 (5.53)
Total operational cost	49987 (77.39)	53879 (78.65)
Fixed cost		
Land tax	12 (0.02)	12 (0.02)
Rental value of land	13000 (20.13)	13000 (19.14)
Depreciation	513 (0.79)	415 (0.61)
Interest on fixed capital	1082 (1.68)	1041 (1.58)
Total fixed cost	14607 (22.61)	14501 (21.35)
Total cost	64594 (100.00)	67924 (100.0)
Yield (q/ha)	47.50	46.50
Gross income (₹/ha)	87875	86025
Net returns (₹/ha)	23281	18101
Benefit and cost ratio	1.36	1.27

Source Authors' estimations (Figures within the parentheses indicate percentage to total cost)

Note *The cost of inputs purchased using PMKISAN Yojana Nidhi was not included beneficiaries (₹ 23281/ha) than non-beneficiaries (₹ 18101) and the benefit-cost ratio was also higher for the beneficiaries (1.36) than non-beneficiaries (1.27). In the total cost, the share of human labour was highest in both beneficiaries (39.40%) and non-beneficiaries (37.67%). It was followed by the cost on machine labour, 11.35 per cent for beneficiaries and 11.78 per cent for non-beneficiaries. Paul et al. (2020) had also stated that human labour had the highest share in cost of paddy cultivation.

Impact of PMKISAN Yojana on Yield and Income of Paddy farmers in Tamil Nadu

To estimate the impact of PMKISAN Yojana on crop yield and income of beneficiaries, the Propensity Score Matching (PSM) was used. The value of log-pseudolikelihood ratio test was found to be 67.77, indicating a significant model-fit and the results have been presented in Table 5. The results indicate that age, education level, landholding size, income and experience were all statistically significant. The age had a positive impact on the beneficiaries of this scheme. The age factor was found to have a role in decision-making on doing multiple enterprises in farming. The elderly farmers were aware about different programmes and schemes of the state and central governments. The education level had a positive influence on the household to be a beneficiary, as education level prompts the households on adoption of newer technologies (Schultz, 1981; Xia et al, 2019).

Table 5 Results of Probit estimation for impact of PMKISAN Yojana beneficiaries in Tamil Nadu

Variables	Coefficient	Std. Error	P-Value
Sex	0.065	0.556	0.906
Age	0.036**	0.017	0.039
Education	0.078**	0.036	0.037
Household size	-0.000	0.086	0.992
Landholding size	-0.091*	0.529	0.083
Income	-0.000***	0.000	0.003
Experience	0.023*	0.013	0.077
Type of landholding	-0.109	0.245	0.655
Constant	0.036	1.172	0.975
Pseudo R^2			0.27
log-pseudolikelihood			67.77

Source: Authors' estimation. ***, ** and * denote significance at 1 per cent, 5 per cent and 10 per cent levels..

To avail the benefits of the scheme, a registration process is involved and therefore, higher the education level of a households, higher was involvement with the scheme. The farming experience also revealed a positive significance. The landholding size has shown a negative significance, indicating that the increase in farm area would reduce the chances of being a beneficiary. Based on the NSO data, it was found that with increase in the farm area, there was an increase in the share of income among the households (Chakravorty et al. 2019). Findings are similar (Winters et al., 2009) in different countries where the land scarcity is a bigger issue. Thus, bigger the landholdings may require lesser income support. Similarly, income also had a negative significance.

The impact of the cash transfer was estimated by the Average Treatment Effect (ATE) using the Nearest Neighbour Matching (5-Nearest Neighbours). The area of common support was derived using the propensity score within the range of lower- and upper-bound estimated values for the households. The estimated propensity score distribution revealed that the common support area with and without adopters of PMKISAN expanded from 0.08 to 0.94 (Fig. 1). The propensity score of untreated group ranges between 0.1 and 0.6, whereas the propensity score of treated group ranges between 0.2 and 0.8 indicating a significant overlap. The distribution of the propensity scores and overlaps in the histogram is a clear indication that the propensity scores between PMKISAN Yojana of beneficiaries and non-beneficiaries were within the region of common support. Apart from this, propensity score matching method aims at balancing the covariates before and after the matching process.

The covariate balancing before and after the matching process is depicted in Table 6. All the non-benefitted households (i.e., 180) and 167 of 180 benefitted households were used in the matching process. Given, those common support and propensity score, the nearest neighbour matching (5-Nearest Neighbours) was estimated and the statistical significance was tested using the t-values (Becker and Ichino, 2002) and the results are presented in Table 7. The results indicate that there was an increase in both farm income and yield among the beneficiaries. The beneficiaries could receive an additional income of ₹ 4831/ ha from paddy cultivation as compared to the non-beneficiaries. Similarly, yield was also found to be higher (1.30 quintals) for the beneficiaries.

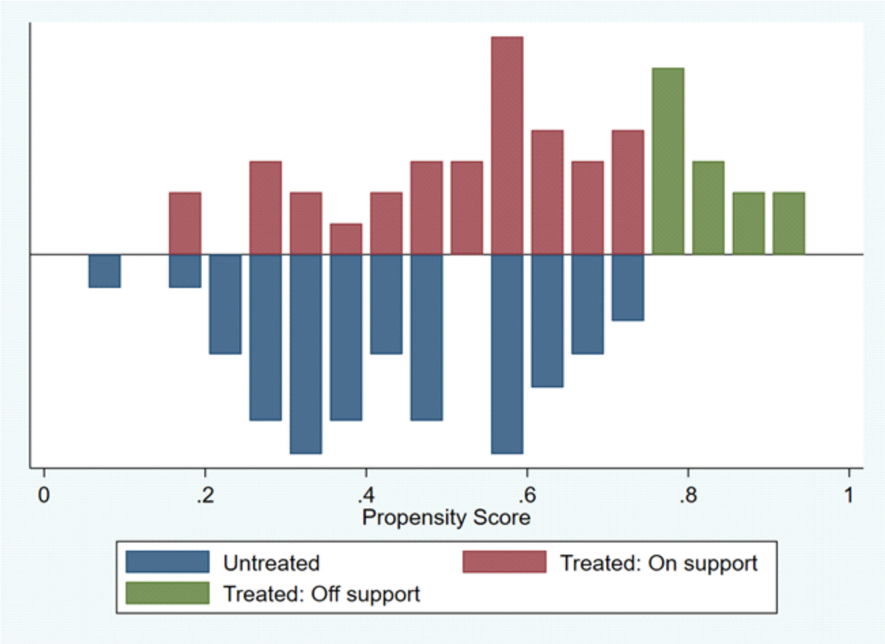

Figure 1 Common support graph showing distribution of propensity score between beneficiaries and non-beneficiaries of PMKISAN Yojana

Table 6 Covariate balancing before and after matching process

Variables	Unmatched (Mean)	Matched (Mean)	Bias Reduction (%)	P-Value
Sex	1.21	1.31	-7.7	0.118
Age	53.72	51.72	80.0	0.046*
Education	6.17	5.97	45.0	0.029**
Household size	3.27	3.07	50	0.034*
Landholding size	7.37	6.97	15	0.012**
Income	40372	41000	46.5	0.038*
Experience	24.70	23.70	34.2	0.090
Type of landholding	1.23	1.13	21	0.072

Source Authors' estimation. ***, ** and * denote significance at 1 per cent, 5 per cent and 10 per cent levels.

Table 7 Average Treatment Effect

Matching Algorithm	Outcome	Average Treatment Effect	Std. Error	P-Value
Nearest neighbor matching (5-NNM)	Income (Rs.)	4831.52	274.367	0.078
	Yield (q)	1.30	0.178	0.000

Source Authors' estimation

Utilization pattern of amount received under PMKISAN Yojana

A sum of ₹ 6000 is provided to farmers in three installments directly into the bank accounts of PMKISAN Yojana beneficiaries. It was found that majority of beneficiaries received cash on time in three installments but some who had enrolled recently in the scheme received the entire amount in a single installment. The utilization pattern of the cash transfer is presented in Table 8. The first installment of

Table 8 Utilization pattern of PMKISAN Yojana Nidhi

Utilization pattern	No. of beneficiaries 1st installment	No. of beneficiaries 2nd installment
Crop Production	84 (46.67)	40 (22.23)
Livestock rearing	68 (37.78)	62 (34.44)
Household consumption	16 (8.89)	72 (40.00)
Others	12 (6.67)	6 (3.33)
No. of total beneficiaries	180	180

Source Authors' estimation (Figures within the parentheses indicate percentage to total)

PMKISAN assistance was utilized by most of the beneficiaries for crop production (46.67%), followed by livestock rearing (37.78%), household consumption (8.89%) and other purposes (6.67%). The second installment was utilized by most of the beneficiaries for household consumption (40%), followed by livestock rearing (34.44%), crop production (22.23%) and other purposes (3.33%). The household consumption included expenditures on maintenance of sprayers and farm machineries. The expenditure on livestock included the spendings on the purchase of poultry birds and goats for rearing purposes. The findings are based on the data collected during the study period, which covered only the first two installments of PMKISAN Yojana. Although, the third instalment was not included, the utilization pattern of first two installments highlights that spending was made towards crop production and livestock rearing.

Table 8 revealed that Pradhan Mantri Kisan Samman Nidhi Yojana was utilized maximum on crop production, therefore the pattern of spending was studied and the results are presented in Table 9. Of the total PMKISAN assistance (₹ 6000), about 55.5 per cent (₹ 3300) was spent for cultivation purposes. Most of the beneficiaries had spent this amount for purchasing seeds and fertilizers and paying wages to human and animal labour. About ₹ 1100 (18.33%) was spent for purchasing of seeds, followed by human labour wages (15.83%), 12.50 per cent was spent on purchase of fertilizers (₹ 750) and machine labour wages (8.83%). Overall, the results indicated that due to Pradhan Mantri Kisan Samman Nidhi Yojana, the cost of cultivation was lower by ₹ 3330/ha for beneficiaries than non-beneficiaries growing paddy. As discussed in Table 4, the average net returns were higher for the beneficiaries by ₹ 5180/ha.

Table 9 Utilization pattern of PMKISAN Yojana Nidhi in total cost of cultivation

Sl. No.	Particulars	Amount (Rs.)
1.	Purchase of seeds	1100 (18.30)
2.	Purchase of fertilizer	750 (12.50)
3.	Human labour wages	950 (15.83)
4.	Machine labour wages	530 (8.83)
Total cash transfer spending (₹)		3330 (55.60)
Total cash transfer (₹)		6000 (100.00)
Additional net returns gained by the beneficiaries (₹)		5180

Source Authors' estimation (Figures within the parentheses indicate percentage to total cash transfer)
Note Utilization pattern was calculated for the first two installments only

Net benefits of farmers by PMKISAN Yojana

We also estimated the net benefits obtained by the PMKISAN Yojana beneficiaries in cost of cultivation. The average spending of beneficiaries from PMKISAN assistance was on crop production (₹ 3330/ha) and the remaining ₹ 2670 was spent towards consumption. Based on NSSO Report No 587 (GoI, 2019), about 56 per cent of the agricultural households in India were cultivating paddy crop and the average gross cropped

Table 10 Net benefits of PMKISAN Yojana beneficiaries (Paddy) in Tamil Nadu

Sl. No.	Particulars	PMKISAN Yojna
1.	Total number of beneficiaries in Tamil Nadu	4752765
2.	Number of registered beneficiaries cultivating paddy crop	2661548*
3.	Average GCA under paddy (ha/ household)	0.61
4.	Average paddy area cultivated by beneficiaries (ha)	1623544
5.	Average spending of Nidhi for crop production by beneficiaries (₹/ha)	3330.00
6.	Difference in net income of PMKISAN Yojna beneficiaries and non-beneficiaries (₹/ha)	5180.00
7.	Total spending by the Government of India (₹ in crores)	159.68
8.	Total benefit realized by beneficiaries on paddy farmers in Tamil Nadu (₹ in crores)	208.93
	Ratio	1.30

Source Authors' estimation; Note: 56 per cent of the beneficiaries were considered as paddy farmers
Note *Number of paddy growers was estimated based on the NSSO report

area under paddy crop per household was 0.61 ha. While Tamil Nadu comprises about 4.32 per cent of the total area under paddy cultivation. However, paddy occupies about 39.6 per cent of Tamil Nadu's net sown area. Thus, the net benefit estimated for PMKISAN Yojana beneficiaries for Tamil Nadu is presented in Table 10. Of the total 47 lakh beneficiaries, 26 lakh (56%) were considered as paddy growers based on the NSSO report. The Government spending towards paddy growing PMKISAN beneficiaries was estimated and the average expenditure was ₹ 159.69 crores. The additional income earned by paddy-growing PMKISAN beneficiaries was ₹ 5180/ha. The total net benefit realized by the beneficiaries was ₹ 208.93 crores. Thus, the ratio of total expenditure to total benefit realized was 1.30.

Conclusion

The impact of Pradhan Mantri Kisan Samman Nidhi Yojana (PMKISAN) has been assessed on crop yield and farmers' income. The findings have revealed that marginal and small farmers are the major beneficiaries of the PMKISAN Yojana with 55.60 per cent of the PMKISAN assistance being utilized for crop production. The majority of beneficiaries utilize this amount for the purchase of seeds, fertilizers, and paying wages to human and machine labour, resulting in an income increase of Rs. 4831/ ha from paddy cultivation as compared to the non-beneficiaries. The study has also found that most of the PMKISAN Yojna non-beneficiaries have complexity in maintaining their old land records and challenges in e-KYC registration due to lower education level. To address these challenges, involvement of post offices in validation of addresses and payment of amount has been recommended. The study concludes that PMKISAN Yojna Nidhi had a significant impact on increasing the farm income of small and marginal farmers in Tamil Nadu.

Acknowledgment

This paper is part of the Ph.D. thesis of the first author, submitted to the School of Post Graduate Studies of Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu. The author is thankful to the Indian Council of Social Science Research, New Delhi for providing financial assistance under its Full-Term Doctoral Fellowship Scheme. The author is also thankful to the anonymous reviewers for their valuable comments.

References

Becker, SO, and A Ichino. 2002. Estimation of average treatment effects based on propensity scores. *The stata journal* 2(4):358-377. https://doi.org/10.1177/1536867X0200200403.

Chakravorty, S, S Chandrasekhar, and K Naraparaju. 2019. Land distribution, income generation and inequality in India's agricultural sector. *Review of Income and Wealth* 65:182-203. https://doi.org/10.1111/roiw.12434.

Gujarathi, DM. 2022. *Gujarati: Basic Econometrics*: McGraw-hill.

GoI, 2019. Department of Agriculture and Co-operation, Ministry of Agriculture and Farmers Welfare. All India report on number and area of operational holdings. https://agcensus.nic.in/document/agcen1516/T1_ac_2015_16.pdf.

Karnik, A, and M Lalvani. 1996. Interest groups, subsidies and public goods: Farm lobby in Indian agriculture. *Economic and Political Weekly*:818-820. https://www.jstor.org/stable/4403965.

Kumar, A, P Kumar, and AN Sharma. 2011. Rural poverty and agricultural growth in India: Implications for the twelfth five year plan. *Indian Journal of Agricultural Economics* 66 (902-2016-67326). doi: 10.22004/ag.econ.204751.

Paramasivam, RM. 2021. Fish consumption in India: probability and demand. *Agricultural Economics Research Review* 34(1):103-110. http://dx.doi.org/10.5958/0974-0279.2021.00008.2.

Paul, KSR, GP Sunandini, S Irugu, and K Suhasini. 2020. "Farm level technical efficiency ofpaddy production in Andhra Pradesh: An empirical evidence from the cost ofcultivation survey data." Economic Affairs 65 (4):659-663.

Radhakrishna, R. 2020. Towards inclusive agricultural development: growth performance, welfare challenges and policy innovations. *Indian Journal of Agricultural Economics* 75 (1):1-28. http://isaeindia.org/wp-content/uploads/2020/06/IJAE-VOL.75-NO.1.pdf.

Rubin, DB, and N Thomas. 1996. Matching using estimated propensity scores: relating theory to practice. *Biometrics*:249-264. https://doi.org/10.2307/2533160.

Schultz, TPX. 1981. *Economics of population*: Reading, MA: Addison-Wesley.

Varma, P. 2019. Adoption and the impact of system of rice intensification on rice yields and household income: an analysis for India. *Applied Economics* 51(45): 4956-4972. https://doi.org/10.1080/00036846.2019.1606408.

Winters, P, B Davis, G Carletto, K Covarrubias, EJ Quiñones, A Zezza, C Azzarri, and K Stamoulis. 2009. Assets, activities and rural income generation: Evidence from a multicountry analysis. *World development* 37 (9):1435-1452. https://doi.org/10.1016/j.worlddev.2009.01.010.

World Bank. 2007. *World development report 2008: Agriculture for development*: The World Bank.https://openknowledge.worldbank.org/entities/publication/ba969388-b5eb-5155-b8f2-6d323a6e5a52.

Xia, D, M Zhang, Q Yu, and Y Tu. 2019. Developing a framework to identify barriers of Green technology adoption for enterprises. *Resources, Conservation and Recycling* 143:99-110. https://doi.org/10.1016/j.resconrec.2018.12.022.

Received 19 June 2024 Accepted 21 November 2024

Agricultural Economics Research Review 2024, 37 (2), 249-260
DOI: 10.5958/0974-0279.2024.00018.8

Evaluating India's apple exports: An analysis of comparative advantage

Eva Sharma[1], Sumit Sutradhar[2]*, Jyoti Kachroo[1], and Anil Bhat[1]

[1]Division of Agricultural Economics and Agri Business Management, Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu, Jammu and Kashmir–180009, India
[2]Division of Agricultural Economics, ICAR-Indian Agricultural Research Institute, New Delhi–110012, India

*Corresponding author: sumitsutradhar2816@gmail.com

Abstract The paper comprehends the export performance of Indian apples, with the aim to discern the country's comparative advantage in the global apple trade. Based on the data sourced from United Nations Commodity Trade Statistics Database and Agricultural and Processed Food Products Export Development Authority, the study has comprehended Revealed Comparative Advantage (RCA) and Revealed Trade Advantage (RTA) indices. The study has highlighted that the rate of increase in apple exports has been relatively lower compared to its imports. This disparity suggests a trade disadvantage for the country, leading to a potential loss of competitiveness in the global apple trade market. This diminishing position can be ascribed to the rising imports and diminishing exports of apples, impacting India's competitiveness negatively at the global level. Consequently, there is an urgent need of concerted and targeted initiatives to enhance India's rank globally and reclaim the erstwhile state in the apple trade. The study has suggested some measures also for boosting apple export from India.

Keywords Apple trade, Revealed Comparative Advantage, RCA, Revealed Trade Advantage, RTA, Revealed Competitiveness, RC, Export performance, India

JEL codes F10, F13, F14, Q17

Introduction

In the realm of Indian horticulture, a substantial segment of the total output is dedicated to the cultivation of fruits and vegetables, constituting a significant proportion (90%). India, as the world's second-largest producer of fruits and vegetables, followed closely behind China, proudly bears the title, "fruit basket of the world" (Lone and Sen 2014; Choudhary and Kundal 2015). The nation has also solidified its position as a major exporter of fresh fruits and vegetables, with a noteworthy export volume of 33.76 lakh tonnes, valued at approximately ₹ 11 thousand crores during the fiscal year 2021-22 (APEDA 2021-22). India is the world's sixth-largest producer of apples (2021) and second largest in terms of its area (Ram and Jahanara 2023). On the other hand, India was at the 8th position internationally in terms of apple output (in terms 2 of weight) and at 69th in terms of yield in 2018, as per the FAO data 2020. After bananas, oranges, and grapes, apples are the fourth most widely produced fruit in the world (Ram and Jahanara 2023).

The emergence of apples in the international trade scenario has brought them into the spotlight within the global fruit economy. The Union Territory of Jammu and Kashmir plays a pivotal role in this narrative, contributing significantly to India's apple production—clocking in at 77 per cent. The Union Territory's escalating percentage share in India's total production has led to its designation as the "Agri. Export Zone for Apples." A total of USD 10 million worth of apples are exported from India each year, of which USD 5 million comes from the state of Jammu and Kashmir, which directly or indirectly employs 1.2 million people. Jammu and Kashmir has the maximum average yield in the nation, produces 67 per cent of all fruit (apples) and 50 per cent of the nation's exports, making it a significant foreign exchange earner and key to the economic progress (Parrey and Hakeem 2015). The apple fruit industry generates the majority of the state's revenue and employs 3.5 million people. About 30 million people in the state, or 500,000–600,000 families, are involved in apple farming either directly or indirectly (Wani et al. 2021). India's foray into the global apple market has been marked by a substantial growth, positioning the country as a remarkable player. In the fiscal year 2021, Indian apple exports amounted to around 30 thousand tonnes, a significant surge from the previous year's 25 thousand tonnes. The Ministry of Commerce data further illustrates an 82% increase in India's apple exports since 2014, facilitating Kashmiri apple growers in expanding their market presence globally. In terms of value, the apple exports have seen an upward trajectory, jumping from USD 8.6 million in 2014-15 to USD 14.45 million in 2020-21. The fiscal year 2022 continued this positive trend, with India's apple exports reaching approximately 32 thousand tonnes.

The rationale for this study arises from the significant role of the apple industry in India's economic development and its expanding footprint in global markets. Despite the notable growth in exports, gaps remain in understanding the specific drivers and bottlenecks that influence India's export performance in the apple sector. Previous studies (Mehta et al. 2013; Islam and Srivastava 2017; Wani and Songara 2017; Shah 2019; Hassan and Bhattacharjee 2022) have focused primarily on production aspects, leaving a critical gap in trade performance analysis, particularly in exploring India's comparative advantage, market competitiveness, and the potential for value chain improvements. This investigation fulfils this gap by systematically evaluating India's export performance and identifying the areas for strategic interventions to enhance competitiveness in the global apple trade. The study also provides insights for policymakers and stakeholders, fostering sustainable growth in the apple export sector of the country.

Materials and methods

Data Source

The data was gathered from the secondary sources, including the Agricultural and Processed Food Products Export Development Authority (APEDA) and the United Nations Commodity Trade Statistics Database (UN Comtrade) for the period 1998 to 2022. The global numerical product classification system known as the Harmonized System code was utilized for the data collection and it was HS08. This code specifically covers edible fruits and nuts. It incorporates apple (HS080810 for edible fresh apples), which was the primary commodity for our research.

Analytical Tools

To understand the direction of trade, the Revealed Comparative Advantage (RCA) and Revealed Trade Advantage (RTA) indices were employed to assess

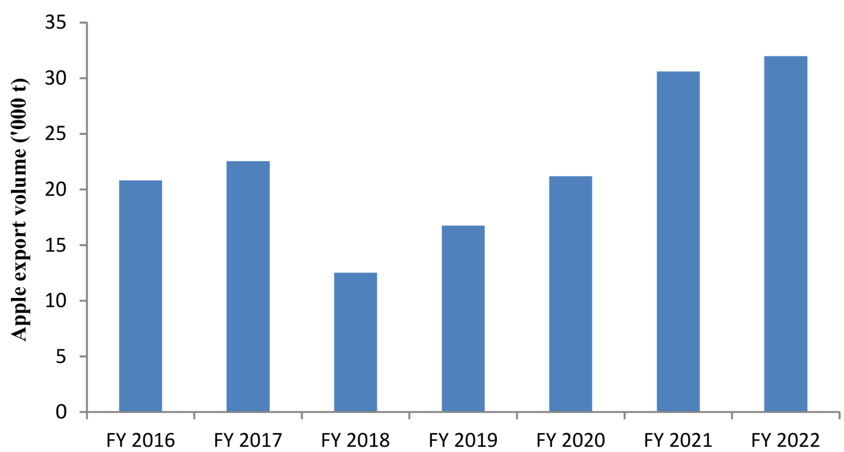

Figure 1 Volume of Indian apples exported during 2016 to 2022

India's advantages in the apple trade. These indices, though widely used, are subject to limitations such as size bias, asymmetry (Stellian and Danna-Buitrago 2022), lack of additivity, and sensitivity to exchange rate fluctuations and trade barriers (Chakrabartty and Sinha 2022). Despite these limitations, RCA-RTA indices remain a common tool for evaluating the export performance of various commodities globally.

Balassa (1965) was the first to introduce the RCA index, which can be expressed as Equation (1):

$$B = \frac{x_{ij}}{x_{it}} \Big/ \frac{x_{nj}}{x_{nt}} \qquad \ldots(1)$$

where, X is the apple exports, i stands for India, j is the apple, t is a set of commodities of HS08 and n is a set of apple-exporting countries in the world.

The RCA index is a metric that evaluates a country's exports of a specific commodity in relation to its total exports and the corresponding exports from a group of nations. This comparison helps determine the comparative advantage of a country's economy. An RCA value greater than 1 suggests that the country is in a comparatively advantageous position in trading that specific product, while an RCA less than 1 indicates a revealed comparative disadvantage.

Advancing the comprehension of comparative advantage, Vollrath (1991) offered additional insights and formulated measures to assess global agricultural competitiveness, expanding on his prior works in Vollrath (1987, 1989). One of these alternative formulations is Relative Trade Advantage (RTA), which considers both imports and exports. The RTA is calculated as the difference between the relative export advantage (RXA) and the relative import advantage (RMA), i.e.

$$RTA = RXA - RMA \qquad \ldots(2)$$

where, RXA is the B (Balassa's index) or RCA .

$$\text{and } RMA = \frac{m_{ij}}{m_{it}} \Big/ \frac{m_{nj}}{m_{nt}} \qquad \ldots(3)$$

where, m represents imports.

Thus, from Equations (1) and (3), we get Equation (4):

$$RTA = \frac{x_{ij}}{x_{it}} \Big/ \frac{x_{nj}}{x_{nt}} - \frac{m_{ij}}{m_{it}} \Big/ \frac{m_{nj}}{m_{nt}} \qquad \ldots(4)$$

The Revealed Comparative Advantage is evident when both RTA and RXA surpass zero. To maintain symmetry across the origin, Vollrath introduced the second measure as the logarithmic function of relative export advantage (ln RXA). The third factor, known as revealed competitiveness (RC), was articulated as the disparity between logarithmic export and import benefit functions (Equation 5)

$$RC = \ln RXA - \ln RMA \qquad \ldots(5)$$

The revelation of a competitive advantage in the trade of a specific commodity occurs when the value of RC exceeds zero.

Results and Discussions

Relative Import Advantage of India in Apple trade from 1998 to 2022

In the domain of agricultural exports, "Relative Import Advantage" signifies the benefit a country gains by importing specific agricultural inputs, resources, and goods from other nations that have a comparative advantage in producing those commodities.

The RMA values as in Table 1 reveal that the RMA remained nearly about 0.00 from 1998 to 2000, indicating minimal imports of apples during that period. However, from 2000, there was a consistent upward trend in apple imports until 2008, where the RMA values surpassed the value of 1. This indicates advancements in apple imports for India, signifying a profitable scenario for the nation and since 2009, the situation has remained favourable. The highest RMA value was recorded in 2021 at 2.07, followed by 1.86 in 2022.

The probable factor behind the increasing apple imports in recent years could be attributed to the implementation of the "New Trade Policy" in 2015. This policy aimed to enhance the "ease of doing business" by easing various trade barriers and offering import duty rebates. This aligns with findings of Bhat and Bahadur (2018), who observed a surge in apple imports following the elimination of quantitative restrictions. This surge surpassed exports, growing twofold between 2008 and 2010. Furthermore, the trend continued with a 33.95% increase in imports in 2017, while exports experienced a decline of -42.51% in the same year.

Table 1 Relative Import Advantage of India in Apple Trade from 1998 to 2022

Years	Apple Import (India) (million US$)	Apple Import (World) (million US$)	HS08 Import (India) (million US$)	HS08 Import (World) (million US$)	Relative Import Advantage (RMA)
1998	0.001	2747.09	390.04	33614.70	0.00
1999	1.28	2768.63	415.26	34180.03	0.04
2000	3.14	2461.57	435.34	31852.32	0.09
2001	8.13	2703.16	252.00	32507.99	0.39
2002	13.02	2929.68	362.23	36181.49	0.44
2003	13.24	3685.44	446.89	43122.25	0.35
2004	9.90	4142.76	608.36	48711.31	0.19
2005	21.22	4135.20	787.56	54452.64	0.35
2006	23.48	4700.26	780.05	59652.18	0.38
2007	52.96	5812.24	834.42	68827.13	0.75
2008	64.28	6453.34	1171.24	80005.20	0.68
2009	82.98	5462.36	1102.36	74717.10	1.03
2010	121.29	6019.00	1315.99	81193.36	1.24
2011	185.57	6820.13	2091.52	93828.66	1.22
2012	196.12	7311.20	1856.83	94864.22	1.37
2013	211.52	8232.80	2162.31	105121.98	1.25
2014	234.38	7624.40	2566.37	110803.74	1.33
2015	209.94	7438.58	3042.95	111507.09	1.03
2016	237.80	7424.14	2802.50	114771.84	1.31
2017	307.66	7600.21	3427.02	123465.51	1.46
2018	298.32	7619.19	3772.30	130827.51	1.36
2019	243.95	7200.02	3074.99	132819.74	1.46
2020	201.31	7405.19	3195.67	137250.82	1.17
2021	377.43	7613.66	3657.87	152427.68	2.07
2022	314.34	4684.19	4417.58	122248.51	1.86

Source Agriculture and Processed Food Products Export Development Authority (APEDA); United Nations Commodity Trade Statistics Database (UN Comtrade)

Revealed Comparative Advantage of India in Apple Trade from 1998 to 2022

An analysis of the trend of Indian apple exports over the study period (1998-2022) involved computing the RCA (values T_2), as detailed in Table 2 and illustrated in Figure 2**.**

The RCA index remained close to 0.00 from 1998 to 2001, reaching its lowest point of 0.01 in 2001. Subsequently, the RCA values fluctuated between highs and lows until 2017, after which a consistent upward trend was observed, peaking at 0.23 in 2022. Therefore, despite the overall increase in export volume over the years, India has not yet achieved a significant comparative advantage in global apple exports. This aligns with the findings of Balamurugan (2013) and Dev et al. (2022), who reported a decline in revealed comparative advantage (RCA) for crops such as apples, coffee, cashews, and nuts. According to a study by Krishnan (2023), there has been a declining trend in India's comparative advantage over the past forty years (1980-2021) with RCA value of 0.13 in 1980, which declined to 0.043 by 2021. The underlying reasons for this trend may stem from the data provided by the Directorate of Horticulture, Kashmir, indicating that apple production remained relatively stable over the past one decade, with quantities of 1852.41 thousand tonnes (2010-11) and 2026.47 thousand tonnes (2019-20).

Table 2 Revealed comparative advantage of India in Apple export from 1998 to 2022

Years	Apple Export (India) (million US$)	Apple Export (World) (million US$)	HS 08 Export (India) (million US$)	HS 08 Export (World) (million US$)	Revealed Comparative Advantage (RCA)
1998	2.38	2587.16	491.15	29430.08	0.06
1999	2.05	2587.92	723.63	29345.64	0.03
2000	1.26	2278.69	606.10	27936.33	0.03
2001	0.35	2458.85	541.81	28844.60	0.01
2002	5.53	2817.78	584.59	31102.66	0.10
2003	1.80	3486.05	527.51	37399.03	0.04
2004	7.09	3928.56	687.59	42044.99	0.11
2005	7.72	3907.67	868.30	48562.94	0.11
2006	7.88	4415.81	855.43	52400.95	0.11
2007	7.76	5593.64	873.45	59532.76	0.09
2008	12.04	6386.59	1133.23	68967.12	0.11
2009	6.73	5510.35	1035.36	66243.93	0.08
2010	13.07	6349.41	1088.70	74454.03	0.14
2011	14.77	7193.47	1448.10	86648.61	0.12
2012	10.43	7105.57	1389.59	86572.56	0.09
2013	13.61	8069.80	1676.46	97216.98	0.10
2014	5.72	7597.47	1632.90	103863.94	0.05
2015	6.78	7050.99	1484.47	102491.83	0.07
2016	5.39	7209.93	1596.32	108685.26	0.05
2017	3.68	7565.20	1840.23	117743.82	0.03
2018	5.88	7624.53	1533.64	122715.74	0.06
2019	9.81	6985.28	1486.75	125661.64	0.12
2020	14.06	7305.22	1313.53	129008.40	0.19
2021	14.35	7494.31	1526.83	133711.09	0.17
2022	21.35	6457.85	1448.37	102813.43	0.23

Source Agriculture and Processed Food Products Export Development Authority (APEDA); United Nations Commodity Trade Statistics Database (UN Comtrade)

Despite consistent production levels, the RCA index hovered around 0.05 until 2018, after which it increased beyond 0.10. This suggests that the demand for Indian apples may have remained stagnant or declined, possibly influenced by the presence of more competitive exporters in the international markets. Another plausible explanation for the decreasing demand could be the inferior quality of the produce or Indian apples not meeting the necessary export standards in terms of quality and safety.

Relative Trade Advantage of India in Apples from 1998 to 2022

The RTA index, derived from the comparison of the RCA ratio to the RMA ratio, serves as an indicator of comparative advantage. The relative trade advantage plays a crucial role in shaping trade policies and promoting economic growth and efficiency on a global scale. During analysis, it was observed that the only instance of our apple exports surpassing imports, occurred in 1998 (0.06 > 0.00), resulting in a slightly advantageous trade scenario. However, in the early years of the study period, the RTA values were slightly negative, with figures of -0.01 in 1999, -0.07 in 2000, and -0.08 in 2004. Over the years, the RTA values exhibited a declining trend, with the RA index remaining below a negative value of 1 till 2009. In 2010, it declined to -1.10, maintaining similar levels due to a sharper increase in imports compared to exports. The lowest RTA index was recorded in 2021

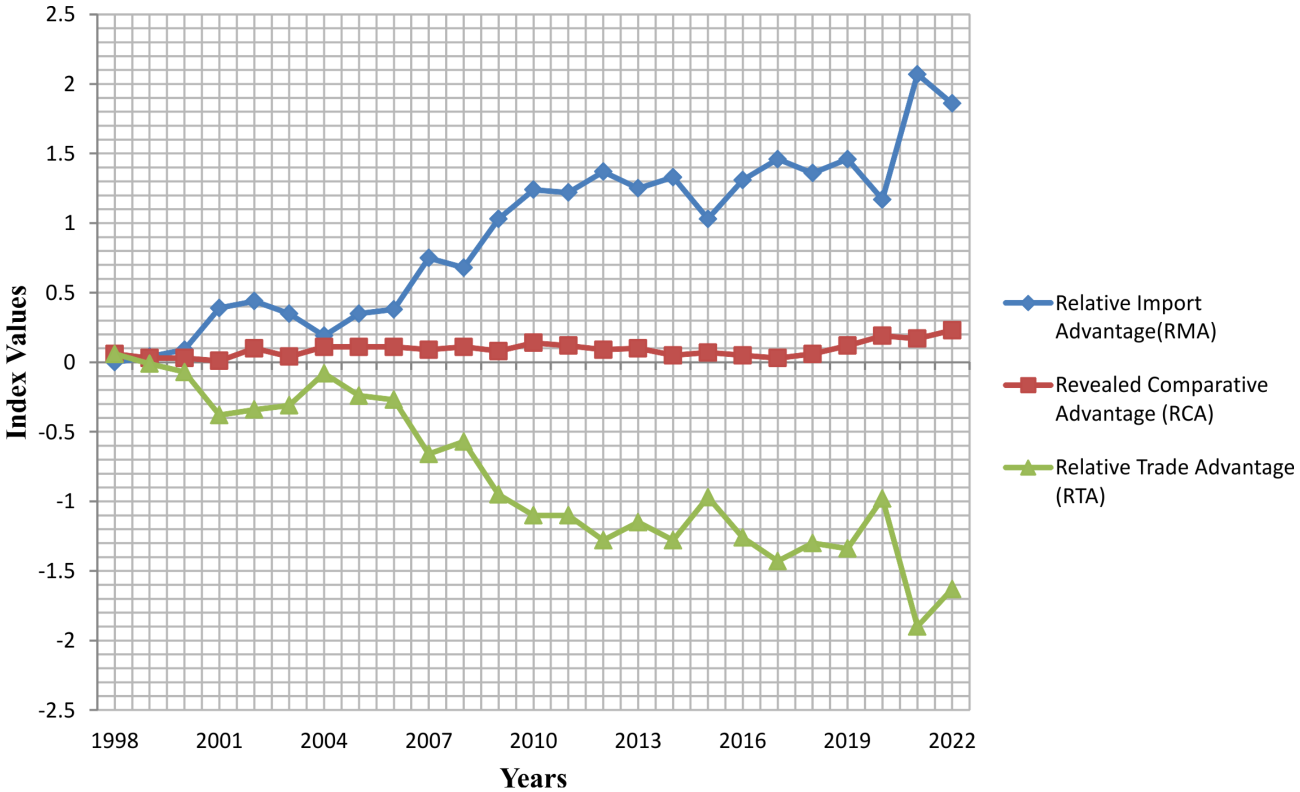

Figure 2 Trade Indices for Indian Apples (1998-2022)

at -1.90, with the RMA reaching its highest value of 2.07 during that year. Despite a modest improvement in 2022, with the RCA index reaching its highest at 0.23 and RMA at 1.86, the RTA value remained negative at -1.63.

Various factors may underlie the observed trends in RTA during the study period of 1998-2022. One potential factor could be the high domestic demand for apples, leading to an upswing in imports. Alternatively, advancements in the apple industry, particularly for processing purposes, might have necessitated a greater supply of raw materials. It is also conceivable that a combination of these factors contributed to the observed changes. Consequently, India's erstwhile dominant position weakened as other global producers started exerting influence on the global apple trade.

Relative Competitiveness of India in Apple Trade from 1998 to 2022

Table 3 elucidates the relative competitiveness of India in apple trade from 1998-2022. By encompassing the natural logarithm of RCA and RMA values, the relative competitiveness offers insights into a country's trade competitiveness at global level. As depicted in Table 3 and Figure 3, the year 1998 stands out with an RC value of 7.27, signifying that India was highly competitive and held a comparative advantage in the apple trade (given that RC > 0 implies a comparative advantage in trade). However, starting from 1999, the RC index (-0.17) turned negative and then continued to decrease. Subsequent years witnessed significant fluctuations in the RC values, indicating a substantial decline in the trade competitiveness of Indian apples. Overall, there was a nearly stagnant trend in the RC values from 2001 to 2011, reaching its lowest point in 2001 at -3.94, followed by -3.85 in 2017, and -3.32 in 2014. These findings suggest a persistent and substantial reduction in the trade competitiveness of Indian apples during the specified period.

The potential factors contributing to this situation may include minimal changes in the area and production of Indian apples over the past one decade, coupled with a decline in apple quality leading to lower costs in

Table 3 Revealed competitiveness of India in Apple Trade from 1998 to 2022

Years	ln RMA	ln RCA	Revealed Competitiveness (RC)
1998	-10.1683	-2.89747	7.27
1999	-3.26856	-3.43656	-0.17
2000	-2.37181	-3.66701	-1.30
2001	-0.94686	-4.88672	-3.94
2002	-0.82098	-2.30259	-1.48
2003	-1.05954	-3.30725	-2.25
2004	-1.65361	-2.20319	-0.55
2005	-1.03627	-2.2022	-1.17
2006	-0.96258	-2.21458	-1.25
2007	-0.28564	-2.36009	-2.07
2008	-0.38523	-2.1651	-1.78
2009	0.028732	-2.5493	-2.58
2010	0.217704	-1.96064	-2.18
2011	0.198851	-2.1128	-2.31
2012	0.314587	-2.39381	-2.71
2013	0.221574	-2.32646	-2.55
2014	0.282533	-3.03987	-3.32
2015	0.033194	-2.714	-2.75
2016	0.270744	-2.97732	-3.25
2017	0.378436	-3.46781	-3.85
2018	0.30783	-2.78666	-3.09
2019	0.377815	-2.13304	-2.51
2020	0.157004	-1.68154	-1.84
2021	0.727549	-1.77196	-2.50
2022	0.620576	-1.46968	-2.09

Source Table 1 Relative Import Advantage of India in Apple trade from 1998 to 2022; Table 2 Revealed comparative advantage of India in Apple Export from 1998 to 2022

international markets compared to other nations. According to World Population Review 2023 records, India ranks fifth globally in apple production, producing 2872 thousand tonnes, surpassing France (1819760 t) and Chile (1759420 t). However, when comparing apple production with export values, despite the substantial production difference, both France and Chile exceeded India in apple trade. France exported apples worth US$402.2 million; Chile had an export value of US$573.2 million, while India's apple trade value stood at US$21.3 million (UN Comtrade). This underscores the notion that one can command higher pricing for its products in the market, even with lower volume, provided it offers a superior quality. Similar indications of diminished competitiveness were highlighted by Balamurugan (2013), who pointed out that higher transportation costs, lower productivity, and poor quality of major fruits, including apples, significantly impacted India's competitiveness in global markets.

Underlying causes of trade disadvantage in apple industry of India

This study revealed a concerning trend of declining apple exports from India, juxtaposed with a consistent increase in imports. To understand the underlying causes of this trade disadvantage, several critical factors need to be considered. These factors broadly encompass production inefficiencies, quality issues, market access challenges and trade policies.

Production inefficiencies and technological limitations

Despite its significant contribution to the economy of Jammu and Kashmir (J&K) and India, the apple

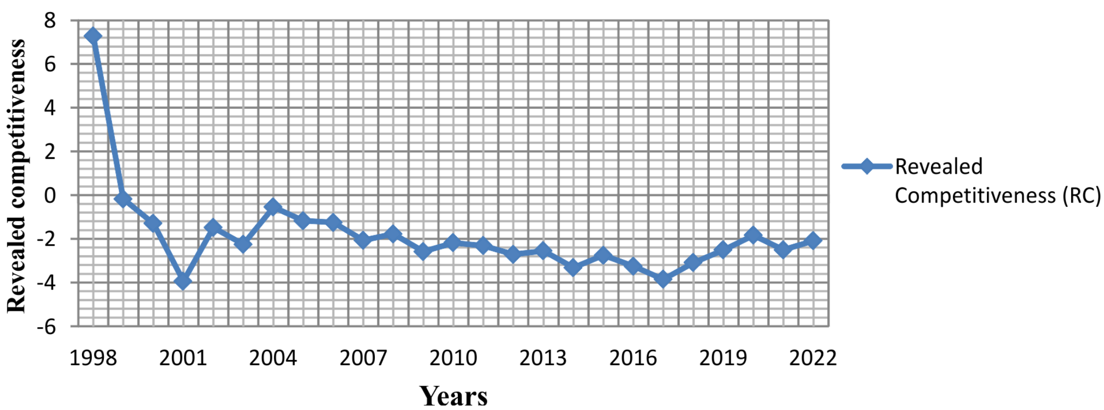

Figure 3 Revealed Competitiveness of India in apple trade (1998-2022)

industry suffers from the limitations in technology and economies of scale. The inefficient production practices result in suboptimal yields and inconsistent quality, making Indian apples less competitive in the international markets (Krishnan 2023). India's apple productivity is lower than of other countries. In 2020, it was reported that China, with ~40.5 million tonnes (47%) (Fotiric Aksic et al 2022), was the leading producer of apples with 58% of total world production, followed by USA (6%), Turkey (3.61%), India (3%), and Iran (2%) (Wani et al 2021). It was estimated that average productivity of apple fruit in India was nearly 6–8 t/ha, much lower than that of other countries, viz. Belgium (46.22 t/ha), Denmark (41.87 t/ha), and the Netherlands (40.40 t/ha) (FAO 2018). The root causes of low productivity, as identified, include socioeconomic factors (11.1%), access to credit (4.2%), infestation of pests and diseases (0.05%), technology awareness (0.9%), access to extension services (2.0%), and access to market (3.5%) (Shah et al. 2022).

In the state of Jammu and Kashmir itself, there are fluctuations in the yield of apples: the average yields of different cultivars vary from 11t/ha to 13 t/ha (Wani et al. 2021) which is much less compared to the yield in other countries, viz. China (17.96 t/ha), the United States (27.85 t/ha), Germany (25.40 t/ha), Italy (40.11 t/ha), France (43.98 t/ha), and the world average (15.49 t/ha) (Wang et al. 2016). However, in such congenial agro-climatic conditions, the potential yield could be increased to 40–70 t/ha, which is the indication of enormous gaps between actual production and the production capacity of apple crops in the state (Shah et al. 2022).

Quality issues

The quality of Indian apples is adversely affected by inadequate infrastructure facilities like cold storage and the supply chain inefficiencies. A poorly-developed cold chain infrastructure limits the ability to preserve apples post-harvest, leading to spoilage and compromises quality, making it far behind the European standards (Hassan et al. 2021). This not only affects the export potential but also diminishes consumer confidence in domestic apples (USDA Report 2022).

Market access challenges

The access to market for Indian apples is hindered by logistical barriers and an inefficient supply chain. The multiple intermediaries inflate costs and reduce farmers' share in revenue, weakening their ability to invest in quality improvements. The marketing system of apples in Jammu and Kashmir is largely disorganised primarily due to the lack of proper attention to the sector, despite contributing significantly to the state economy (Bhat and Choure 2014). Additionally, limited distribution capabilities restrict the movement of apples to different regions, reducing their visibility and competitiveness on a global scale (Singh et al. 2015).

Consumer preferences, income disparities, and trade competition

The trade policies of India do not adequately shield the domestic apple producers from the influx of imported apples, particularly from Turkey and Iran. The imported apples, often priced competitively and perceived to be of higher quality, attract consumers from middle and high-income groups who are willing to pay a premium price for taste, nutrition and aesthetic appeal (Lê and Pagès 2010; Balraj 2016). This consumer preference further erodes the market share of domestic apples.

In India, the high-income consumers tend to prefer a diverse range of fruits, including imported apples, due to their perceived superior quality. Middle and lower-income groups, constrained by price sensitivity, often opt for more affordable fruit options such as bananas and mangoes (Kavitha et al. 2016). The price remains a critical factor influencing consumer decisions, with imported apples sometimes viewed as offering better value for money despite their higher cost (Beag and Singla 2014; Wani et al. 2015).

Structural issues in apple supply chain

A fragmented and inefficient supply chain exacerbates the trade disadvantage. The lack of cold-storage facilities, poor price-risk distribution among the growers and contractors, lack of proper market information among the farmers, and negligible value-addition in the supply chain plagues the growth of apple production in the Kashmir valley (Malik, 2013). The lack of adequate cold chain infrastructure and food processing units prevent the reach of apples to markets in best condition. Consequently, the domestic apples have to compete with imported apples that enjoy the benefit of superior supply chain management and consistent quality (Pandey et al. 2013; Chaudhary et al. 2016). These factors, driven by the lack of competition in the marketing system, insufficient investment and the marketing and price risks growers face, also undermine the competitiveness of domestic produce. As a result, the exports of locally-grown apples are constrained, while reliance on imports from other nations increases (USDA, 2006)

Future outlook

The future outlook for India's apple trade is promising with significant growth potential driven by a combination of domestic and international factors. The investments in technological advancements, such as cold chain infrastructure and modern storage facilities, are expected to enhance the product quality, extend shelf-life, and improve distribution efficiency, bolstering both domestic consumption and export opportunities. However, the impact of climate change on apple-growing regions like Jammu and Kashmir and Himachal Pradesh is becoming visible and requires growers to adopt more sustainable and climate-resilient farming practices, while exploring new areas for cultivation. The global market, increasingly shaped by the shifting consumer preferences for healthier, organic produce, presents opportunities for India to tap into premium segments, especially as domestic incomes rise and urbanization continues. The geopolitical factors and changing international trade dynamics, including new sustainability standards and regulatory frameworks, will also play a pivotal role in India's export potential. By aligning with global market trends, such as increasing demand for eco-friendly and traceable produce, India can enhance its competitiveness against established exporters like China and the EU. The integration of research and innovation into India's apple industry, focusing on better varieties and improved farming techniques, will further solidify its position in the global market and ensure its long-term growth.

Conclusions and policy implications

Using the RCA-RTA indices, the study has distinctly indicated a consistent decline in apple export from India since 1998. This diminishing position can be ascribed to the rising imports and diminishing exports of apples, impacting India's competitiveness negatively at the global level. Consequently, there is an urgent need of concerted and targeted initiatives to enhance India's rank globally and reclaim the erstwhile state in the apple trade. Achieving this goal may entail the implementation of a thoughtfully designed export policy. Therefore, the study has made following recommendations:

Boost Export Markets and Trade Partnerships — The study has indicated a surge in apple imports, therefore, India must actively explore and strengthen trade relations with the potential markets. The key regions such as the Middle East and Southeast Asia present significant opportunities. Nepal and Bangladesh have been identified as high potential partners for Indian apple trade followed by U.A.E, Oman, Saudi Arabia, Qatar, Bahrain, Kuwait, Maldives, and Singapore (Krishnan 2023). Further, a focus on niche markets like Bhutan and Sri Lanka can help diversify and stabilize apple exports.

Improve Infrastructure and Cold Chain Facilities — The Investments in modern storage, refrigeration, and transportation systems would improve the supply chain efficiency, reduce wastages, and enhance India's export potential. The adoption of advanced technologies for packing and sorting can ensure quality aspects of apple fruit.

Adopt Sustainable and Climate-Resilient Practices — The India's apple industry must transit towards environment-friendly and climate-resilient farming practices. This involves investing in water-efficient irrigation, organic farming, and adopting practices that reduce the carbon footprints of apple production. The international markets, especially in Europe and North America, are increasingly prioritizing sustainability certifications and traceability. There is a need to invest on R&D of climate-resilient apple varieties to help mitigate the risks posed by climate change.

Enhance Product Quality and Standardization — India should invest on the development of high-yield, pest-resistant apple varieties that may suit both domestic conditions and international market demands. The adherence to global certification standards (e.g., GlobalGAP) and improvement in the consistency of apple size, colour, and taste would ensure competence of Indian apples with established exporters like China, the EU, and the US.

References

APEDA (Agricultural and Processed Food Products Exports Development Authority). 2021-22. India export of agro food products. https://agriexchange.apeda.gov.in.

Ahmad, R, H Barkat, and A Tariq. 2021. Fresh and dry fruit production in Himalayan Kashmir, sub-Himalayan Jammu and trans-Himalayan Ladakh, India. *Heliyon* 7(1): e05835. http://dx.doi.org/10.1016/j.heliyon.2020.e05835

Beag, F A, and N Singla. 2014. Cointegration, Causality and Impulse Response Analysis in Major Apple Markets in India. *Agricultural Economics Research Review* Vol.27, No.2, pp.289-298. DOI: http://dx.doi.org/10.5958/0974-0279.2014.00032.9.

Balamurugan P. 2013. Revealed comparative advantage of the Indian fruits-An analysis. *Indian Journal of Economics* (373):319-354. https://www.researchgate.net/publication/356144668_Revealed_Comparative_Advantage_of_the_Indian_Fruits_-_An_Analysis

Balassa B. 1965. *Trade liberalisation and "revealed" comparative advantage 1*. The Manchester School of Economics & Social Studies 33(2):99-123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x

Balraj, N. 2016. Issues and Challenges in the Supply Chain of Fruits and Vegetables Sector in India: A Review. *Splint International Journal of Professionals* Vol.3, No.8, pp.113. http://dx.doi.org/10.5121/ijmvsc.2015.6205

Bhat A A and R Bahadur. 2018. Growth, import and export strength of J&K apple in India. *International Journal of Research and Analytical Reviews*, 5(4): 669-675. https://ijrar.com/upload_issue/ijrar_issue_20542440.pdf

Bhat TA, T Choure. 2014. Status and strength of apple industry in Jammu and Kashmir. *International Journal of Research*. 1(4):277-283. https://journals.pen2print.org/index.php/ijr/article/download/64/48

Chakrabartty, S N, and D Sinha. 2022. Composite Revealed Comparative Advantage Index: A Non-parametric Approach. *Eurasian Journal of Business and Economics 15*(30), 25-44. https://ejbe.org/EJBE2022Vol15No30p025-CHAKRABARTTY-SINHA.pdf

Choudhary K and R Kundal. 2015. A study on area, production and yield of tomatoes in India from 2002 to 2011. *International Journal of Advance Research in Computer Science and Management Studies* 3(7):90-93. https://ijarcsms.com/docs/paper/volume3/issue7/V3I7-0025.pdf

Chaudhary, R, J Yasmin, M Piyush, and V Tushar. 2016. An Analytical Study of Apple Marketing Channels in Himachal Pradesh, India. *International Journal of Bio-Resource and Stress Management* Vol.7, No.2, pp.291-294. http://www.pphouse.org/admin/uploadpdf/17%20IJBSM%20April-16%20Chaudhary%20et%20al.pdf

Dev K, D Raj, R Sharma, and A Guleria. 2022. Performance and prospects of agricultural commodities in India: An economic analysis. *Indian Journal of Economics and Development* 18(3):655-663. http://dx.doi.org/10.35716/IJED/22005

FAO-Food and Agriculture Organization of the United Nations (FAO). 2018. *Production Year Book* Rome, Italy. https://scholar.google.com/scholar_lookup?title=Production+Year+Book&author=FAO-Food+and+Agriculture+Organization+of+the+United+Nations+(FAO)&publication_year=2018

Fotiric Aksic, M.; Dabic Zagorac, D.; Gasic, U.; Tosti, T.; Natic, M.; Meland, M. 2022. Analysis of Apple Fruit (Malus_domestica Borkh.) Quality Attributes Obtained from Organic and Integrated Production Systems. *Sustainability* , *14*, 5300. https://doi.org/10.3390/su14095300

Hassan B, M Bhattacharjee and S Wani. 2021. Post-harvest management inadequacy and its impact on apple industry in Kashmir. International Journal of Applied Research and Studies 20(7):246-250. DOI: https://doi.org/10.22271/allresearch.2021.v7.i5d.8577

Hassan B, M Bhattacharjee and S A Wani. 2022. Determinants of Apple Production among Agricultural Households in India. *Indian Journal of Economics and Development 10*(1): 1-10. https://doi.org/10.17485/IJED/v10.2021.272

Islam R T, & S Shrivastava. 2017. A Study on Area, Production and Productivity of Apples in J&K from 2006-07 to 2015-16. *International Journal of Scientific Research and Management 5*(7): 6513-6519. DOI: 10.18535/ijsrm/v5i7.90

Kavitha V, M Umanath, R Paramasivam and K Chandran. 2016. Determinants of Consumption Probability and Demand for Fruits in India. *Agricultural Economics Research Review* Vol.29 (Conference Number) 2016, pp.161-170. DOI: 10.5958/0974-0279.2016.00043.4.

Krishnan G. 2023. A study on International trade of apple of India. M.Sc. Thesis, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. J&K. India. https://krishikosh.egranth.ac.in/handle/1/5810210338

Lê S, and J Pagès. 2010. DMFA: Dual Multiple Factor Analysis. *Com Stat The Meth* Vol.39, pp.483-492, DOI: https://doi. org/10.1080/03610920903140114.

Lone R A and V Sen. 2014. Centrality of agriculture to inclusive growth in India. *Asian Journal of Research in Social Sciences and Humanities* 4(5):127-147. https://www.indianjournals.com/ijor.aspx?target=ijor:ajrssh&volume=4&issue=5&article=012

Malik ZA. 2013. Assessment of apple production and marketing problems in Kashmir valley. *Journal of Economic & Social Development* 9(1):152-156. https://www.researchgate.net/publication/202143242_Assessment_of_Problems_and_Prospectus_of_Apple_production_Marketing_in_Kashmir_Valley

Mehta P, R K Thakur and & S Chauhan. 2013. Production and Marketing of Apple Fruit Crop-a Study Premise to Shimla District of Himachal Pradesh, India. *International journal of Bio-resource and Stress Management 4*(4): 610-613. https://www.indianjournals.com/ijor.aspx?target=ijor:ijbsm&volume=4&issue=4&article=024

Pandey M, G A Baker and D T Pandey. 2013. Supply Chain Re-engineering in the Fresh Produce Industry: A Case Study of Adani Agrifresh. *International Food and Agribusiness Management Review* Vol.16, No.1, pp.113-134. http://dx.doi.org/10.22004/ag.econ.144676

Parrey, S H and I A Hakeem. Exploring marketing activities of apple growers: empirical evidence from Kashmir. *Pacific Business Review International* 7(12): 73-74. http://www.pbr.co.in/2015/2015_month/June/9.pdf

Ram K and M Jahanara. 2023. Constraints and Suggestions Regarding Training Need Assessment of Apple Growers in Mandi District of Himachal Pradesh. *Asian Journal of Agricultural Extension*, *Economics & Sociology* 41: 39-46. https://doi.org/10.9734/ajaees/2023/v41i71941

Shah I A. 2019. Trend analysis of area, production and productivity of apple fruit in Jammu and Kashmir. *Journal of Gujarat Research Society 21(15):*601-611. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3519662

Shah Z A, M A Dar, E A Dar, C A Obianefo, A H Bhat, M T Ali, M El-Sharnouby, M Shukry, H Kesba, & S Sayed. 2022a. Sustainable Fruit Growing: An Analysis of Differences in Apple Productivity in the Indian State of Jammu and Kashmir. *Sustainability 14*(21), 14544. https://doi.org/10.3390/su142114544

Shah Z A S, M A Dar, E A Dar, R Mir, M T Ali. 2022b. Technological Gap in Recommended Practices of Apple Cultivation in Kashmir Valley. *Indian J. Ext. Educ. 58*, 158–162. https://doi.org/10.48165/IJEE.2022.58238

Statista. 2022. Volume of fresh apples exported from India between financial year 2016 and 2022. https://www.statista.com.

Stellian R, and J P Danna-Buitrago. 2022. Revealed comparative advantage and contribution-to-the-trade-balance indexes. *International Economics 170*, 129-155. https://doi.org/10.1016/j.inteco.2022.02.007

Singh B, B K Sikka and S P Singh. 2015. Enhancing Global Competitiveness of Indian Apple: Investigating the Value Chain Perspective. *Acta Hortic* 1099: pp.525-532 DOI: 10.17660/ActaHortic.2015.1099.64. https://doi.org/10.17660/ActaHortic.2015.1099.64.

United Nations Commodity Trade Statistics Database (UN Comtrade). 2022. Trade Data. https://comtradeplus.un.org/TradeFlow

USDA (United States Department of Agriculture) 2006. Prospects for India's Emerging Apple Market. https://www.ers.usda.gov/webdocs/outlooks/37020/29556_fts31901_002.pdf?v=3722

USDA-FAS (United States Department of Agriculture, Foreign Agricultural Service). 2022. India: Fresh deciduous fruit annual. https://fas.usda.gov/data/india-fresh-deciduous-fruit-annual-3#:~:text=Link%20to%20report%3A&text=India's%20domestic%20apple%20and%20pear,tons%20(MT)%2C%20respectively

Vollrath T L. 1991. A theoretical evaluation of alternative trade intensity measures of revealed comparative advantage. *Weltwirtschaftliches Archiv* 127(2):265-280. https://doi.org/10.1007/BF02707986

Vollrath T L. 1987. Revealed competitive advantage for wheat. Staff Reports 277915. US Department of Agriculture, Economic Research Service, International Economics Division. DOI: 10.22004/ag.econ.277915. https://ideas.repec.org/p/ags/uerssr/277915.html

Vollrath T L. 1989. Competitiveness and protection in world agriculture (No. 567). *Agricultural Information Bulletins* 309494. US Department of Agriculture, Economic Research Service. DOI: 10.22004/ag.econ.309494. https://ideas.repec.org/p/ags/uersab/309494.html

Wang N, J Wolf, F S Zhang. 2016. Towards Sustainable Intensification of Apple Production in China-Yield Gaps and Nutrient Use Efficiency in Apple Farming Systems. *J. Integr. Agric. 15*, 716–725. DOI: 10.1016/S2095-3119(15)61099-1.

Wani M H, R K Paul, N H Bazaz and M Manzoor. 2015. Market Integration and Price Forecasting of Apple in

India. *Indian Journal of Agricultural Economics* Vol.70, No.2, April-June, pp.169181. https://isaeindia.org/wp-content/uploads/2020/11/01-Article-MH-Wani.pdf

Wani F, & M Songara. 2017. Production and Marketing of Apple in Himachal Pradesh: An Empirical Study. *International Journal of Research Culture Society 1*(10): 34-40. https://www.researchgate.net/profile/Firdoos-Wani/publication/322276315_Production_and_Marketing_of_Apple_in_Himachal_PradeshAn_Empirical_Study/links/5a4fb8b6aca2725638c3c9cf/Production-and-Marketing-of-Apple-in-Himachal-PradeshAn-Empirical-Study.pdf

Wani S A, K Shiv, N Farheen, F A Shaheen, J W Fehim, and U R Haseeb. 2021. Potential of Apple Cultivation in Doubling Farmer's Income through Technological and Market Interventions, An Empirical Study in Jammu & Kashmir. *Indian Journal of Agricultural Economics* 76(2): 278-291. https://isaeindia.org/wp-content/uploads/2021/07/05-Shabir-Wani.pdf

Received 16 January 2024 Accepted 25 November 2024

Agricultural Economics Research Review 2024, 37 (2), 261-269
DOI: 10.5958/0974-0279.2024.00020.5

Environmental efficiency of pork supply chains originating from Punjab

Simran Kaur* and Jasdev Singh

Department of Economics and Sociology,
Punjab Agricultural University, Ludhiana, Punjab–141004, India

*Corresponding author: simranmohal24@gmail.com

Abstract The study has provided an analysis of the marketing efficiency in relation to environmental efficiency of pork supply chains originating from Punjab. By selecting two distinct markets [local and distant (North-Eastern India)], the study has revealed that an inverse relationship exists between the length of pork supply chain and its marketing efficiency. Further, a direct relationship has been found between marketing efficiency and environmental efficiency. Amount of CO_2 released during the delivery of one kilogram of pork in the distant market was nearly double (35-37 kg) of that released in the local supply chains (15-20 kg). Thus, it is suggested that sustainable supply chains of pork should be promoted.

Keywords Environmental efficiency, Marketing efficiency, Pork Supply chains, Punjab

JEL codes Q13, Q56, L11, R41

Introduction

The piggery sector has a significant potential to contribute towards the development of Indian livestock sector. It is a profitable venture which provides food security, livelihood and numerous other economic benefits. Pig production requires less inputs, has higher fecundity, better feed-conversion efficiency, shorter maturity period and shorter generation interval in comparison to other livestock species. However, the country has not been able to fully exploit the potential of this enterprise yet. For a long time, the pig production has remained confined to the North-Eastern parts of the country (Chauhan *et al.*, 2016). In Punjab, the pig farming gained impetus during the previous decade and is being regarded as one of the most lucrative livestock business ventures (Bhadauria *et al.*, 2019).

Different piggery supply chains involving different agents are found to exist in the country, which include commission agents, wholesalers, processors, traders/exporters, slaughterers, transporters, etc. These middlemen directly impact the overall marketing efficiency of the supply chains. Several studies have found that marketing activities also act as a source of emissions of numerous greenhouse gases. The post-farm activities including transportation, packaging and refrigeration emit greenhouse gases which further lead to global warming (GLEAM, FAO, 2010).

Globally, extensive research has been conducted to study the impact of different supply chain agents and activities on the marketing efficiency and climate change. However, very few studies have been carried out in India where marketing efficiency has been evaluated in relation to the climate impact of different supply chains. With this backdrop, the present study was formulated with the following objectives: (i) identification of different pig/pork supply chains in Punjab, (ii) estimating marketing efficiency of identified supply chains, and (iii) analysis of climate impact of different pig/pork supply chains in relation to marketing efficiency.

Material and methods

With consultation of experts and different stakeholders involved, two markets were identified where the pigs

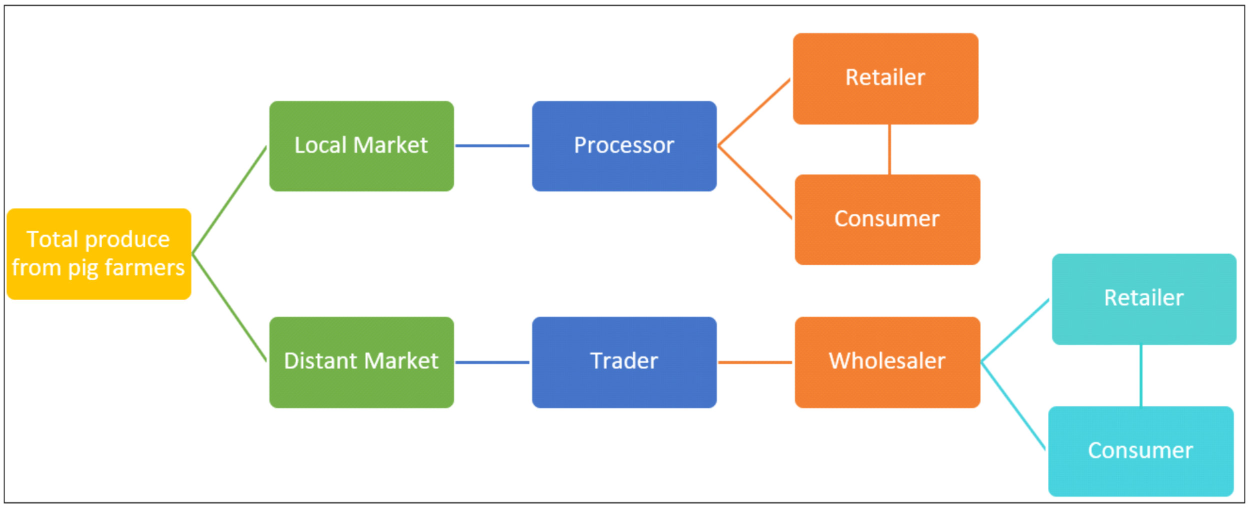

Figure 1 Identified supply chains for pork produced in Punjab

reared by the Punjab-farmers were disposed off. These were mainly local and some distant markets, particularly in Dimapur, Nagaland. Using simple random sampling and snowball sampling techniques, a sample of different stakeholders consisting of 30 farmers, 5 traders, 5 wholesalers (distant market), 10 processors (local market) and 15 retailers (10 local retailers and 5 distant retailers) was selected from the identified markets/supply chains.

Using semi-structured questionnaires and personal as well as telephonic interviews method, primary data was collected from the selected respondents for the reference year 2022-23. The information collected comprised of socio-economic characteristics of respondents, piggery-related cost and return structure, disposal pattern, prices, marketing costs and margins. The information regarding type and volume of energy used at various stages of pork supply chain, manure production during transportation, packaging material, etc. was also collected from the respondents.

Marketing efficiency (ME) was estimated using Acharya's method (Acharya and Aggarwal, 2020) and environmental impact was assessed by calculating Global Warming Potential (GWP) (GHG Platform, India, 2022). These methods have been briefly described below.

Live-retail weight equivalent and modified price received

Since different supply chains involve supply of live pigs as well pork and the form of entity (here pig) for sale changes at different stages of a supply chain, a measure is needed to compare live weight with meat weight. For this purpose, a live retail weight equivalent was calculated, which was the amount of live animal required to produce one kilogram of retail weight. Since a pig's entire live weight is not equivalent to its meat weight and some components are removed in the form of certain by-products and waste, this concept was used to convert price received by an agent for the live weight of a pig to gross price received.

Further, as the total value of an animal is the sum of the value of its meat as well as its by-products, the retail weight equivalent overestimates the gross value of meat as it does not consider the value of by-products during estimation. Therefore, the gross price received was further converted to modified net price received by subtracting the value of by-product. The by-product value here refers to the value of all the by-products such as various internal organs, fat, etc. which are not sold directly in the meat marketing channels (Ross, 1984; Hahn, 2004). The following formulae (1) and (2) were used in the study:

$$GPR = eqr \times FP \qquad \ldots(1)$$

$$Ppm = GPR - BPV \qquad \ldots(2)$$

where,

GPR = Gross price received by farmer/ trader for live pigs (₹/kg live weight)

eqr = Retail weight equivalent (unitless)

FP = Net price received by farmer/trader for live pigs (₹/kg live weight)

Ppm = Modified net price received by farmer/trader (₹/kg live weight)

BPV = By-product value (₹/kg live weight)

The modified net price received was further used to work out the marketing costs, margins and price spread in the identified supply chains.

System boundaries

The GHG emissions were calculated starting from the farm gate till the point where raw pork reached the consumers. The emissions occurring during cooking and storage of pork by the consumer were not included in the system boundary.

Functional unit

The functional unit considered for GHG emissions was 1 kg pork.

Activity data

Activity data refers to the data regarding the use or production of different emitters such as petrol, diesel, LPG, electricity, manure and polyethene.

Emissions from use of diesel, petrol, LPG and electricity

The activity data obtained during data collection was processed by making unit conversions. The activity data for transportation fuel in litres was converted into kilograms by using relationship (3):

Mass = Density × Volume …(3)

The density of petrol and diesel was taken to be 840 kg/m^3 and 747.5 kg/m^3, respectively (transportpolicy.net 2022). The activity data of electricity obtained in kilowatt hour (kWh) was converted into kg coal by using the relationship (1 kWh = 0.51 kg coal) as suggested by Energy Information Administration (EIA, 2022).

Further, the GHG emissions from the use of petrol, diesel, LPG and electricity were estimated using relationship (4) proposed by GHG platform, India:

$Emissions_{Gas} = Activity\ Data_{Emitter} \times NCV_{Emitter} \times Emission\ Factor_{Gas}$ …(4)

where,

$Emissions_{Gas}$ = Emissions of CO_2 or CH_4 or N_2O in tonnes

$Activity\ Data_{Emitter}$ = Amount of emitter used in kilotonnes (kt)

$NCV_{Emitter}$ = Net Calorific Value in terajoules per kilotonnes (TJ/kt)

$Emission\ Factor_{Gas}$ is the representative value of amount of GHG emitted on combustion or production of 1 unit of emitter in tonnes/ TJ. The net calorific value and emission factors of some emitters are given in Table 1.

Emissions from manure production

Manure is produced when the animals are in transit during marketing process. The emissions from the production of manure during marketing were calculated using Equation (5):

1 Animal = 1 kg CH_4/ year …(5)

It was noted that the average waiting period from farm gate till an animal was slaughtered by a processor in the local market and wholesaler in the distant market varied among different supply chains. The information regarding the same gathered during primary data collection is presented in Table 2.

Table 1 Net calorific value and emission factors of various emitters

Fuel	NCV (TJ/kt)	Emission Factor (tonnes/TJ)		
		CO_2	CH_4	N_2O
Diesel	43.00	74.10	3.90	3.90
Petrol	44.30	69.30	33.00	3.20
LPG	47.30	63.10	5.00	0.10
Non-coking coal (electricity)	17.09	96.76	1.00	1.40

Source GHG Platform, India, 2022; IPCC, 2022

Table 2 Waiting period of pigs during marketing before slaughtering

Sr. No.	End user/ slaughtering agent	Waiting period
1.	Processor (local market)	15 days
2.	Wholesaler (distant market)	12 days

Source Primary data collected by authors

Emissions from packaging

Polyethylene is the commonly used packaging material for wholesale and retail sales in India. As per IPCC guidelines, the production of polyethylene is a source of emission of methane. Therefore, emissions from the use of polythene during packaging were calculated using the relation that 1.73 tonne carbon dioxide (CO_2) and 3 kg of methane (CH_4) are released from the production of one tonne of ethylene (IPCC, 2022). For calculation purposes, the weight of polythene bag of 1 kg capacity was taken as 4 grams.

Emissions from refrigeration

The emissions from the leakage of refrigerant act as a source of GHG emissions when refrigerated vehicles are used for transportation. Since, temperature-controlled vehicles are not used for transportation in pork supply chains of Punjab, the emitter holds no significance in the current context.

Global warming potential and environmental efficiency

The Global Warming Potential (GWP) refers to the amount of energy that one tonne of gas can absorb over a given period of time relative to the emissions of one tonne of CO_2. This concept was used to arrive at the single representative value which gives an estimate of total emissions. It is a measure of environmental efficiency. The lower the emissions, the lower is the GWP and thus, higher the environmental efficiency. The GWP of some GHGs is given in Table 3.

Formula (6) was used to convert the emissions from any GHG to equivalent CO_2 emissions (GHG Platform, India, 2022).

$$\text{Equivalent}_{CO2} = \text{Emissions}_{Gas} \times \text{GWP}_{Gas} \quad \ldots(6)$$

Table 3 Global Warming Potential (GWP) of Different Green House Gases (GHG)

Green House Gases (GHG)	Global Warming Potential (GWP)
CO_2	1
CH_4	28
N_2O	265

Source GHG Platform, India, 2022

Results and discussions

Major supply chains in commercial piggery

Several marketing channels exist in the country for the supply of pigs and involve intermediaries such as traders, wholesalers, processors and retailers. The direct sales of piglets to the consumers form a significant part of the pig supply chain (Deka *et al.*, 2007; Deka and Thorpe, 2008; Wright *et al.*, 2010).

The pork supply chains aimed to supply raw pork and various processed products to consumers in the local as well as distant markets. As demand for the processed pork products including pickle, kebab and sausage was seasonal and contributed towards relatively only a small proportion to the total sales of processor, the supply chains for these products have not been analysed in the present study. Amongst the identified pork supply chains, Chains 1 and 2 catered to the demand of pork in the local market and involved processors and retailers as market intermediaries. On the other hand, Chains 3 and 4 fulfilled the pork demand in the distant market (Dimapur, Nagaland in the present study) and involved traders, wholesalers-cum-processors and retailers as middlemen.

Supply chain 1: Farmer – Processor – Retailer – Consumer

Supply chain 2: Farmer – Processor – Consumer

Supply chain 3: Farmer – Trader – Wholesaler-cum-processor – Retailer – Consumer

Supply chain 4: Farmer – Trader – Wholesaler-cum-processor – Consumer

Marketing efficiency

The information on the modified price received, price spread, farmer's share in consumer's rupee and

Table 4 Modified net price received, price spread, producer's share and marketing efficiency of identified pork supply chains (₹/kg)

Particulars	Local market		Distant market	
	Supply Chain 1	Supply Chain 2	Supply Chain 3	Supply Chain 4
Net price received by farmer	125.40	125.40	101.35	101.35
Retail weight equivalent	1.39	1.39	1.05	1.05
Gross price received by farmer	174.31	174.31	106.42	106.42
By-products value	44.35	44.35	-	-
Modified net price received	129.96	129.96	106.42	106.42
Total marketing costs	31.67	27.8	37.78	33.91
	(13.53)	(11.93)	(12.59)	(11.30)
Total marketing margin	72.37	75.24	155.8	159.67
	(30.93)	(32.29)	(51.93)	(53.22)
Price spread	104.04	103.04	193.58	193.58
	(44.46)	(44.22)	(64.53)	(64.53)
Producer's share in consumer rupee	55.54	55.78	35.47	35.47
Price paid by consumer	234	233	300	300
Modified marketing efficiency (MME)	1.25	1.26	0.55	0.55

Note Figures within the parentheses indicate the percentage of price paid by consumer

marketing efficiency in various pork supply chains has been presented in Table 4.

To calculate the modified price received by farmers, the retail weight equivalent of 1.39 was used for conversion of live weight of pigs to retail weight in the local market. This means that 1.39 kg of live pig weight is equal to one kg of retail pork weight. Similarly, retail weight equivalent of 1.05 was used in the case of pig supply to distant market (Dimapur, Nagaland), where 95 per cent of the live weight of pigs was consumed for meat purposes. Thus, gross price received using retail weight equivalent represented the total value of animal which was the sum of its meat value and by-product value. The by-product value was subtracted from the gross price received to obtain modified net price. The by-product value was ₹ 44.35/kg in the case of local market. No by-product value was observed in the case of supply to distant market (Dimapur, Nagaland) as all the by-products such as internal organs, head and feet, etc. were being consumed as meat and therefore were not considered as by-products.

It was found that the modified net price received by the farmer was the highest (₹ 129.96/kg pork) when the finisher pigs were sold in the local market (supply chains 1 and 2). In distant market (supply chains 3 and 4), through which the major proportion of sales took place, the modified net price received by a farmer was lower (₹ 106.42/kg). The total marketing cost was the highest and ranged from ₹ 33.91/kg to ₹ 37.78/kg in the distant market channels. In the local market, total marketing cost was found to be ₹ 31.67/kg in supply chain 1 and ₹ 27.8/kg in chain 2 respectively. Further, in the pork supply channels of distant market, marketing margins ranged from ₹ 155.80/kg to ₹ 159.67/kg with price spread of ₹ 193.58/kg. The lowest marketing margins (₹ 72.37/kg - ₹ 75.24/kg) and price spread (₹ 103 -104/kg) were found in the local market.

The study has revealed that consumers paid a relatively higher price of ₹ 300/kg pork in the distant market vis-a-vis local market (₹ 233-234/kg). Due to various taboos, the demand for pork is low in the local market resulting in lower retail prices. The farmers received the highest share in consumer's rupees (about 55%) in the local market supply chains, whereas in distant market supply chains farmers got only 35.47 per cent of the price paid by the consumer.

Finally, it was found that the local market supply chains of pork which comprised relatively less number of intermediaries were highly efficient with estimated

Table 5 GHG emissions and GWP of identified pork supply chains (kg. GHG/ kg. pork)

Emissions (in kg/ kg pork)		Supply Chain 1	Supply Chain 2	Supply Chain 3	Supply Chain 4
Diesel and Petrol	CO_2	0.21	6.9×10^{-2}	1.92	1.86
	CH_4	9.2×10^{-2}	2.5×10^{-2}	0.12	0.12
	N_2O	9.9×10^{-3}	3.3×10^{-3}	0.10	9.7×10^{-2}
LPG	CO_2	0.13	0.13	0.13	0.13
	CH_4	1.1×10^{-2}	1.1×10^{-2}	1.0×10^{-2}	1.0×10^{-2}
	N_2O	2.15×10^{-4}	2.15×10^{-4}	2.01×10^{-4}	2.01×10^{-4}
Electricity	CO_2	2.94×10^{-3}	2.94×10^{-3}	-	-
	CH_4	4.1×10^{-2}	4.1×10^{-2}	-	-
	N_2O	4.1×10^{-2}	4.1×10^{-2}	-	-
Manure	CH_4	4.1×10^{-2}	4.1×10^{-2}	3.3×10^{-2}	3.3×10^{-2}
Polythene(packaging material)	CO_2	6.9×10^{-3}	6.92×10^{-3}	6.9×10^{-3}	6.9×10^{-3}
	CH_4	1.2×10^{-5}	1.2×10^{-5}	1.2×10^{-5}	1.2×10^{-5}
Total	CO_2	0.36	0.14	2.05	1.99
	CH_4	0.15	0.12	0.16	0.16
	N_2O	5.1× 10-2	4.4×10^{-2}	0.10	9.8×10^{-2}
GWP	CO_2	19.71	15.16	36.78	35.75

market efficiency of 1.25-1.26, as compared to the distant market supply chains in which the observed market efficiency was only 0.55.

Environmental impact of commercial piggery supply chains

Information regarding greenhouse gase emissions (GHGs) from post-farm gate activities of the identified pig/pork supply chains and related global warming potential has been presented in Table 5. All emissions have been given in kg GHG released per kg of pork.

It could be seen that amongst local market pork supply chains 1 and 2, the emissions from the use of fossil fuels (diesel and petrol) were higher in chain 1. Further, emissions from other sources such as LPG, electricity, manure and use of polythene were observed to be the same in both these chains. In the pork supply chains catering distant markets, viz. supply chains 3 and 4, the use of diesel/petrol led to a release of slightly higher amount of GHG's in chain 3. Once again, an equal amount of emission was observed from the use of LPG, manure production and use of packaging material.

Overall, the GWP per kg of end product (pork) was observed highest in pork supply chain 3 (36.78 kg CO_2), followed closely by chain 4 (35.75 kg CO_2), chain 1 (19.71 kg CO_2) and chain 2 (15.76 kg CO_2). For all the emitters, except manure produced, the amount of emissions was either equal or higher in the distant supply chains as compared to the local supply chains. The statement could be supported by the fact that average waiting period (Table 2) was higher (15 days) in the local markets than in distant markets (12 days). Further, the waiting period was higher in the local markets as average daily sales were observed to be relatively low (owing to the low demand) in comparison to distant market.

Source-wise composition of emissions

The information regarding average GHG emissions (expressed in terms of equivalent CO_2) contributed by different resources used and their proportionate share in total emissions has been depicted in Figure 2. The source-wise average GHG emissions in a sample pork supply chain were estimated by considering the relative contribution of each marketing channel. The "relative weights" refer to the proportion of pigs supplied through each channel during the study, which helped calculate emissions based on actual distribution patterns.

It could be seen that during supply of pigs to consumers, the use of fuels (petrol/diesel) during transportation operation released 24.11 kg CO_2 per kg of end-product and this source alone contributed 94.84 per cent to the

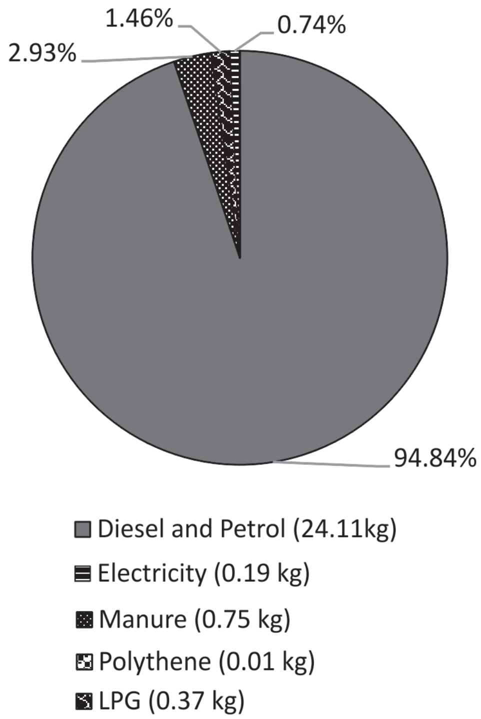

Figure 2 Share of different emitters in overall emissions of identified pork supply chains

Note Figures within the parentheses indicate weighted emissions in kg CO_2/kg end-product

total emissions in the overall supply chains of piggery. On account of significant waiting period involved from sale till slaughtering of animal, the manure production was the second important source which released 0.75 kg CO_2 per kg end-product and its contribution towards total emissions was 2.93 per cent. Besides, use of LPG and electricity in supply chains on an average released 0.37 kg and 0.19 kg CO_2 /kg of pork and the proportionate contribution of these sources in the total GHG emissions was 1.46 per cent and 0.74 per cent, respectively. The polythene-use in packaging of pork and pork products in the supply chains also contributed towards the GHG emissions, however, its contribution towards total GHG emissions was only marginal.

Marketing efficiency in relation to environmental efficiency

To find the relationship between marketing efficiency and environmental efficiency it is very important to understand that environmental efficiency is indicated by GWP. The higher the GWP, the lower is the environmental efficiency. In other words, environmental efficiency is inversely proportional to GWP.

Table 6 reveals that pork supply chain 2 had the highest marketing efficiency and lowest GWP, which indicates that this was the most efficient supply chain among all the four identified chains. It was followed by chain 1, which was the second most efficient supply chain. On the other extreme were channels of distant market which were not only least efficient from marketing perspective but also from environmental dimension. Although, the magnitude of marketing efficiency was equal in channels 3 and 4, the GWP was relatively higher in channel 3, indicating that supply chain 3 was the least efficient chain in the supply of pork to the consumers.

Based on Table 6, it could be asserted that there is a direct relationship between marketing efficiency and environmental efficiency. Some previous studies have suggested that price spread is an indicator of the cost of marketing services such as transportation, processing and packaging (Ross, 1984). Further, it has been highlighted that these marketing services are the source of various greenhouse gases (GLEAM, FAO, 2010). Therefore, lower the cost of marketing services, higher is the marketing efficiency as well as environmental efficiency. This suggests that marketing efficiency is positively correlated with environmental outcomes.

A perusal of Table 4 reveals that channels with higher marketing costs & margins and a greater number of supply chain intermediaries (Figure 1) have lower marketing efficiency. As per Fazio (2016), lengthening of supply chains due to addition of marketing agents has impact on the environmental, economic and other aspects of pork supply chains. Further, it has been suggested that short supply chains could reduce cost, promote aggregation and bring positive results from the economic as well as environmental points of view (Canfora, 2016). Thus, it could be concluded that reducing the length of supply chains by eliminating middlemen could significantly enhance both marketing efficiency and environmental efficiency.

Table 6 Marketing efficiency and GWP relationship amongst pork supply chains

Market supply chain	Marketing efficiency	GWP
Chain 1	1.25	19.71
Chain 2	1.26	15.16
Chain 3	0.55	36.78
Chain 4	0.55	35.75

The study has also revealed that the magnitude of impact of marketing efficiency on GWP is significant, even a small decrease in the marketing efficiency affects the environmental efficiency with much larger magnitude. Also, equal marketing efficiencies do not necessarily guarantee equal environmental efficiency which emphasizes the complex interplay between these two factors.

Conclusions

The study has revealed that the commercially-raised pigs in Punjab are being disposed off through two different markets – local and distant markets (North-Eastern states). The processors and retailers act as the middlemen in the local market. However, the distant market comprises of inter-state traders, wholesalers and retailers. The marketing efficiency of pork supply chains was higher in the local market than distant markets. The longer distance and greater number of intermediaries result in higher marketing costs, higher marketing margin and reduced producer's share in consumer's rupee, ultimately reducing the marketing efficiency.

The analysis of greenhouse gase emissions in the piggery supply chains has revealed that about 36.78 kg carbon dioxide (CO_2) per kg pork was released in the longest supply chain (Chain 3) which was observed to be the highest among all the identified chains. The lowest emissions (15.16 kg CO_2) were observed in chain 2 supplying pork in the local market. The study has shown that marketing efficiency and environmental efficiency have a direct relationship.

The study has suggested that there is a need to promote short supply chains, which would reduce cost, promote aggregation and bring positive results from the economic as well as environmental points of view (Canfora, 2016). Further, the demand in local markets should be boosted through various awareness programs which could enlighten the people about nutritional advantages of pork and aim at removing the existing taboos and misconceptions. To cater the demand in distant markets, there is a need to encourage development and use of environment-friendly, low emission, highly efficient fuels/transport means.

It has been reported that over the years, the demand for pork has been increasing and there is supply- deficit in the NE states (Deka *et al.*, 2007; Deka and Thorpe 2008). This implies that in an attempt to meet the rising demand with increased production there could be a substantiate increase in the GHG emissions too if necessary steps for mitigation are not taken. Thus, future studies should explore sustainable and efficient supply chain solutions to support the industry's expansion. In this regard, potential of Green marketing could be uncovered. Further, to have a bigger picture estimate of overall emissions from pig husbandry, life-cycle assessment could be incorporated to include emissions starting from production till final consumption.

It is noteworthy that, due to resource constraints, only a small sample from distant markets was surveyed, which may not fully represent the broader market dynamics. As there is visible inter-dependence between Punjab and North-East in context of pork supply and demand, there lies an opportunity for collaboration. For best use of resources and benefit of both, institutes in respective states could partner for larger-scale data collection which could enhance the credibility and provide more robust insights.

Acknowledgements

One of the authors (S. Kaur) is thankful to the Punjab Agricultural University, Ludhiana, for granting permission to conduct this research work as a part of her master's thesis, titled "Supply Chain Analysis of Commercial Piggery in Punjab."

References

Acharya S S and Agarwal N L. 2020. Agricultural Marketing in India. pp. 475-86. CBS Publishers and Distributors Private Limited, New Delhi.

Bhadauria P, Sharma A, Verma H K, Singh I and Singh R. 2019. Pig Farming: Promising Agri-Business in Punjab. pp. 1-80. Indian Council of Agricultural Research-Agricultural Technology Application Research Institute, Ludhiana. https://atariz1.icar.gov.in/pdf/PIG%20Farming%20Book—website.pdf

Canfora I. 2016. Is the short food supply chain an efficient solution for sustainability in food market. *Agriculture and Agricultural Science Procedia* 8:402-07. https://www.sciencedirect.com/science/article/pii/S2210784316300365

Chauhan A, Patel B H M, Maurya R, Kumar S, Shukla S and Kumar S. 2016. Pig production system as a source of livelihood in Indian scenario: An overview.

International Journal of Environmental Science and Technology 5:2089-96.

https://www.researchgate.net/profile/Anuj-Chauhan-9/publication/3pig production

Deka R P and Thorpe W R. 2008. *Nagaland's pig sub-sector: Current status, constraints and opportunities,* 30-38. International Livestock Research Institute, Guwahati, Assam. https://cgspace.cgiar.org/server/api/core/bitstreams/6703ffb6-eedd-47ef-a1fc-2bf800b538ce/content

Deka R P, Thorpe W R, Lapar M and Kumar A. 2007. *Assam's pig sub-sector: Current status, constraints and opportunities*, 31-40. International Livestock Research Institute, Guwahati, Assam. https://cgspace.cgiar.org/server/api/core/bitstreams/1c419a9f-cdae-4a96-be34-a62704538a30/content

EIA. 2022. US Energy Information Administration https://eia.gov/

Fazio D M. 2016. Agriculture and sustainability of the welfare: The role of the short supply chain. *Agriculture and Agricultural Science Procedia* 8:461-66. https://www.sciencedirect.com/science/article/pii/S2210784316300444

GHG platform India. 2022. Ministry of Environment Forest and Climate Change http://www.ghgplatform-india.org/

GLEAM, FAO. 2010. Global livestock environmental assessment model. pp.93-95. United Nations Food and Agricultural Organization. https://www.fao.org/climatechange/42050-09ec47f2ffd4be66e383046681c07df00.pdf

Hahn W. 2004. Beef and pork values and price spreads explained. *USDA Economic Research Service.*5. https://www.ers.usda.gov/webdocs/outlooks/37369/49585_ldpm11801.pdf?v=1000.3

IPCC (Intergovernmental Panel on Climate Change). 2022. *IPCC Emission Factor Database (EFDB) Version 2.0.* https://www.ipcc-nggip.iges.or.jp/EFDB/find_ef.php

Ross J. 1984. *Farm to Retail Price Spreads for Livestock*. vol 37, 129–133. American Meat Science Association, Kearney, United States.

https://www.meatscience.org/docs/default-source/publications-resources/rmc/1984/farm-to-retail-price-spreads-for-livestock.pdf?sfvrsn=ac1fbbb3_2.

TrasnportPolicy.net. 2022. International Council on Clean Transportation and DieselNet. https://www.transportpolicy.net/

Wright I A, Deka R P, Thorpe W R and Lapar M L. 2010. *The pig sector in North East India: status, constraints and opportunities. International Symposium on Sustainable Land Use and Rural Development in Mountainous Regions of Southeast Asia,* Hanoi. Nairobi: International Livestock Research Institute https://cgspace.cgiar.org/server/api/core/bitstreams/00a5fa27-f839-4436-a3cb-90562b1fabcc/content

Received 4 October 2024 Accepted 3 December 2024

Agricultural Economics Research Review 2024, 37 (2), 271-276
DOI: 10.5958/0974-0279.2024.00021.1

Unveiling consumer preferences for fresh potatoes: A conjoint analysis in Hooghly, West Bengal

Saptaparna Karmakar[1], Debabrata Basu[1], Amitava Ghosh[2]*, and Martina Meinam[2]

[1]Department of Agricultural Extension, BCKV, Mohanpur, Nadia, West Bengal–741252, India
[2]Department of Fisheries Extension, Economics & Statistics, College of Fisheries, Central Agricultural University (Imphal), Tripura–799210, India

*Corresponding author: amitava.skg@gmail.com

Abstract The consumer preferences being pivotal in shaping agricultural practices and driving market demand, this study has conducted conjoint analysis to delve into consumer preferences for fresh potatoes in the Hooghly district of West Bengal, a region renowned as the potato hub. Focusing on attributes like price, texture, and size of potatoes, the study has found the drivers of consumer choices in this agricultural market. It has found that consumers prefer potatoes priced below ₹ 10/kg, prefer sandy texture, and opt for medium-sized potatoes. The attribute, 'texture' has emerged as the most influential attribute, followed by 'price' and 'size'. These insights could have profound implications for market-led extension strategies and agricultural profitability optimization.

Keywords Conjoint analysis, Consumer preferences, Fresh potatoes, Market-led extension, Potato, Hooghly

JEL codes D12, C25

Introduction

In today's dynamic and competitive marketplace, consumer preference is a pivotal factor that guides the success and profitability of businesses across various sectors, including the agricultural sector. Understanding what consumers' desire and value is essential for producers and other stakeholders in shaping agricultural practices, product offerings, and marketing strategies that resonate with their target audience. This understanding is crucial not only for achieving high yields and efficient resource utilization but also for promoting sustainable and market-driven agriculture.

The consumer preference refers to the specific choices and inclinations exhibited by individuals or groups when observed various options in the market. These preferences are shaped by a myriad of factors, including personal tastes, cultural influences, economic considerations, and social trends (Al Gahaifi and Svetlik 2011; Deshingkar et al. 2003; Goyal and Singh 2007; Kuhar and Juvancic 2010). In agriculture, these preferences can encompass factors such as crop varieties, farming practices, sustainability considerations, and product quality. Understanding these preferences is akin to deciphering the roadmap to sustainable agricultural success in a world where market dynamics, environmental concerns, and changing consumer demands are continually evolving (Masoom et al. 2015).

The market-led extension is a strategic approach that empowers businesses, especially those in the agricultural and food industries, to align their operations with the demands and expectations of the market (Lahiff et al. 2007). It acknowledges that the market is not static; it is influenced by factors like consumer preferences, environmental concerns, and global food trends (Kaur et al. 2017). To optimize yields, profitability, and resources management, the agricultural stakeholders must adapt their practices to meet market demands and capitalize on the emerging opportunities. The market-led extension is a proactive approach that involves tailoring agricultural production and marketing strategies to meet the ever-changing needs of both the consumers and market.

Understanding consumer preferences plays a crucial role in agriculture across various dimensions. Firstly, it aids farmers in making informed decisions about crop selection, ensuring they cultivate varieties that align with market demand, thereby increasing the likelihood of success and profitability. Moreover, consumer preferences can shed light on the importance of adopting sustainable and environment-friendly agricultural practices (Anuradha 2015). This valuable insight not only meets market requirements but also contributes to sustainability goals.

Additionally, aligning farming practices with consumer preferences opens doors to profitable markets and heightened sales and income for farmers. The resource allocation becomes more efficient as farmers focus on crop varieties and techniques in demand, thereby reducing wastages and resource-overuse. Lastly, adaptation to evolving consumer preferences grants farmers a competitive advantage, enabling them to respond swiftly to market-shifts and outperform competitors who may lag in adapting to changing consumer demands. In essence, understanding and acting upon consumer preferences are pivotal for the prosperity, sustainability, and competitiveness of the agricultural sector. In this context, one powerful tool for unraveling the intricate web of consumer preferences is conjoint analysis.

Conjoint analysis (Green and Srinivasan 1978; 1990) is a market research technique that identifies consumer preferences by breaking down products or services into their constituent attributes and assessing how different combinations of these attributes are perceived by the consumers. Through conjoint analysis, the agricultural stakeholders can gain profound insights into what matters most to consumers in their target markets (Jaeger et al. 2001; Guerrero et al. 2012; Adegbola et al. 2019). It helps determine which attributes such as crop quality (Ohen et al. 2014), sustainability (Moser et al. 2011), texture (Oliver et al. 2018), size (Badar et al. 2020) or pricing (Maxwell 2001), are most influential in driving consumer choices and how individuals prioritize them. This information guides decisions related to crop selection, farming practices, pricing strategies, and marketing efforts. The conjoint analysis is a valuable tool for agriculture sector, enabling the stakeholders to meet market demands and shape them proactively, resulting in greater competitiveness and sustainable agricultural growth (Deliza et al. 2003).

Potato constitutes an important component of the Indian diet (Paul and Birthal 2023). Therefore, a conjoint analysis of consumer preferences for fresh potatoes in Tarakeswar, Hooghly, West Bengal, is highly desirable. Hooghly, often referred to as the 'potato hub,' is a critical region in the potato supply chain. Understanding consumer preferences in this region is of importance for both growers and marketers. It enables farmers to make informed decisions about potato varieties and cultivation practices, aligning their produce with the local market's demands (Leksrisompong et al. 2012).

The preference identification through conjoint analysis has been done for various fruits and vegetables, such as apples (Manalo 1990), cucumbers (Guerrero et al. 2012), and tomatoes (Adegbola et al. 2019), there seems to be the absence of similar studies on fresh potatoes and their related products. This study, therefore, bridges this research gap and adds to knowledge in the realm of consumer preferences in the Indian context.

Materials and methods

For study, the Hooghly district of West Bengal was selected because of its prominence as the epicenter of potato production in the state. Within Hooghly district, Tarakeswar municipality area was chosen randomly among the 12 municipalities, and Ward No. 10 was randomly selected from the 15 wards within the Tarakeswar municipality. From the total of 426 families in this ward, a random sample of 100 families was chosen as respondents for the study. This number was set as a practical limit, primarily due to constraints imposed by the COVID-19 pandemic during the data collection period (January to June 2021). Given the pandemic context, personal interviews were conducted with strict adherence to social distancing guidelines, making large-scale data collection both challenging and potentially unsafe.

For study, three attributes - price, texture and size - were selected for assessing the preference pattern for fresh potatoes by using conjoint analysis. Three price levels of potato selected were: above ₹ 20/kg, ₹ 10-20/kg and below ₹ 10/kg. Two levels of texture, viz. sandy and gummy were selected. Three size levels - large, medium and small - were selected. These levels and attributes were selected based on pre-testing.

This analysis determined the utility of different levels of attributes. The study presented respondents with 3×2×3=18 combinations (cards) in the stimulus set of these attributes. These respondents were then asked to rate these combinations based on their preferences, using a scale from 1 to 18, with 1 indicating the most preferred combination and 18 representing the least preferred. A stimulus set of hypothetical profile for evaluation by respondents is shown in Table 1.

Table 1 Stimulus Set of Hypothetical Profile for Evaluation by Respondents

CARDS	Price (₹/kg)	Texture	Size
CARD 1	Above 20	Sandy	Large
CARD 2	Above 20	Sandy	Medium
CARD 3	Above 20	Sandy	Small
CARD 4	Above 20	Gummy	Large
CARD 5	Above 20	Gummy	Medium
CARD 6	Above 20	Gummy	Small
CARD 7	10 to 20	Sandy	Large
CARD 8	10 to 20	Sandy	Medium
CARD 9	10 to 20	Sandy	Small
CARD 10	10 to 20	Gummy	Large
CARD 11	10 to 20	Gummy	Medium
CARD 12	10 to 20	Gummy	Small
CARD 13	Below 10	Sandy	Large
CARD 14	Below 10	Sandy	Medium
CARD 15	Below 10	Sandy	Small
CARD 16	Below 10	Gummy	Large
CARD 17	Below 10	Gummy	Medium
CARD 18	Below 10	Gummy	Small

After data collection, the rankings were analyzed to determine the utility (part-worth) values associated with each attribute level. To calculate the utility values, Ordinary Least Squares (OLS) regression analysis was conducted using SPSS software. The dummy variables were assigned to each attribute level, adhering to specific rules (No. of dummies in every variable = No. of categories -1). For instance, the 'Price' attribute, which had three levels (Below ₹ 10/kg, ₹ 10–20/kg, and above ₹ 20/kg), was represented by two dummy variables (D_{10} and D_{20}), with level one (Below ₹ 10/kg) serving as the reference category. The 'Texture' attribute, which had two levels (Sandy and Gummy), was represented by one dummy variable (D_{Sandy}), with the Gummy level serving as the reference category. Similarly, the 'Size' attribute, which had three levels (Small, Medium, and Large), was represented by two dummy variables (D_{Medium} and D_{Large}), with the Small size level serving as the reference category. This dummy coding approach ensured that the sum of the coefficients for each attribute equaled to zero, allowing for a clear interpretation of the relative importance of each level within an attribute.

In this regression model, the dependent variable was the preference ranking provided by the respondents, and the independent variables were dummy-coded levels of each attribute. The general form of the regression equation for this conjoint analysis can be expressed as follows:

$$\text{Utility} = \beta_0 + \beta_1 D_{10} + \beta_2 D_{20} + \beta_3 D_{Sandy} + \beta_4 D_{Medium} + \beta_5 D_{Large} + \varepsilon$$

where,

β_0 =Intercept (Utility value for the reference category: Below ₹ 10/kg for price, Gummy for texture, and Small for size)

β_1 = Coefficient for the dummy variable D_{10} (Price: ₹ 10–20/kg)

β_2 = Coefficient for the dummy variable D_{20} (Price: Above ₹ 20/kg)

β_3 = Coefficient for the dummy variable D_{Sandy}

β_4 = Coefficient for the dummy variable D_{Medium}

β_5 = Coefficient for the dummy variable D_{Large}

ε = Error- term

From the unstandardized coefficients derived from this analysis, the utility of each attribute level was calculated, effectively quantifying the consumer preferences.

Results and discussion

The utility values of all the three attributes (Price, Texture and Size) are presented in Table 2 for each level. For the attribute 'Price', the utility values have been found as 2.55 for level 'Above ₹ 20/kg', -0.49

Table 2 Utility and Relative Importance of Selected Levels of Attributes

Attributes	Level	Utility Value	Rank of Preference	Range Importance	Relative
Price (₹/kg)	Above ₹ 20/kg (D_{20})	2.55	3		
	₹ 10–20/kg (D_{10})	-0.49	2	4.61	29.35% (2nd)
	Below ₹ 10/kg	-2.06	1		
Texture	Sandy (D_{Sandy})	-4.29	1	8.58	54.58% (1st)
	Gummy	4.29	2		
Size	Large (D_{Large})	0.25	2		
	Medium (D_{Medium})	-1.39	1	2.53	16.07% (3rd)
	Small	1.14	3		

for '₹ 10–20/kg' level and -2.06 for 'Below ₹ 10/kg' level. The most preferred level of price attribute had the lowest utility. Similarly, the utility of other attribute levels were calculated. The findings revealed intriguing insights into the consumer behaviour. For instance, in terms of price, the study identified that consumers favoured potatoes priced below ₹ 10/kg over those priced above ₹ 20/kg. Texture preferences leaned towards 'sandy' over 'gummy,' while in size, 'medium' was preferred, followed by 'large,' and 'small.'

After identifying the preferred levels of attributes, the relative importance of these three attributes was calculated to identify which attribute was more important for the consumer. The range of utility was calculated for this by following formulas:

Range = maximum utility of levels - minimum utility of levels.

Relative importance of attribute = Range of the attribute / Summation of the range of all attributes.

Following this formula the relative importance of three attributes was calculated. It was found that, among these three attributes, the texture held the greatest sway over consumer choices. The price came at second stage, and size was deemed the least influential.

Since, 'texture' emerged as the most influential factor in consumer preference; planting and marketing strategies should prioritize the 'sandy' texture of potatoes. Further, this preference was notably associated with the 'Chandramukhi' variety, which is very popular in the Hooghly district. Positioning the Chandramukhi variety as a premium product due to its desirable sandy texture could justify a higher price point, appealing to consumers who value this specific quality. The research can explore the ways to enhance or consistently maintain the sandy texture in new potato-varieties, or adapt agricultural practices to ensure this texture. Although size was found to be the least influential factor, the 'medium' size potatoes were preferred by the consumers. Therefore, agricultural R&D should ensure that cultivation practices or sorting mechanisms yield more medium-sized potatoes.

The pricing of an agri-product is highly crucial for both farmers and consumers. Balancing fair pricing for farmers with consumer willingness to pay is crucial, especially considering the high input costs associated with potato cultivation. To ensure that farmers get considerable profit with meeting of consumer expectations, some suggested strategies are: (i) the farmers could adopt quality differentiation strategies, such as planting specific varieties with desirable qualities (e.g., the Chandramukhi variety with a sandy texture) as premium products, (ii) the farmers could adopt cooperative or direct-to-consumer sales models for marketing their produce, (iii) the farmers could adopt input-cost-reducing technologies such as precision farming, integrated pest management, sprinkler technology etc. along with using bio-fertilizers and fungicides.

These findings underline the critical role that consumer preferences play in driving market demand for agricultural products, including fresh potatoes. Moreover, these insights are not limited to the potato market; similar studies have been conducted on various agricultural products, such as apples (Manalo 1990), cucumbers (Guerrero et al. 2012) and tomatoes

(Adegbola et al. 2019) reaffirming the importance of understanding consumer preferences for successful market-led extension and sustainable agricultural profitability.

Conclusion

The study has underlined the significance of consumer preferences in shaping agricultural practices and driving market demand for fresh potatoes by selecting Hooghly market in West Bengal. In terms of attributes, the study has found that consumers in the selected region preferred potatoes priced below ₹ 10/kg, with sandy texture and medium size. It has revealed the critical importance of 'texture' of potato as a driving factor in consumer choices, followed by price and then size. To ensure that farmers get considerable profit with meeting consumer expectations, the suggestions given are: (i) adoption of quality differentiation in planting varieties, (ii) adoption of input-cost-reducing agri-technologies and (iii) adoption of newer marketing technologies.

References

Adegbola, Y. P., Ahoyo Adjovi, N. R., Adekambi, S. A., Zossou, R., Sonehekpon, E. S., Assogba Komlan, F., and Djossa, E. 2019. Consumer preferences for fresh tomatoes in Benin using a conjoint analysis. *Journal of International Food and Agribusiness Marketing*, **31**(1): 1-21.

Al-Gahaifi, T., and Svetlik, J. 2011. Factors influencing consumer behaviour in market vegetables in Yemen. *Acta Universitatis Agriculturaeet Silviculturae Mendelianae Brunensis*, **59**(7): 17-28.

Anuradha, A. 2015. Analysis on the behavioural Pattern of Organized and Unorganized Vegetable Retail Shoppers. *Bonfring International Journal of Industrial Engineering and Management Science*, **5**(2): 90.

Badar, H., Mohsin, Z., Mushtaq, K., Ahmad, B., Mehdi, M., and Rasool, A. 2020. An assessment of consumer preferences for fresh potatoes in Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences*, **57**(3).

Deliza, R., Macfie, H. A. L., and Hedderley, D. 2003. Use of computer generated images and conjoint analysis to investigate sensory expectations. *Journal of Sensory Studies*, **18**(6): 465-486.

Deshingkar, P., Kulkarni, U., Rao, L., and Rao, S. 2003. Changing food systems in India: Resourcesharing and marketing arrangements for vegetable production in Andhra Pradesh. *Development Policy Review*, **21**(5 6): 627-639.

Goyal, A., and Singh, N. P. 2007. Consumer perception about fast food in India: An exploratory study. *British Food Journal*, **109**(2): 182–195.

Green, P. E., and Srinivasan, V. 1978. Conjoint analysis in consumer research: Issues and outlook. *Journal of Consumer Research*, **5**(2): 103-123.

Green, P. E., and Srinivasan, V. 1990. Conjoint analysis in marketing: New developments with implications for research and practice. *Journal of Marketing*, **54**(4): 3-19.

Guerrero, J. F. J., Abad, J. C. G., García, R. H., and Jiménez, J. A. M. 2012. Estimating consumer preferences for extrinsic and intrinsic attributes of vegetables. A study of German consumers. *Spanish Journal of Agricultural Research*, 3: 539-551.

Jaeger, S. R., Hedderley, D., and MacFie, H. J. 2001. Methodological issues in conjoint analysis: A case study. *European Journal of Marketing*, **35**(11/12): 1217-1237.

Kaur R., Kaur R. and Singh P. 2017. Market-led-extension: Scope and challenges in the present scenario. *Indian Journal of Economic Development*, **13**(2a): 661-666.

Kuhar, A., and Juvancic, L. 2010. Determinants of purchasing behaviour for organic and integrated fruits and vegetables in Slovenia. *Agricultural Economic Review*, **11**(2): 70–83.

Lahiff E., Borras Jr S. M. and Kay C. 2007. Market-led agrarian reform: Policies, performance and prospects. *Third World Quarterly*, **28**(8): 1417-1436.

Leksrisompong P.P., Whitson M.E., Truong V.D. and Drake M.A. 2012. Sensory attributes and consumer acceptance of sweet potato cultivars with varying flesh colors. *Journal of Sensory Study*, **27**(1): 59-69.

Manalo, A. B. 1990. Assessing the importance of apple attributes: An agricultural application of conjoint analysis. *Northeastern Journal of Agricultural and Resource Economics*, **19**(2): 118-124.

Masoom, M. R., Pasha, S. H. A., andAsif-Ur-Rahman, S. M. 2015. Factors affecting the consumer purchasing decisions of perishable foods: Exploring the attitudes and the preferences. *Management Dynamics in the Knowledge Economy*, **3**(3): 509.

Maxwell, S. 2001. An expanded price/brand effect model A demonstration of heterogeneity in global consumption. *International Marketing Review*, 18(3): 325-343.

Moser, R., Raffaelli, R., and Thilmany, D. D. 2011. Consumer preferences for fruit and vegetables with credence-based attributes: A review. *International Food and Agribusiness Management Review*, **14**: 121-142.

Ohen, S. B., Umeze, G. E., and Inyang, E. O. 2014. Consumer purchasing behaviour for fruits and vegetables among civil servants in EssienUdim Local Government Area, AkwaIbom State, Nigeria. *Food Science and Quality Management*, 23: 55-64.

Oliver, P., Cicerale, S., Pang, E., and Keast, R. 2018. Identifying key flavors in strawberries driving liking via internal and external preference mapping. *Journal of food science*, **83**(4): 1073-1083.

Paul, R.K., and Birthal, P.S. 2023. The prices of perishable food commodities in India: The impact of the lockdown. *Agricultural Economics Research Review*, **34**(2), 151–164. doi:10.5958/0974-0279.2021.00033.1.

Received 12 January 2024 Accepted 30 November 2024

Agricultural Economics Research Review 2024, 37 (2), 277-278
DOI: 10.5958/0974-0279.2024.00022.8

Book review

Agricultural Sector in India Accelerating Growth and Enhancing Competitiveness by Mruthyunjaya, Edited. London: Routledge.

India's agricultural sector has undergone considerable transformation over the past three decades transcending the achievements of Green Revolution in the 1960s. The agricultural transformation, however, has been uneven with a rise in income disparity among the regions and farming classes, sporadic incidence of agrarian distress and increased exposure to climatic risks. The various policy initiatives at the central and state levels aimed at improving the welfare of farmers, are narrowly focused, cluttered with idealistic targets and disintegrated from the emerging micro- and macro-agricultural challenges. The present volume under review sheds light on various dimensions of agricultural development in India in the recent years and proposes a model for agricultural transformation. More specifically, the volume sets out a macro-agricultural policy based on microlevel evidence from the state of Karnataka. There are 21 chapters broadly organized in four different themes, viz. natural resources management, enhancing productivity growth in primary agriculture, policy for sustainable agricultural development, and institutions for strengthening agricultural support services. The scholars with vast experience as researchers, teachers and administrators have contributed to this volume. The volume has been brought out in the honour of Professor R Ramanna whose contribution to teaching and research in agricultural economicsin India stands par excellence.

The Introduction lays out the outline of the book and highlights the salient features of each chapter. The state of Karnataka has been a pioneer in launching of structural reforms in the economy and has been striving for bringing more investments in production of primary and processed agricultural goods. But, these initiatives did not seem to have impacted the farm sector considerably and they did not address the problem of market failure either. This is evident from a low agricultural growth and increased variability in farmers' income during the past three decades. This peculiar problem is termed as *More Investment-Less Impact Paradox*.

The quest to increase food production through a narrow base of staple crops led to the loss of biodiversity and plant genetic resources. Globally, the researchers did not pay adequate attention for estimating costs and benefits of biological diversity and resources used for identification of useful traits for varietal development. The discussion on components of agrobiodiversity, methods of valuation and related challenges will certainly encourage future research in this area. The farmer-producer organisations are still in a nascent stage of development. But, they can play an important role in the promotion of sustainable agriculture including conservation of genetic resources, which canbe a promising area of policy intervention.

Three chapters deal with the issues related to governance of watershed programme, surface and groundwater irrigation. While defining property rights over aquifer remains a challenge, it is contentious to argue for enforcement of correlative rights on groundwater-use. The resource-poor marginal and small farmers are in a disadvantageous position as they do not have adequate capitalto compete with resource-rich farmers who have capacity to invest more onextraction of groundwater. The suggested policy interventions on demand and supply side management of water resources are in vogue for decades. But, these policies are implemented lackadaisically with meagre financial resources and little political commitment, which haveresulted in lopsided and lower sustainable impact on farm productivity in India.

In the light of ongoing debate on food, feed and fuel competition, it will be useful to break down the demand for grains into direct demand (human consumption) and indirect demand (livestock feed and biofuel) while estimating total demandfor agricultural commodities. A rise demand for grain-based concentrate feed has been highlighted in a chapter on livestock sector.It is important to note that for forecasting supply (production) of crops to 2030, it is technically appropriate to forecast area and yield separately and, then multiply them to obtain production.

Four chapters were devoted to discussion on setting policy directions for sustainable agricultural development. These chapters present an overview of changes in income, consumption expenditure, rural poverty and inequality in Karnataka at the disaggregate level. Drivers of agricultural growth such as total factor productivity, commodity prices and exports have been identified. Six chapters deal with agricultural support services required for facilitating agricultural transformation, which in the longrun considered to be complete when agriculture is integrated with macro economy and indistinguishable from other sectors of the economy. While there is a strong need to bring changes in the way economics of agriculture taught across the Indian agricultural universities, one should look at the methods of economic analysisbeyond the mainstream neoclassical economics framework. Discussions on a range of modern technologies, growth in secondary agriculture, rural credit market dynamics, supply chain management and big data analytics provide critical inputs for successful integration of the farm sector with rest of the economy. The final chapter provides implementable action points for transformation of agriculture in the medium term. Indeed, these action points have been carefully drafted and deserve to be on the national agenda for wider deliberation, perhaps in the form of National Agricultural Policy. Overall, this volume will be highly useful for students, researchers and administrators engaged in critical analysis of India’s agricultural policy.

Elumalai Kannan
Centre for the Study of Regional Development
School of Social Sciences
Jawaharlal Nehru University
New Delhi-110067

AGRICULTURAL ECONOMICS RESEARCH ASSOCIATION (INDIA)

EXECUTIVE COMMITTEE

Regd. No. F2 (A/67)/89

Agricultural Economics Research Association (India)

The Agricultural Economics Research Association (India), a registered society, came into being in 1987, and on date has around 1100 life members, 110 ordinary members, and 120 institutional members from India and abroad. Through it journal *Agricultural Economics Research Review* the Association contributes towards improving quality of research in agricultural economics and rural development. To encourage young professional, the journal also publishes abstracts of the Master's and Doctoral dissertations in agricultural economics. Besides, the Association regularly organizes annual conference on the issues of contemporary importance, and also undertakes sponsored research in agricultural economics and rural development. The Association is now widely recognized for its professional contributions and credibility. Its journal *Agricultural Economics Research Review* is highly rated by the National Academy of Agricultural Science, New Delhi.

Address for correspondence:

Secretary
Agricultural Economics Research Association (India)
F-4, A Block, National Agricultural Science Centre (NASC) Complex
Dev Prakash Shastri Marg, Pusa
New Delhi 110 012, India
Email: aeraindia@gmail.com
Webpage: www.aeraindia.in

Printed at Cambridge Printing Works, B-85, Naraina Industrial Area, Phase-II, New Delhi - 110 028.