Sustaining long-term agricultural exports from India

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In this study, we analysed the trend, composition and dynamics of India's comparative advantage in agricultural exports from 2001 to 2021 using data from the INTRACEN database for seven agricultural commodities, namely rice, crustaceans, bovine meat, cotton, pepper, cane sugar and tea. The contribution of agricultural exports to the agricultural gross value added (GVA) has increased over time. The country has the highest comparative advantage in rice, followed by pepper and tea, while crustaceans and bovine meat show a lower comparative advantage. The COVID-19 pandemic disrupted the supply chains, causing a decline in exports of bovine meat and tea. The study also probed the reasons behind export rejections in major importing markets. Pesticide residues, microbial infections and consignment management emerge as the major reasons for export rejection. Effective value-chain management is critical for the quality and safety compliances of the commodities.

Keywords: Agricultural exports, comparative advantage, COVID-19 pandemic, rejections, trend.

THE agricultural sector contributed 19% to the gross value added (GVA; at current prices) and employed 45.5% of India's workforce in 2021–22, exhibiting a 4.6% annual growth during 2014–22. This sector accounts for about 12% of the total exports[1]. Since the economic reforms in 1991, India has maintained a positive net export of agri-products, culminating in an all-time high of US$ 50.2 billion in agricultural exports[2] and US$ 28.27 billion in imports in 2021–22 (ref. 3). The country's ability to generate exportable surpluses is a key factor in determining its export prospects[4], which can change dynamically over time due to macro-economic shifts and changes in the production environment. Furthermore, novel institutional advancements such as contract farming and farmer-producer organizations have emerged. Simultaneously, there has been a shift in the nature of demand for agricultural commodities in the domestic market[5]. The policy on supporting technology-led innovations by start-ups further helped strengthen the export infrastructure and integration with the global supply chains. There has also been a shift towards high-value crops, resulting in differential growth experiences for various commodity groups.

India possesses a diverse set of agro-climatic zones, encompassing tropical, subtropical, arid, semi-arid and temperate regions. This diversity facilitates the country in achieving a competitive advantage in multiple agricultural products, thus bolstering its agricultural exports. Despite the benefits of India's diverse agro-climatic and geographical conditions, there are also challenges to contend with, such as climatic aberrations, rapid transmission of global price fluctuations to local markets, and increased instances of export rejections due to sanitary and phytosanitary (SPS) compliances, changes in global demand patterns and political conflicts. The COVID-19 pandemic and geo-political instabilities also disrupted the global production and supply chains.

The Government of India (GoI) has been facilitating agricultural exports through its recent Agricultural Export Policy, which intends to double agricultural exports and strengthen the integration of Indian farmers with global value chains[6]. Additionally, GoI has announced initiatives such as the establishment of agriculture export zones, improvements in value-chain infrastructure and promotion of value-added agricultural products[7]. Its commitment to increasing farmers' income by boosting agricultural and processed food exports is reflected in the recent significant increase in agri-exports. With this background, the present study was conducted with the following objective: (1) to examine the trend and composition of agricultural exports; (2) assess the dynamics of comparative advantage; (3) to explore the reasons for Indian agri-exports rejection and (4) ascertain the impact of the COVID-19 pandemic on Indian agricultural exports.

Methodology

The study sourced export data from the INTRACEN database, using a classification system that categorizes products at the four-digit level under the harmonized system (HS) from 2001 to 2021, and provides a comprehensive view of India's exports over two decades. The study was confined to seven agricultural commodities, including rice (HS 1006),

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crustaceans (HS 0306), bovine meat (HS 0202), pepper (HS 0904), tea (HS 0902), cane sugar (HS 1701) and cotton (HS 5201). Information regarding export rejections was gathered from two sources: the United States Food and Drug Administration (FDA) and the European Union's Rapid Alert System for Food and Feed (RASFF) of the European Union (EU).

Dynamics of comparative advantage

The dynamics of comparative advantage were analysed through kernel density estimations for the revealed symmetric comparative advantage (RSCA) index of selected commodities. For calculating the RSCA index, data from 2001 to 2021 were used.

RSCA index: Dalum *et al.*[8] introduced the RSCA index in 1998 as a modified form of the revealed comparative advantage (RCA) index. Equation (1) is used to calculate the RCA index.

$$\mathrm{RCA}_{ij} = \frac{\left(\dfrac{X_{ij}}{X_i}\right)}{\left(\dfrac{X_{\mathrm{w}j}}{X_{\mathrm{w}}}\right)}, \qquad (1)$$

where X_{ij} is the value of country *i*s export of product *j*, X_i the value of country *i*s agricultural exports, $X_{\mathrm{w}j}$ the value of world export of product *j* and X_{w} the value of world agricultural exports.

To overcome the issue of asymmetric distribution, the RSCA index was assessed by transforming the RCA index. Equation (2) presents the formula for calculating the RSCA index.

$$\mathrm{RSCA}_{ij} = \frac{\mathrm{RCA}_{ij} - 1}{\mathrm{RCA}_{ij} + 1}. \qquad (2)$$

The RSCA index ranges between –1 and +1. The values above zero indicate a country's comparative advantage in a particular commodity, while values less than zero signify the opposite.

Kernel density estimation: The estimation of kernel density is a statistical approach that does not rely on assumptions about the underlying distribution of continuous random variables to determine their probability density function. If we have a random sample ($x_1, x_2, x_3, \ldots, x_n$) drawn from the same unknown probability density function $f(x)$, then we can use eq. (3) to obtain its kernel density estimator[9].

$$f(x) = \frac{1}{n}\sum_{i=1}^{N} K_h(x - x_i) = \frac{1}{nh}\sum_{i=1}^{N} K\left(\frac{x - x_i}{h}\right), \qquad (3)$$

where K represents the kernel function, and $h > 0$ is referred to as the smoothing parameter or bandwidth. We utilized the Epanechnikov kernel function as the default option in the Stata software to generate the kernel density curve.

Impact of COVID-19 on agricultural exports

The study also examined the impact of the COVID-19 pandemic on the exports of selected commodities. This was done using the artificial neural network (ANN), seasonal auto-regressive integrated moving average (SARIMA) and hybrid ANN–SARIMA. These techniques were employed to predict the export values of selected commodities. The predicted values were then compared with the actual export values following the outbreak of the pandemic. The study utilized data spanning from January 2011 to September 2021. Data from January 2011 to December 2019 were employed as the training set, while data from January 2020 to September 2021 were used as the test set.

ANN method: It is a computational framework replicating the architecture and functionality of neurons in the human brain. It is a machine-learning technique that can recognize and learn complex patterns in various types of data, such as speech and image recognition, classification and forecasting. The architecture of an ANN comprises input and output layers, and one or more hidden layers. Each layer is composed of artificial neurons, also called nodes. These nodes receive inputs from the previous layer and generate an output based on a mathematical function that combines these inputs. The ANN model is mathematically as defined eq. (4) below[10–12].

$$Y_t = \beta_0 + \sum_{j=1}^{q} \beta_j g\left(\sum_{i=1}^{p} \omega_{ij} X_{t-i} + \omega_{0j}\right) + \varepsilon_t, \qquad (4)$$

where Y_t is the output vector of the multilayer perceptron (MLP) at time t and g denotes the transfer function of the neurons in the hidden layer. X_{t-i} is the input value at time $t - i$, p represents the number of input nodes and q represents the number of neurons in the hidden layer. The weights connecting neuron j from the input to the hidden layer are represented as ω_{ij}, and those connecting the output neuron j from the hidden layer to the output neuron are denoted as β_j. The error terms at time t are indicated by ε_t. To identify the optimal model, various architectures were tested in this study. The network structure that resulted in the lowest mean squared error (MSE) was considered the best forecasting model.

SARIMA method: The SARIMA (p, d, q) (P, D, Q) model is defined by three parameters: p, d, and q, which represent the order of the non-seasonal autoregressive, integrated and moving average terms respectively. Similarly, P, D,

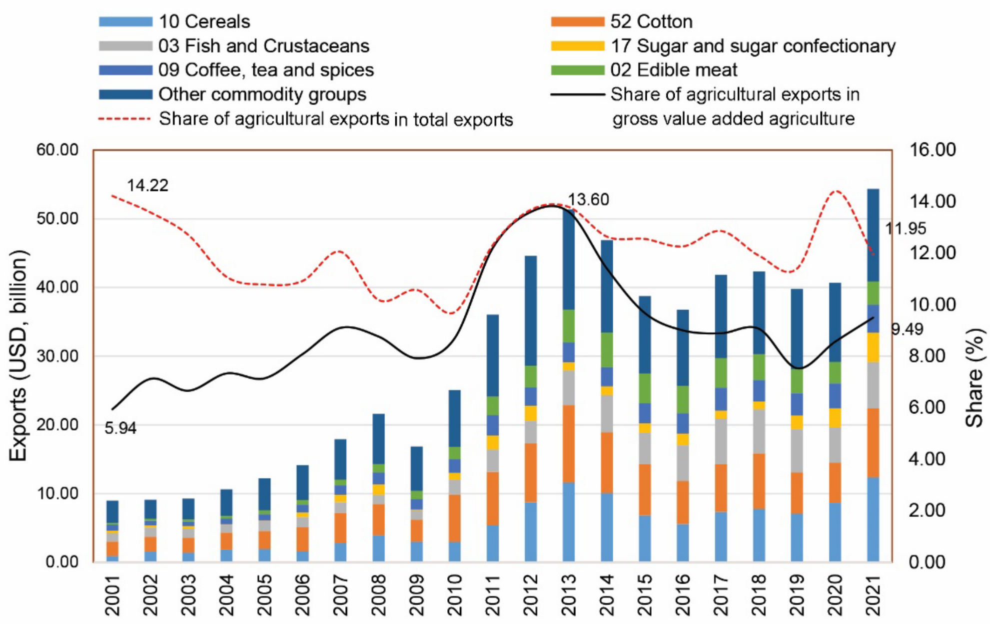

Figure 1. Trend and composition of agricultural exports.

and Q are the parameters indicating the order of the seasonal autoregressive, integrated and moving average terms respectively, in the model. The SARIMA model functions by initially eliminating the seasonal element from the data and subsequently fitting an ARIMA model to the deseasonalized data. The predicted values are then combined with the seasonal component to obtain the ultimate forecast.

Hybrid ANN–SARIMA method: The hybrid ANN–SARIMA technique combines the SARIMA and ANN models that provide a robust and accurate approach for time-series forecasting[13]. This methodology takes advantage of the strengths of both models to enhance the forecasting accuracy. Initially, the SARIMA model is applied to the time-series data to capture and eliminate seasonal patterns from the original data. Then, the remaining non-seasonal data are used as input into the ANN model, which is trained using back propagation. After the ANN model is trained, it is used to predict the non-seasonal component of the time-series data. Finally, the previously removed seasonal component is added back to the forecasted values to obtain the final prediction.

Results and discussion

Trends and composition of agricultural exports

Indian agricultural exports are gaining prominence globally and strengthening their growth linkages with the country's economy. The share of agricultural exports in GVA from agricultural and allied activities increased from 7.12% in 2002–03 and reached a peak of about 14% in 2013–14; then it decelerated to 7.3% in 2019–20. However, the share of agricultural exports in agriculture GVA has increased after 2019–20 and reached 9.5% in 2021–22 (Figure 1). Similarly, the share of agricultural exports to total exports was 14.2% in 2001–02, which declined to 9.71% in 2010–11. However, with continuous policy support, the share increased to 11.95% in 2021–22.

India has been able to consistently maintain a trade surplus in agricultural commodities, owing to significant growth and diversification in agricultural production. This growth trajectory has transformed the country from a food-deficit to a self-sufficient and export-surplus economy. The production and export of high-value commodities are emerging rapidly. This success can be attributed to the various agricultural innovations, incentives and institutions that have revolutionized agricultural production in the country, resulting in India becoming a net exporter of agricultural products[14]. As a consequence, the country's agricultural exports scaled a new peak of US$ 50 billion in 2021–22. The major commodity groups in terms of agricultural exports in 2021–22 were cereals (22.7%), cotton (18.4%), fish and crustaceans (12.4%), sugar and sugar confectionery (7.9%), coffee, tea and spices (7.5%), and edible meat (6.2%). However, other commodity groups, such as live animals, live trees and plants, vegetable planting materials, etc., have a comparatively lower share in agricultural exports.

Dynamics of comparative advantage

Over 75% of India's agricultural exports include cereals, cotton, fish and crustaceans, sugar and sugar confectionery, coffee, tea and spices, and edible meat. Among these groups,

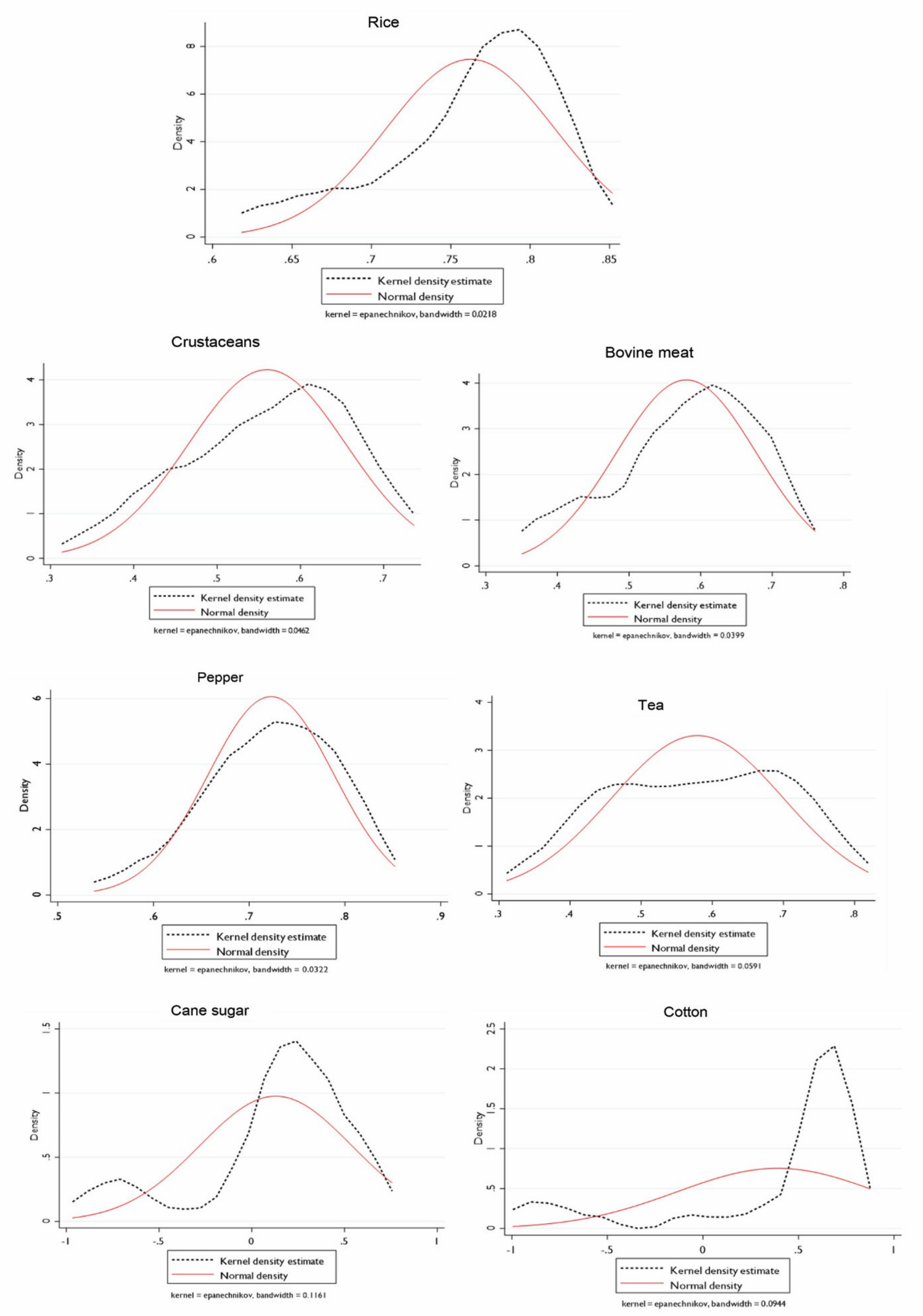

Figure 2. Kernel density distribution of revealed symmetric comparative advantage indices for selected commodities.

Table 1. Reasons for commodity-wise rejection (2011–21)

Commodity	Number of rejections	Reasons for rejection*
Rejections by USA		
Rice	2095	Pesticide residue (67%), filthy (28%)
Crustaceans (shrimp and prawn)	798	Microbial (42%), filthy (21%), veterinary drug residue (17%)
Pepper (black pepper and powder)	766	*Salmonella* (42%), filthy (41%), adulteration (17%)
Rejections by the European Union		
Rice	184	Pesticide residue (74%), filthy (18%)
Crustaceans (shrimp and prawn)	141	Veterinary drug residue (62%), microbial (13%)
Pepper (black pepper and powder)	10	Pesticide residue (40%), adulteration (30%)

*These may be more than one for a consignment.

rice, crustaceans, bovine meat, pepper, tea, cane sugar, and cotton are the most exported agricultural commodities from India. To better understand the competitiveness of these products, RSCA indices have been used as they are more appropriate for functional analysis than RCA indices[15].

Figure 2 presents the kernel density distribution (KDD) of the selected commodities. The shape of KDD for rice RSCA index is asymmetric and left-skewed. The RSCA indices for rice ranged between 0.77 and 0.92 during the last two decades, establishing that rice has historically been an export-competitive commodity from India. A similar distribution was observed for crustaceans. The RSCA indices for crustaceans were between 0.58 and 0.82, revealing a higher comparative advantage. In the case of bovine meat, pepper and tea, the distribution of RSCA index was symmetric. The RSCA indices averaged 0.77, 0.85 and 0.77 for bovine meat, pepper and tea respectively. Cane sugar and cotton indicated varied patterns; currently, both are reasonably competitive in the global market.

Indian export rejections in USA and EU markets

Ensuring food safety is paramount in global trade for protecting human and animal health. Contaminants such as pesticide residues, heavy metals, microbial contaminants and unsafe additives or substances, as well as adulteration and filth, can make food unsafe for consumption. Examining export rejections can provide insights into their causes, which can help strengthen agricultural supply chains, build infrastructure, ensure capacity and compliance with importing country standards, and reduce rejections. Indian exporters have been facing difficulties in exporting agricultural and food products to the USA and the EU, on grounds of their inability to meet food safety requirements. The export rejections were higher in the USA compared to the EU (Table 1). Pesticide residue, *Salmonella* and pathogenic microbial contamination emerged as the major reasons for rejections in rice, crustaceans and seed spices like pepper, other spices and mixtures. Moreover, there are other issues such as the presence of tricyclazole in rice, ciguatoxins and nitrofurans in seafood, azo dye in food products, etc., that have resulted in export rejection notifications by the EU member states[16].

Food safety challenges include inadequate sanitation infrastructure, limited knowledge and adherence to food safety practices, and the lack of effective implementation of food safety management systems. It is important to strengthen the capacity to implement best practices at different levels of the export supply chains, such as good agricultural practices at the production level, good manufacturing practices at the processing level, and good handling practices at all levels. It is also necessary to improve quality control and food safety handling by domestic supply chain actors by improving infrastructure like cold chain management systems, pre-processing and processing facilities, and laboratories.

Impact of COVID-19 on Indian agricultural exports

The worldwide supply chains were disrupted, and economic activities such as food production, processing, distribution, consumption and trade were affected due to the COVID-19 pandemic. However, despite the pandemic, India's rice exports increased by 24.4% in the biennium ending in 2021, surpassing expectations (Figure 3 *a*). This spurt in India's rice exports has been attributed to the measures by GoI to ensure the export of rice and other cereals while taking COVID-19-appropriate safety precautions. Crustaceans such as shrimp, crab, lobster and prawn account for three-fourths of the total fish exports from the country. The exports of crustaceans were volatile, declining in 2020, followed by a recovery in 2021. However, despite this recovery, the actual exports of crustaceans fell short of the projected exports, resulting in an overall decline (Figure 3 *b*). This was mainly due to supply-chain disruptions and low demand in the importing nations.

India has been one of the largest global exporters of bovine meat, but its export has declined in recent years due to global competition and quality concerns. The COVID-19 pandemic exacerbated this, resulting in a greater decline in actual exports than the projected exports (Figure 3 *c*). This was primarily due to a decrease in demand for beef resulting from the closure of restaurants and food service

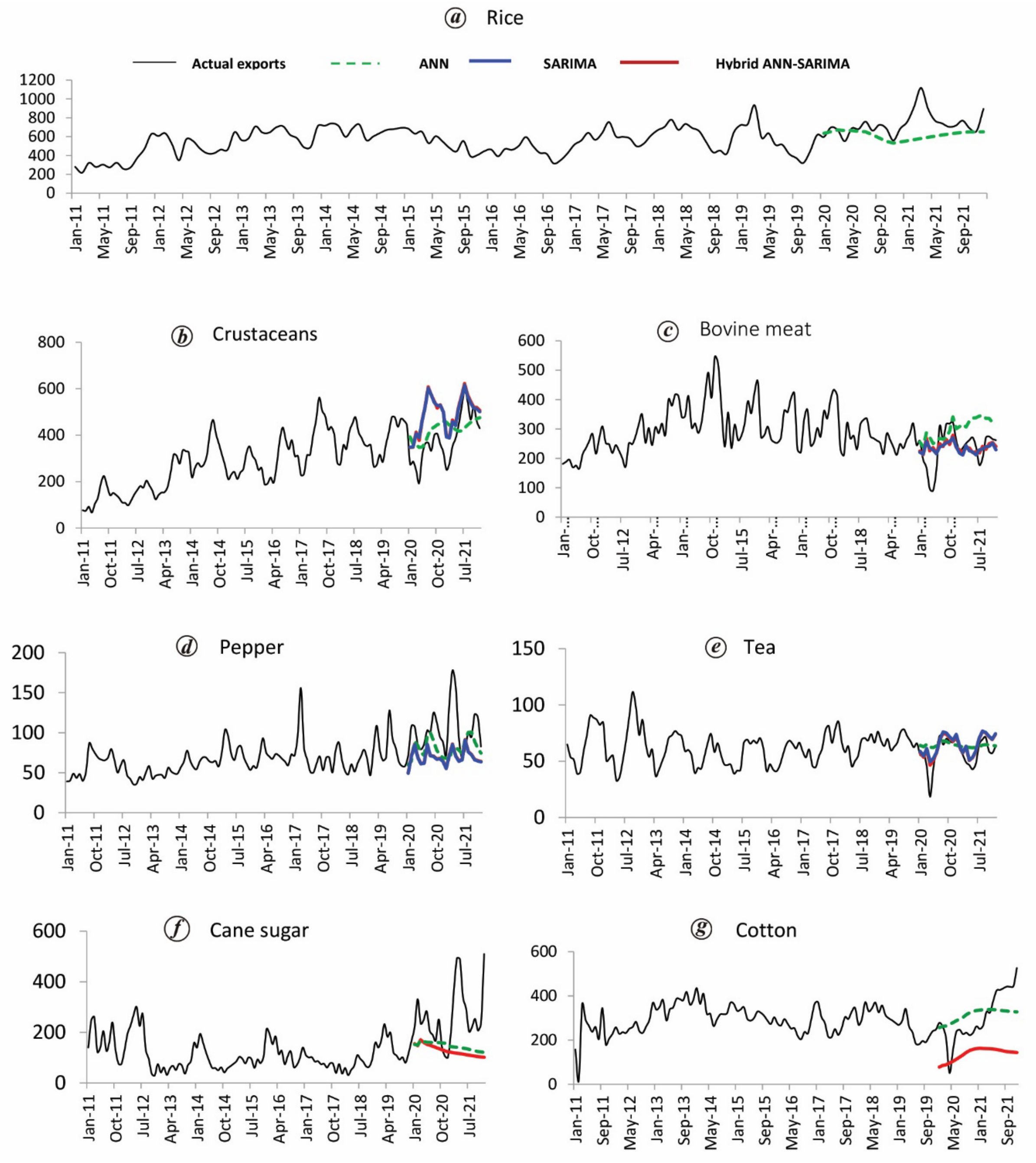

Figure 3. India's exports during the COVID-19 pandemic (US$, million).

industries in the importing countries. Moreover, the growing demand for natural remedies and traditional medicines in countries such as the USA, Germany, and the UK has led to growth in the export of pepper as a therapeutic agent. Accordingly, India exported more pepper than the projected exports during this period (Figure 3 *d*).

The tea industry worldwide, including tea export from India, has been greatly affected by the COVID-19 pandemic. India is the second largest producer and exporter of tea globally, and the pandemic has caused disruptions in the entire tea value chain, from production to consumption. This has led to a decrease in tea exports during the pandemic, falling below the expected scenario (Figure 3 *e*).

India holds a prominent position as one of the leading global producers and exporters of sugar, commanding a substantial share of the international market. GoI has also implemented policies to support sugar exports, including subsidies and incentives for the exporters. Consequently, sugar witnessed a significant increase in its exports even during the COVID-19 pandemic (Figure 3 *f*).

India is a major player in the cotton trade, being one of the largest producers and exporters globally, with a production share of approximately 25%. Despite the COVID-19 pandemic, India's cotton exports have significantly increased in recent years (Figure 3 *g*). The country's ability to produce cotton at a large scale, favourable agro-climatic conditions, and Government support are the factors that will help boost cotton exports in the future.

Due to the COVID-19 pandemic, many countries implemented trade-related measures to handle the effects on health, economy and food security. The majority of these measures, over 80%, were intended to limit exports or permit imports. Conversely, less than 8% of the measures were designed to facilitate exports[17]. During the pandemic, India's exports performed well due to its utilization of its overseas missions, organization of buyer-seller meets, liaison with authorities, and resolution of obstacles.

Conclusion and implications

In this study, we examined the trend, composition and dynamics of comparative advantage in rice, crustaceans, bovine meat, cotton, pepper, cane sugar and tea. India has the highest comparative advantage in rice, followed by pepper and tea. In contrast, a lower comparative advantage exists for crustaceans and bovine meat. Cane sugar and cotton appear to have a mixed pattern in comparative advantage. Pesticide residue was the most important reason for rejecting export consignments in the US and EU markets. The performance of agricultural exports during the COVID-19 pandemic was encouraging for rice, pepper, cane sugar and cotton. Effective export facilitation can tap the huge potential of international markets and boost agricultural exports.

India must diversify its agricultural exports beyond traditional products such as rice, tea and spices[18]. There is a huge potential for the export of fruits, vegetables, dairy and meat products. GoI has implemented several measures to simplify and streamline exporting agricultural products. Improved logistic support to facilitate the export of perishable agricultural commodities is the need of the hour. The country must invest in 'branding and marketing' to make the exports more attractive to international buyers. Further, the capacity building of farmers, exporters and other stakeholders in quality management, packaging and handling across the value chain is critical. The institutional support for market intelligence, technical assistance and infrastructure finance can be further strengthened to link various actors in the supply chain and create stringent safety compliances. Digitalization can help build effective traceability systems, generating real-time information and making value chains more efficient. Policy facilitation through partnerships, export incentives and infrastructure can further boost the trade.

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