Food and Agriculture Organization of the United Nations

FAO COMMODITY AND TRADE POLICY RESEARCH WORKING PAPER

No. 57

Improving the resilience of the agricultural sector to external shocks

The impact of the COVID-19 pandemic on the dairy industry with reference to India

Background paper prepared for the "Guidelines to increase the resilience of agricultural supply chains: Getting on the Right Track to Stabilize Production and Markets" project

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The impact of the COVID-19 pandemic on the dairy industry with reference to India

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Abstract

This study provides a quantitative assessment of the Indian dairy sector and aims to determine the underlying factors of the observed price movements. We analyse producer prices over time, differentiated by milk-producing 'zones,' and identify the underlying factors that might explain the observed discontinuities or interruptions in producer prices. The findings show that the market lockdown had not caused a statistically significant change in wholesale milk prices immediately after in any of the five milk zones after imposing a sudden lockdown. In contrast, retail prices increased in the East zone, while dairy product sales plummeted in all milk production zones. The study found disruption in milk marketing channels, logistics and transportation in the East milk zone, where the cooperative institutional structure is less widespread and active than in other zones. The East zone also has a thinly spread dairy infrastructure such as cold chains, exposing producers to market vagaries. The analysis of milk prices, procurement and sales confirms that the decision of the dairy cooperatives to continue to pay milk producers even when sales plummeted played a critical role in strengthening the resilience of India's dairy sector during the COVID-19 crisis. The findings show that building strong institutional infrastructure such as dairy cooperatives is necessary but insufficient for sustaining market resilience. Dairy processors need resources for assuming higher risks while relaxing certain regulations such as labour movements and enhancing access to essential inputs for maintaining production. It is crucial to provide government assistance for those who fail to use market channels for reasons beyond their control, especially bottlenecks to accessing markets, such as small-scale farmers who operate only in the unorganized sector.

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FAO gratefully acknowledges funding for this research provided by the Government of Japan under the project "Guidelines to increase the resilience of agricultural supply chains: Getting on the Right Track to Stabilize Production and Markets." The project, which was in operation from April 2021 to June 2022, was conceived in the wake of the COVID-19 pandemic, which, through the imposed containment measures and a myriad of direct and indirect transmission channels, has harmed economic activity, impacted food systems, disrupted agricultural value chains and put households' food security at risk by undermining their livelihoods and capacity to access food. In particular, low- and middle-income countries could be severely affected, as large shares of their populations depend on agriculture for their livelihoods. As the COVID-19 pandemic unfolds, considerable attention has focused on the resilience of food supply chains in times of crises. Agricultural and input supply chains have had to adjust rapidly to demand side shocks, including panic buying and changes in food purchasing patterns, as well as plan for any supply side disruptions due to potential labour shortages and disruptions to transportation and supply networks. Drawing on its experience and expertise in agricultural markets, trade and economic analysis of agricultural policies, FAO has undertaken research, including the case study presented in this paper, on the impacts of the COVID-19 crisis, as well as of other natural disasters, on agricultural supply chains and markets. The findings have fed into the preparation of the "Guidelines for increasing the resilience of agricultural supply chains." For additional information on the project and copies of the background papers and the "Guidelines for increasing the resilience of agricultural supply chains," please contract Cristian Morales Opazo, Senior Economist, Agrifood Economics Division, FAO or Pascal Liu, Senior Economist, Markets and Trade Division, FAO.

Abbreviations

AI	artificial insemination
ASF	African swine fever
BSE	bovine spongiform encephalopathy
COVID-19	coronavirus pandemic
DCSs	dairy cooperative societies
EVD	Ebola Virus Disease
FAO	Food and Agriculture Organization of the United Nations
HPAI	Highly Pathogenic Avian Influenza
INR	Indian rupees
ITSA	Interrupted Time Series Analysis
KCMMF	Kerala Co-operative Milk Marketing Federation
MILKFED	Milk Producers Federation Limited
MNC	multinational corporation
NITI	National Institution for Transforming India
RCT	randomized controlled trial
RD	Regression on Discontinuity
RDiT	Regression Discontinuity in Time
SARS	Severe Acute Respiratory Syndrome
TLPD	thousand litres per day
UHT	ultra-high temperature

1. Introduction

1.1. The context

The coronavirus pandemic (COVID-19) and the containment measures have led to widespread economic disruption and a considerable degree of economic, social and political instability in many countries. The lockdowns imposed by governments across the world to contain the spread of the virus exacerbated these instabilities. These measures impacted different sectors and value chain actors in heterogeneous ways and with different intensities.

A significant volume of research has appeared since the pandemic, suggesting theoretical foundations and undertaking empirical assessments on the transmission channels and impact of different shocks in recent years. The Severe Acute Respiratory Syndrome (SARS) crisis in 2002 and the Ebola Virus Disease (EVD) outbreak from 2014 to 2016 highlighted the broad impact of widespread disease outbreaks, and the transmission of these effects through agricultural systems (Fan, 2003); Siu and Wong, 2004; McKibbin and Sidorenko, 2006; Keogh-Brown *et al.*, 2010; Alpha, Figuié and Food and Agriculture Organization of the United Nations, 2016; and De la Fuente, Jacoby and Lawin, 2020). Similarly, a well established research strand exists on animal disease outbreaks such as the African swine fever disease (ASF), the bovine spongiform encephalopathy (BSE) and the Highly Pathogenic Avian Influenza (HPAI) and their impacts on prices, production and consumption. This research has provided invaluable insights into the onset of disease outbreaks, the impact transmission channels and effective responses to mitigate their impacts (Lloyd *et al.*, 2001; Sanjuán and Dawson, 2003; Livanis and Moss, 2005; Acosta, Barrantes and Ihle, 2020). Finally, recent studies have focused on the COVID-19 pandemic, covering its many facets.

These research findings provide insights into the impact of shocks as widespread as the pandemic. The pandemic has impacted the entire world compared to other shocks that the agriculture sector faced recently, giving limited opportunity to use geographical arbitrage to mitigate the impact. Research into the effects of shocks on agrifood systems agrees that widespread shocks transmit to food and agricultural systems through both demand and supply sides. From the demand side, government measures, including social distancing requirements and market shutdowns, to contain the pandemic’s spread, initially caused panic buying among consumers. Subsequently, consumers have shifted away from food services (e.g., hotels, restaurants, bars and schools) to home consumption. Beckman and Countryman (2021) show that from January to October 2020, compared to the same period in 2019, expenditures at food services and drinking places have declined by rates ranging from slightly over 10 percent in Australia to close to 20 percent in the European Union and the United States of America and nearly 40 percent in India and Argentina. These changes also resulted in significant increases in retail sales and online purchases, with important implications for long term consumer behaviour (Liu and Rabinowitz, 2021; Bruma *et al*., 2021; and Khan, Alroomi and Nikolopoulos, 2022). In the dairy sector, this involved moving away from purchasing higher value dairy products such as specialized cheese products to products with longer shelf life and ingredients required for home consumption and cooking, such as butter, cooking cream, cheese and ultra-high-temperature (UHT) milk. Although retail demand increased significantly, evidence shows that it was inadequate to fully compensate for the decline in food service sales.

On the supply side, the pandemic placed significant stresses on the dairy supply chain from farms to markets. At the farm level, small scale dairy enterprises have been observed to reduce feeding concentrates and increase those offering dry forages, while the sale of lactating cows has also been observed to increase significantly (Alam, Schlecht and Reichenbach, 2022; Hambardzumyan and Gevorgyan, 2022). The overall decline and shift in demand from perishable products to those with longer shelf-life meant that suppliers had to adjust their product mix by allocating more milk to products with higher demand, such as milk powders and UHT milk and changing packaging from bulk to the sizes suitable for retail sales when the manufacturing capacity already existed (Acosta *et al*., 2021). Adapting to the new production was not frictionless. The regions with limited transport facilities, or where producers transport milk over long distances, had faced the most daunting challenges in adapting to the unfamiliar environment. Producers with limited financial leverage were the second group that faced difficulties in adapting to the changes, especially when combined with lower milk sales but existing contracts for collecting milk. Producers also faced severe labour shortages due to the need to follow health guidelines, limited transport services or border crossing difficulties. Besides, logistical disruptions due to lockdowns and social distancing requirements made it difficult for producers to secure raw materials and transport their produce to markets. The unpredictability of consumer demand due to lockdowns and social distancing requirements magnified these demand and supply changes. Simultaneously, consumers faced supply uncertainties, leading some to hoard ‘essential’ products, further adding to market disruptions.

Significant differences in the impacts of the COVID-19 pandemic across different geographical regions, attributed mainly to technological development, institutional arrangements or the availability or lack thereof of government assistance, were also observed during the pandemic. Milk production reached near normalcy after dropping significantly immediately after the onset of the pandemic in high income countries such as Canada, the European Union and the United States of America, owing to a combination of government assistance, increased use of automation, online marketing sales using e commerce and direct supply arrangements with supermarkets, thereby minimizing the impact of labour shortages and transport and logistical hurdles. In parts of Latin America, the Caribbean and Asia, the pandemic has had a high level impact on production and sales, along with intensive involvement of the informal sector and mutual help in stabilizing production (Tittonell *et al*., 2021; Blazy, Causeret and Gudayer, 2021). In African countries, the pandemic has constrained access to inputs such as animal feed and veterinary services, forcing farmers to ration feed, reducing livestock numbers and reducing production altogether (Middendorf *et al*., 2021; Nchanji *et al*., 2021; Obese *et al*., 2021). Reduced demand for livestock products has also been challenging in some countries, resulting in cash flow issues and business closures (Fang *et al*., 2021).

Recent research also points out that the welfare effects of price changes affect different actors differently along the supply chain. Producers often bear much of the burden during animal disease outbreaks, as producer prices are the ones to fall first. Retail prices may even rise, reflecting scarcity. Even during the pandemic, milk producer prices have fallen much faster than retail prices in several countries. Based on country level data in the United States of America, Haqiqi and Horeh (2021) find that the impacts are heterogeneous on farmers operating on different farm sizes and from different racial groups and geographical locations. Moreover, yield levels were important in determining the intensity of the negative impact and overall farm resilience. The pandemic affected production processes and consumer demand more strongly immediately after the first round of infections, but over time the intensity of the impact has declined, enabling livestock production systems to reach some normalcy with the adoption of mitigation strategies (Acosta, Barrantes and Ihle, 2020).

1.2. Purpose of the study

While there is extensive literature on the impact of shocks on agrifood production systems, studies on the dairy sector employing quantitative assessments over a more extended time that is adequate to trace the full extent of the impact, also differentiated by geographical regions, do not yet exist. The study aims to fill a critical vacuum within this context by undertaking quantitative assessments focusing on the Indian dairy sector and explaining the underlying factors of the observed price movements. The study will analyse the producer prices over time, differentiated by milk-producing 'zones,' and identify the underlying factors that might explain the observed discontinuities or interruptions in producer prices. This is expected to help design appropriate policy responses for developing countries to face exogenous shocks in the future. The findings of this research are likely to have a broader relevance given that the dairy industry is one of the most widespread economic activities globally, demonstrated by rising production and international trade in dairy products.

1.3. Method of analysis

After setting out the salient features of the Indian dairy sector, the study uses producer prices, differentiated by milk-producing zones in India, as the entry point, hypothesizing that COVID-19 related market disruptions would have led to discontinuities or interruptions at the time of the shock. Impact evaluation needs a valid control group or a counterfactual for the impact estimates to be reliable. As the pandemic has affected the entire population, constructing a valid control group or a counterfactual is challenging. However, the sudden nature of the lockdown announcement allows us to use it as a natural experiment to model producer prices over the pandemic and measure lockdown effects as the differences in mean prices before and after the lockdown. This naturally introduces a 'discontinuity threshold', where the discontinuity occurs at the moment. This allows for applying the Regression Discontinuity in Time (RDiT)[1] design to analyse data to identify immediate impacts. The appeal of Regression on Discontinuity (RD) rests on the fact that the framework is intuitively similar to the randomized controlled trial (RCT) within the narrow bandwidth around the cutoff, where the objective is to estimate the average treatment effect. In a well-designed experiment, observations are randomly assigned to a treatment or controlled group using computer software or a lottery. This random assignment generates identical groups which can be compared. In the RD framework, treatment occurs on one side but not on the other of the threshold. Typically, many units of observation fall in the neighbourhood of the threshold, allowing estimation via a cross-sectional comparison of observations 'just above' and 'just below the threshold. The observations 'just above' and 'just below' the threshold will be identical mimicking an RCT. Therefore, comparing the outcomes at the threshold and just below can approximate the treatment effect. One of the well known advantages of the RDiT is that the effect is estimated at the discontinuity point, which requires fewer observations than in a randomized experiment. Despite this advantage, a known disadvantage is the tendency for the treatment effect to be more accurate around the threshold and may not be readily generalizable.

Given the possibility of observations away from the threshold level when the RDiT approach is used, this report employs an additional econometric methodology known as Interrupted Time Series Analysis (ITSA) to identify possible long-term effects of price changes following lockdown (Cariappa *et al*., 2021; and Ruan, Cai and Jin, 2021). This methodology allows for: a) determining whether there is a discernible effect in milk prices, production, or trade after the introduction of lockdown in India; b) possible delayed or intermittent effects; c) determining if the shift is likely to be permanent or temporary; and evaluate which variables were subject to

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[1] See annex for a technical summary of the approach.

significant changes due to the introduction of the lockdown by observing the slopes of trend lines before and after the intervention. This approach is chosen over alternative methods, given the simplicity of the technique without the need for randomisation.

In both the RDiT and ITSA, the intuition behind the identification strategy is straightforward. The key assumption is that the nationwide lockdown is the only reason for discontinuous milk price change during the lockdown months (Chen and Whalley, 2012; Ruan, Cai and Jin, 2021).

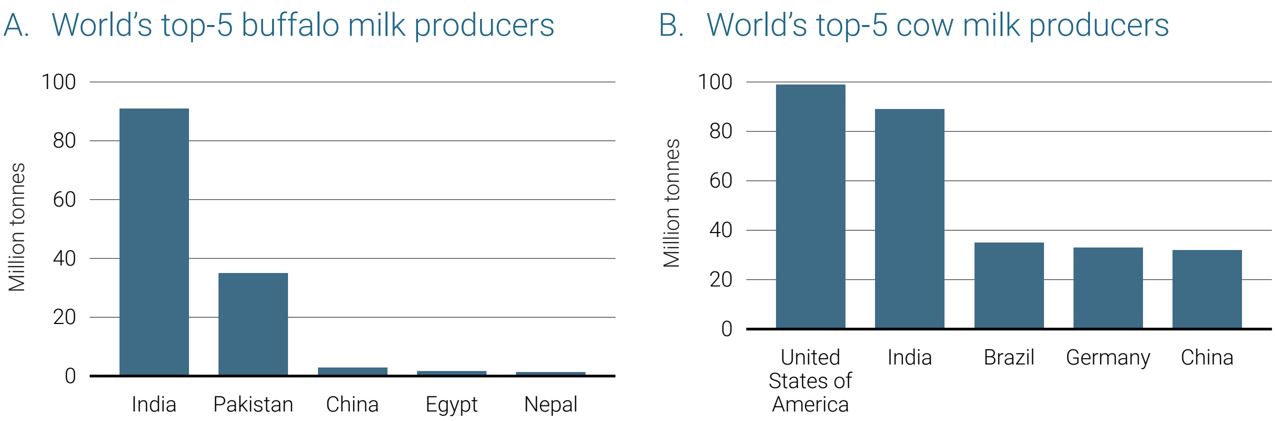
2. Salient features, the supply chain, and the main stakeholders of the dairy sector in India

2.1. Salient features of the Indian dairy sector

The dairy sector plays a vital role in ensuring food and nutritional security in India, as around 72 percent of the agricultural households, the majority of which are marginal and small landholders, rear livestock (NSSO, 2015). India is the largest milk producer globally, with buffalo milk leading the output (**Figure 1**), driven primarily by the world's largest bovine herd. However, yields are low and India's cow milk productivity is eight times and six times lower than in Israel and the United States of America, respectively (**Figure 2**). The dominance of unorganized dairy market channels, the poor genetic potential of dairy breeds and their high mortality, scarce feed and fodder use, high input costs and post-harvest processing constraints are some reasons for lower productivity (Kumar and Parappurathu, 2014). However, over the past decade, India's milk production has been growing at a rate of 5.6 percent, while cow milk yield is increasing at 3.6 percent annually.

The Indian economy is undergoing a structural transformation. The share of the agricultural sector in the total output declined from 18.5 percent in 2011/12 to 14.9 percent in 2017/18 (**Figure 3**, panel A). On the other hand, the share of the livestock sector in agricultural output has risen from 21.8 percent in 2011/12 to 27.4 percent in 2017/18. The demand for milk, products, and animal proteins is expected to continue growing. The milk group is the major sub-component in the livestock sector, accounting for 66.2 percent of the livestock value addition and expanding at an increasing rate (**Figure 3**, panel B).

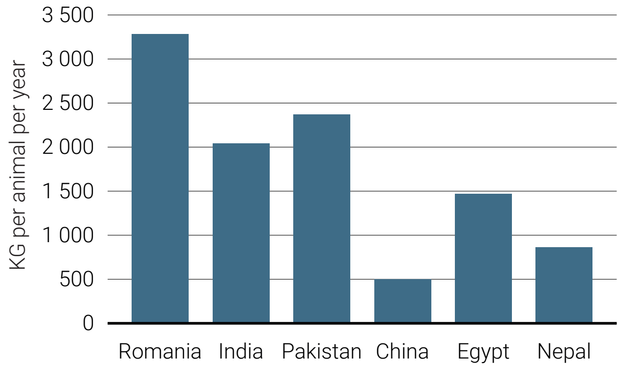
Figure 1. World's top-5 buffalo and cow milk producers



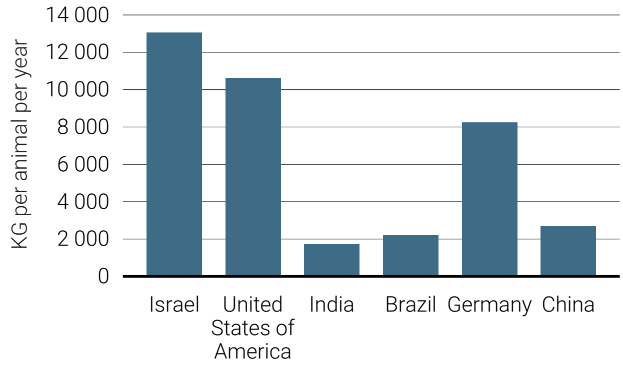
Source: FAO. 2020. FAOSTAT. Rome. [Cited 1 November 2020] http://www.fao.org/faostat/en/#home.

Figure 2. Milk yields of world's top-5 producers in comparison to world's highest yield

A. Buffalo milk yield



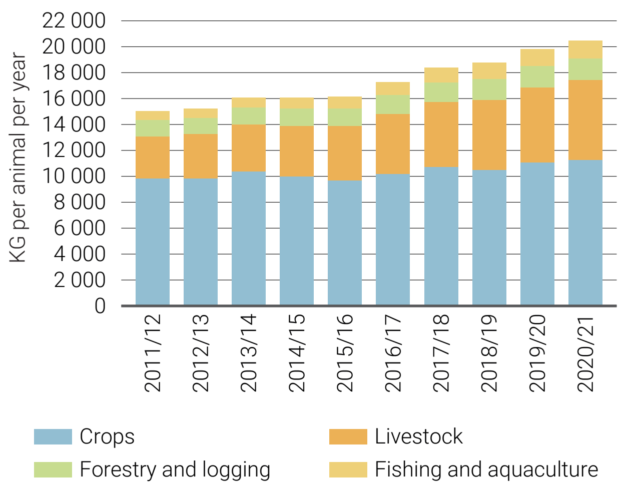
B. Cow milk yield



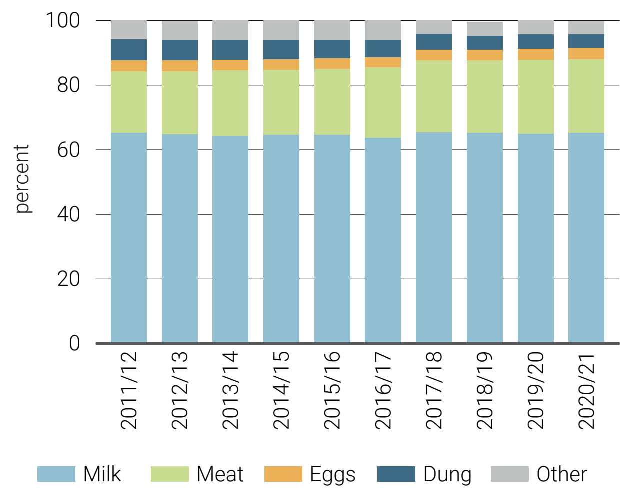
Source: FAO. 2020. FAOSTAT. Rome. [Cited 1 November 2020] http://www.fao.org/faostat/en/#home.

Figure 3. Economic transformation in India

A. Gross value added by economic activity in India



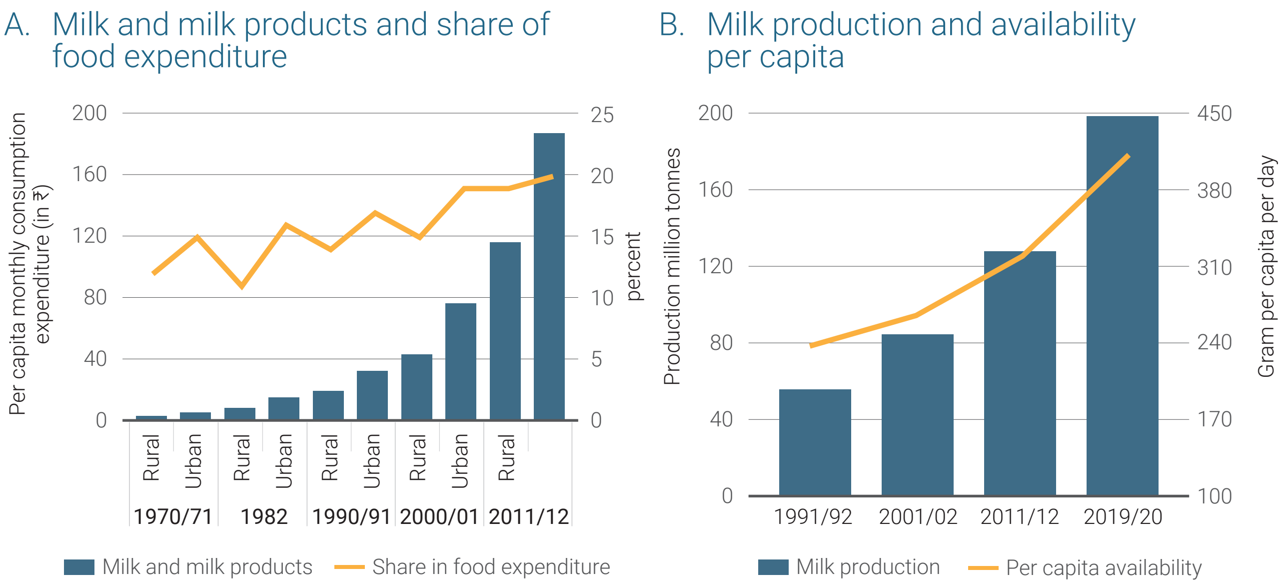
B. Share of sub-components in livestock sector output value



Source: Government of India. 2022. National Accounts Statistics 2022. New Delhi, India.

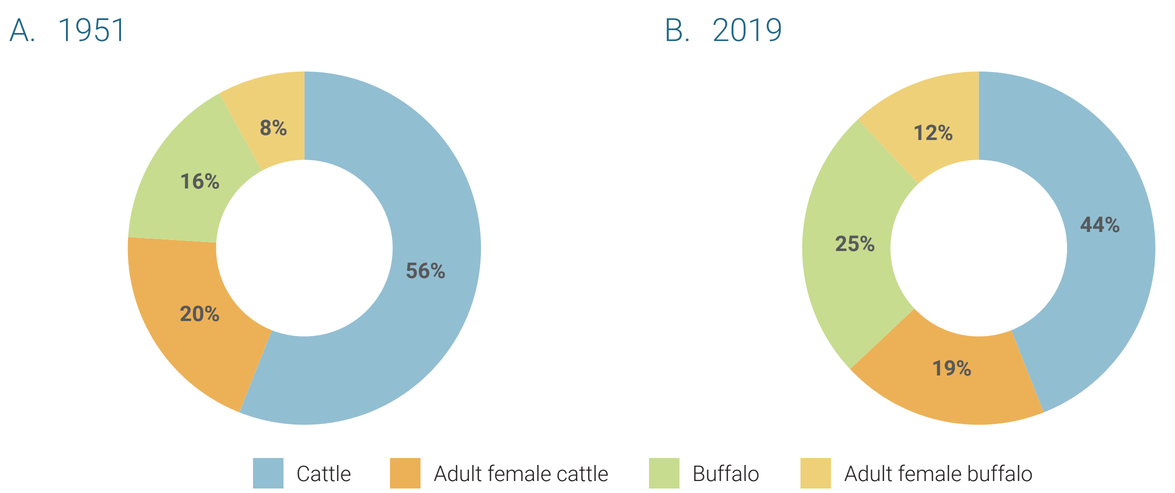
India has a vast dairy market, valued at Indian rupees (INR) 11 357 billion in 2020 (IMARC, 2021). Per capita availability and consumption of milk and milk products are increasing. For instance, milk availability per person in 2019/20 was 406 grams against 178 grams per day in 1991/92 (**Figure 4**). The share of milk and milk products expenditure in total food expenditure increased from 12 percent to 19 percent in rural areas and 15 percent to 20 percent in urban areas from 1970/71 to 2011/12, respectively. The latest estimates suggest that rural consumers spend INR 116 while urban consumers spend INR 187 per month on milk and milk products.

Figure 4. Dairy production, availability and consumption in India



Source: National Dairy Development Board. 2022. Per capita availability of Milk by States/UTs. Anand, Gujarat, India. https://www.nddb.coop/information/stats/percapitavail .

Figure 5. Percentage share of cattle and buffalo population in India



Source: National Dairy Development Board. 2022. Livestock population in India by Species. Anand, Gujarat, India. https://www.nddb.coop/information/stats/pop.

Over the years, the composition of bovine (cattle and buffalo) populations has transformed in India. The share of the buffalo population in the total bovine population has increased from 24 percent in 1951 to 37 percent in 2019 (**Figure 5**). On the fodder production front, according to the Agricultural Census 2015/16, India produces fodder crops on about 6.7 million hectares. Among the states, Rajasthan and Gujarat have the highest area under fodder crops and their share in the total cropped area of the state is around 11 percent and 7 percent, respectively. During 1995/96, 24 percent of the area under fodder crops was grown under irrigation, increasing to 29 percent in 2015/16. This shift towards irrigated fodder cropping indicates dairy farming is getting highly intensified in India.

2.2. The emergence of the COVID-19 pandemic in India and its immediate impacts

The Government of India nudged its citizens into a voluntary curfew (Janata curfew) before suddenly announcing a nationwide lockdown on 25 March 2020 to stop the coronavirus spread and prepare the emergency health infrastructure in the country. The COVID-19 data collected by Johns Hopkins University (Johns Hopkins University, 2021) showed that new cases had been rising steadily since March 2020. However, the virus reproduction rate had declined except at the beginning of February 2020. Meanwhile, the lockdown was very stringent in the first three months, as measured by a composite measure based on nine response indicators, including school closures, workplace closures and travel bans, rescaled to a value from 0 to 100, with 100 showing the strictest lockdown level, calculated by the Johns Hopkins University. This sudden lockdown disrupted the daily life of all the people in the country. Most services were shut down, including schools, colleges, restaurants, logistics, tourist places, trains, buses, flights and seaports. In addition to the lockdown media excitement, news of longer lockdowns in developed countries, job losses and a young population that has not experienced anything of this sort translated into a panic of an unprecedented amount (Cariappa *et al*., 2021).

On the supply side, dairy farmers faced a shortage of animal feed (Abhijit, Sivaram and Thejesh, 2021). Farmers also could not access veterinary services like artificial insemination (AI), which led to lower productivity in the short run and missing heat cycles and reproductive health of animals in the long run (Chandel *et al*., 2020). Lockdowns have caused a loss of an estimated 3.5 percent of the value of the product of the overall value of the milk group (Chandel *et al*., 2020). Farmers' incomes also declined due to the increased cost of inputs on the one hand and decreased milk sales during the lockdown due to lesser demand (Jaacks *et al*., 2021; Kumar *et al*., 2021; VikasAnvesh Foundation and Sambodhi, 2020), resulting in selling off cattle by 9 percent of the farmers (VikasAnvesh Foundation and Sambodhi, 2020). However, the dairy manufacturing industry remained resilient during the lockdown, as shown by the stability of the index of industrial production of dairy companies (Gulati, Jose and Singh, 2021).

On the demand side, the consumption of milk and milk products declined during the lockdown (Bhandari, Lal and Kumari, 2021; Gupta *et al*., 2021; Jaacks *et al*., 2021; Sanyal, Singh and Kapoor, 2021). Some research has shown that most pandemic measures have negatively impacted dairy wage earners and those in informal settlements with disruptions to food supply systems (Gupta *et al*., 2022). The survey results reported by Harris *et al*., (2020) indicate that 17 percent of households encountered disruptions to their diets, with 20–30 percent of households registering declines in non farm produced food items and increasing consumption of farm produced food items such as dairy and vegetables. Women farmers were significantly more likely than men to report a more substantial reduction in consumption of vegetables, fruits and dairy, given their limited access to land and farm production. Based on survey results, research has reported steep declines in consumption among women and women-headed families during the lockdown, reflecting lower access to productive resources or the general fact that female headed households and households with daily labourers both have lower incomes and higher income volatility than the general population (Gupta *et al*., 2022; and Sanyal, Singh and Kapoor, 2021).

The lockdown has also exacerbated food insecurity among the disadvantaged migrant workers from various indigenous groups based in cities such as New Delhi, Mumbai and Kolkata, with only 49 percent reporting milk availability and only 15 percent reporting the consumption of any milk product (Saxena *et al*., 2020). By contrast, 90 percent of urban households reported sustaining milk consumption, whereas nearly 65 percent continued to consume curd, paneer and cheese despite disruptions (Aneesh and Patil, 2021), indicating that a larger proportion of urban populations did not face significant impacts from the lockdown or supply chain disruptions. While the farmers' income decreased during the pandemic in Tamil Nadu, the annual expenditure on milk and milk products increased by 23 percent (Selvi *et al*., 2021). Further, the supply restrictions and dampened demand due to the lockdown did not immediately alter the milk prices or cause any structural changes in the long term price trends, highlighting the dairy sector's resilience in India (Cariappa *et al*., 2021; and Narayanan and Saha, 2021).

3. Data and results

3.1. Data

The monthly wholesale and retail milk prices were collected from the Ministry of Consumer Affairs (Ministry of Consumer Affairs, 2022). Retail and wholesale price data in India are collected by the Civil Supplies Department from 114 centres daily. Additionally, weekly retail milk price data were also collected from the Ministry of Agriculture and Farmers' Welfare (Ministry of Agriculture and Farmers' Welfare, 2022).

3.2. Results

3.2.1. Impacts on milk prices and their spreads

Immediate impacts on milk prices:

The RDiT estimates show that wholesale prices, a proxy for the price received by farmers, did not register a statistically significant increase immediately after the lockdown in any of the milk zones although wholesale prices have trended upward in the post COVID-19 lockdown across all the five zones (**Table 1**, panel A). However, the retail milk prices, which is a good proxy for the price paid by the consumers, rose 4.7 percent immediately after the post-lockdown in the East Zone of India (**Table 1**, panel B).

The fact that no notable change in retail prices was observed in zones other than the East zone suggests a high resilience to the lockdown. To establish if the price increase in the East zone of India was indeed due to the lockdown, the RDiT model was re estimated with a cut-off date of one year before the lockdown. This falsification test of the model (**Table 2**) shows that there had not been statistically significant price increases in wholesale or retail prices across all zones during the intervention period, reinforcing that the lockdown has indeed caused a price rise in the East zone.

To further investigate the results, the model was re estimated using weekly rather than monthly data as in previous models (**Table 3**). The results indicate a 3 percent rise in retail prices in the East zone. In addition to the falsification test, this finding further confirms that the pandemic induced lockdown had a statistically significant adverse effect in the East zone.

Immediate impacts on the price spread:

The price spread is the difference between the retail and wholesale milk prices, which is a good proxy for the extent of intermediary costs like processing and transport costs. The lockdown should theoretically have increased costs of labour movements, logistic services essential for functioning dairy production processes and raised market uncertainties and supply demand gaps. The present study analysed price spreads between retail and wholesale prices in the five milk zones using weekly wholesale and retail price data to identify if this was true in India. The results indicate that the price spread increased by 56.9 percent immediately after the post lockdown in the East Zone (**Table 4**, panel A), suggesting disruptions to milk marketing channels compared to the other zones. The falsification test further confirmed that there were no similar changes in the same month of the previous year (**Table 4**, panel B), indicating that the lockdown must be the most logical reason for the price increase immediately after the post-lockdown period in the East Zone.

Long term impact on milk prices and the price spread:

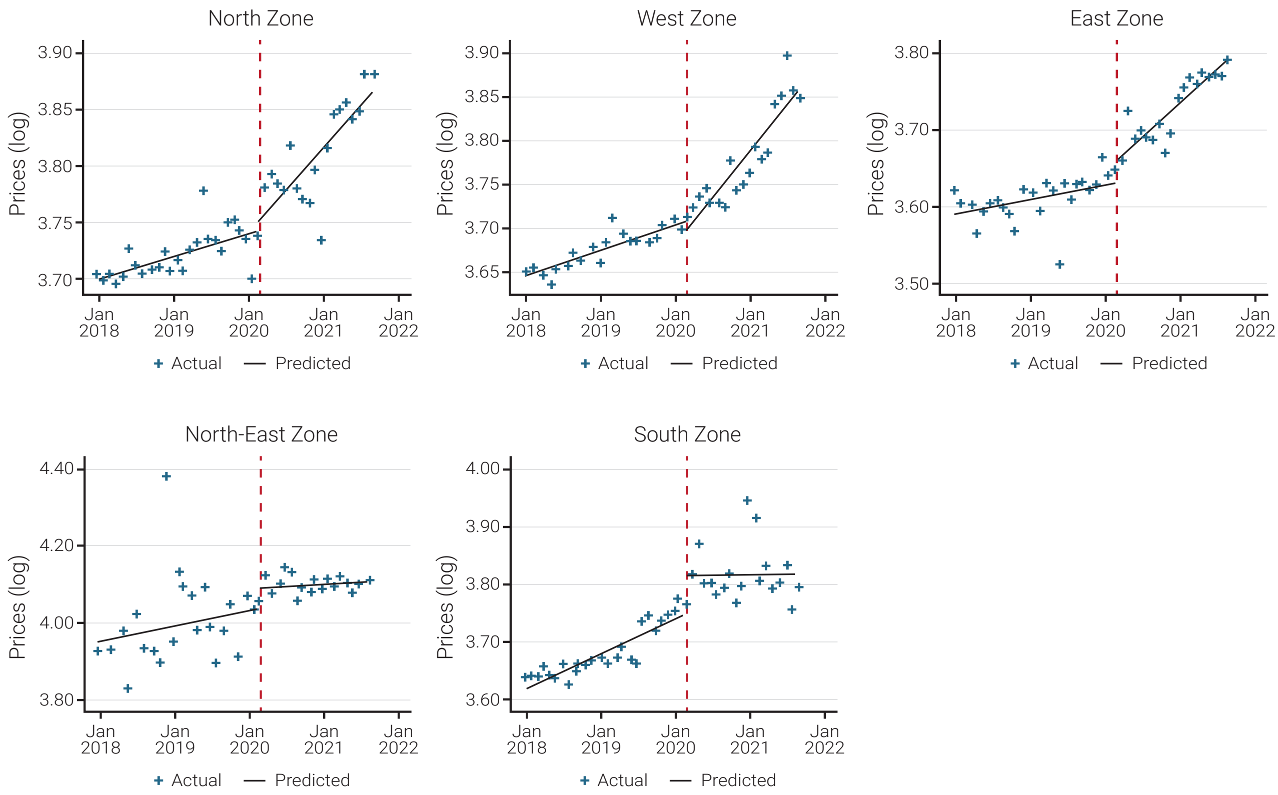
Wholesale milk prices have shown an increasing trend beyond the immediate period after the lockdown in India's North, West, and East zones (**Figure 6**, panel A), whereas prices have been stable or flat in the North East and South zones in the post-lockdown period.

By contrast, consumers' retail prices have continuously increased since the lockdown in all the regions (**Figure 6**, panel B). The result is not surprising, as India relaxed pandemic social distancing requirements and reopened the economy, allowing the food services sector (restaurants, hotels and other institutions) to function more freely, increasing demand for milk and milk products in tandem with increased income.

The price spread between retail and wholesale prices in the North, East and South zones has not changed since the lockdown, whereas it has decreased continuously in the West and increased in the North-East region (**Figure 6**, panel C). The likely reasons for the heterogeneous outcome across milk zones in the post lockdown period are the extent of milk production infrastructure, the adaptive capacity to external shocks and institutional arrangements. While the next section reviews the institutional arrangements, namely the dairy cooperatives and their milk production infrastructure, undertaking a detailed technical analysis is beyond the scope of this paper.

Figure 6. Actual and predicted wholesale milk prices in the five milk zones

Panel A: ITSA - Impact on Wholesale Milk Prices



Panel B: ITSA - Impact on Retail Milk Prices

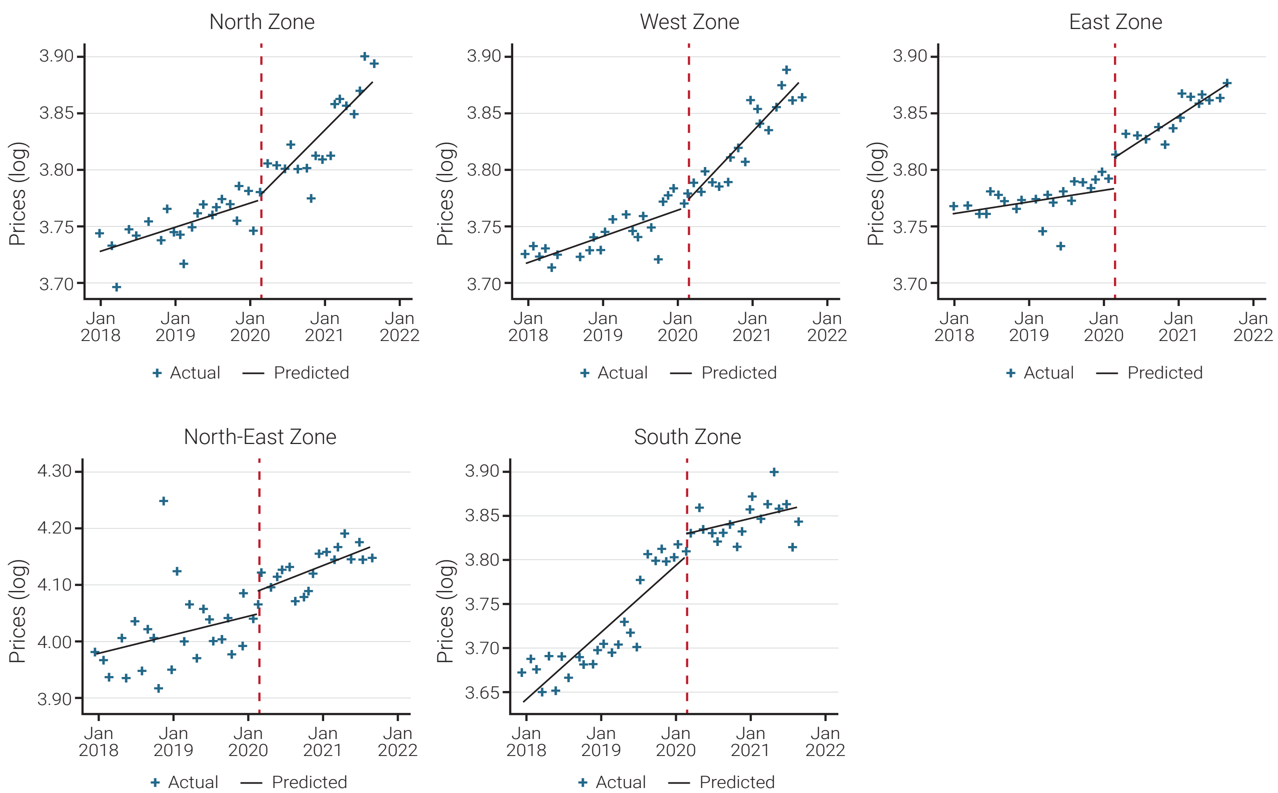
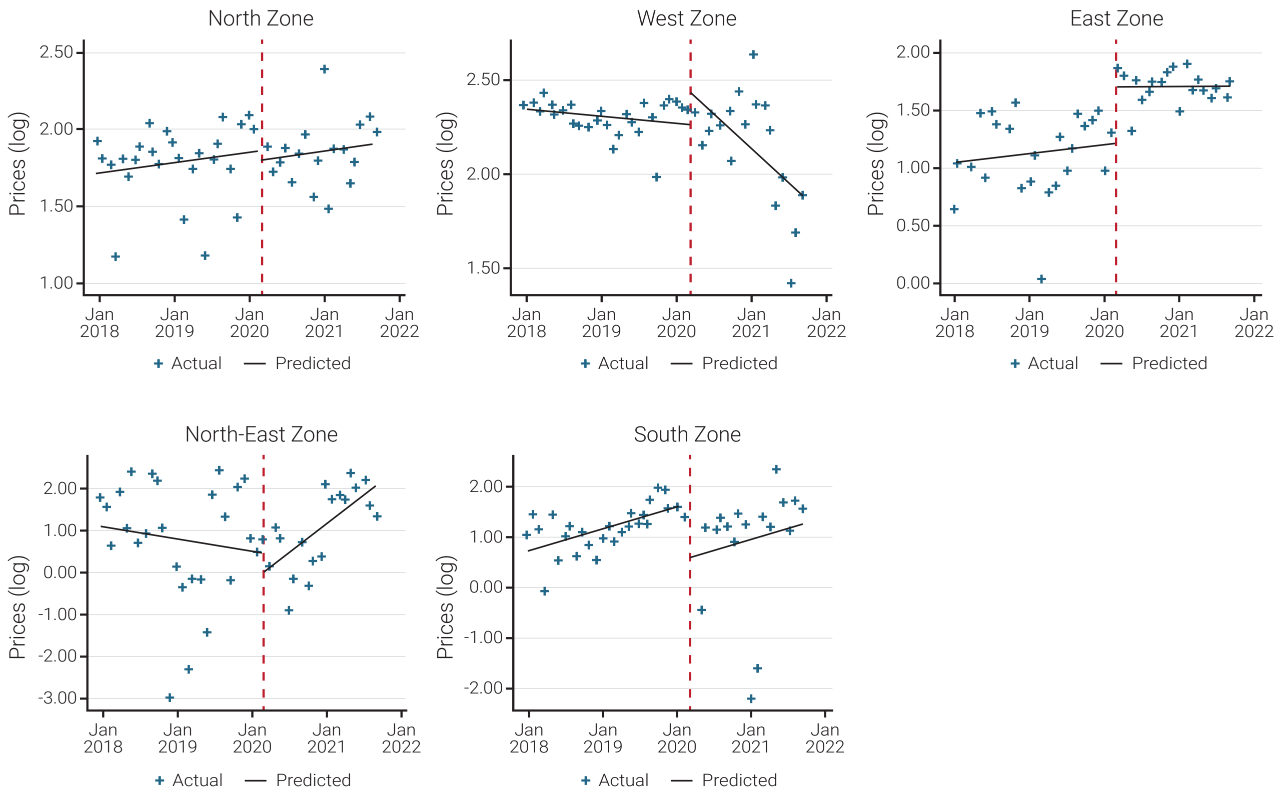


Figure 6. Actual and predicted wholesale milk prices in the five milk zones

Panel C: ITSA - Impact on Price Spread (retail - wholesale)



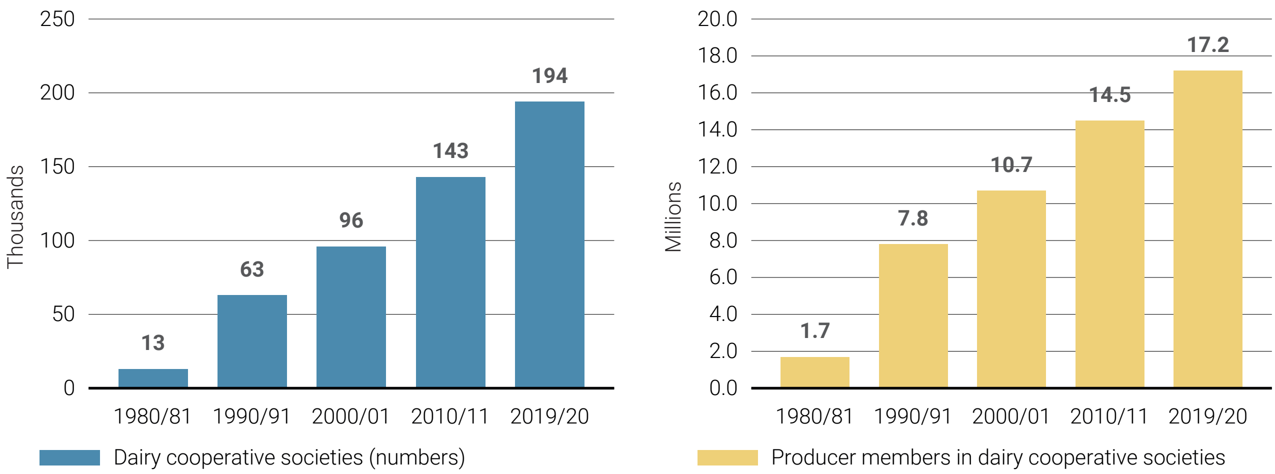
Source: Author's own elaboration.

3.2.2. Explaining the resilience factors of the dairy sector in India

News reports abound of dumping milk during pandemic related lockdowns, but in India, the crisis or the five-week long lockdown from 20 March 2020 had almost no impact on the volume of milk collected. However, demand for milk declined significantly following the lockdown. Milk sales of informal vendors consisting of confectionery shops and small businesses such as tea stalls, which account for nearly 20 percent of sales, came to a virtual halt for three months. Despite the sharp fall in milk sales, wholesale milk prices did not fall as expected. Even retail prices did not experience a discontinuity or shift except for the East Zone. One explanation is the significant role the vast network of dairy cooperatives played in sustaining milk production, absorbing the risk nearly entirely.

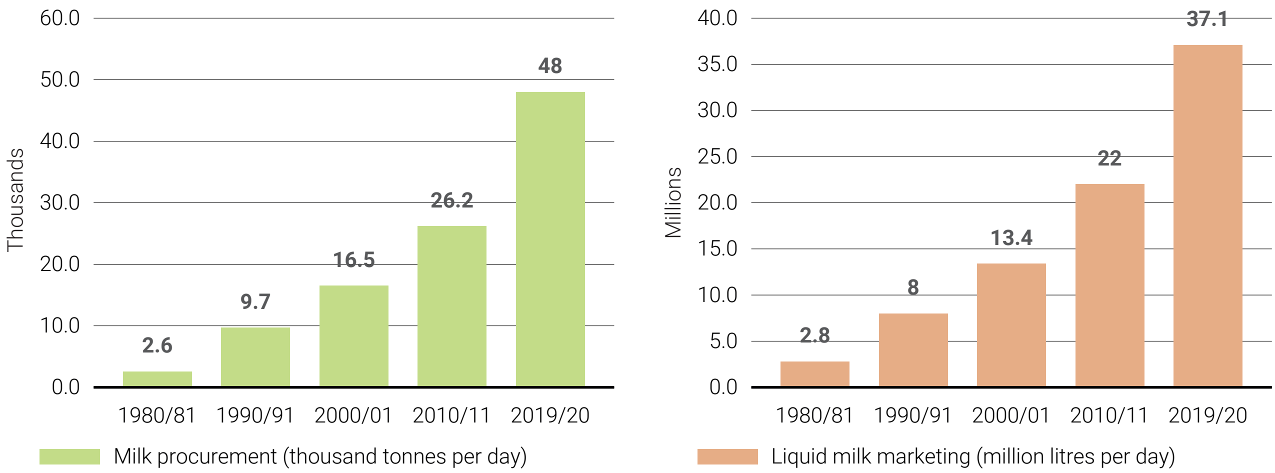
Dairy cooperatives and private diaries account for a significant share of milk production and sales in India. Dairy cooperatives have become a vast network involving stakeholders throughout the entire milk value chain, with dairy cooperatives not only functioning as a source of milk collection, distribution and marketing of milk products, but the system has evolved since the 'Operation Flood'[2] into a vast network linking millions of farmers, milk collectors, manufacturers and marketers contributing toward alleviating poverty and improving the living standards in rural India (Kumar *et al.*, 2018). During the last four decades (from 1980/81 to 2019/20), India's dairy cooperative societies (DCSs) increased from 13 284 to 194 195, whereas the number of producer members increased from 1.7 million to 17.2 million (**Figure 7**) with the volume of milk procured and marketed by the dairy cooperatives rising from a few thousand tonnes daily in 1980/81 to nearly 50 000 tonnes in 2019/20 (**Figure 8**).

Figure 7. Growth of dairy cooperative societies in India



Source: National Dairy Development Board. 2019-20. Annual Report. Anand, Gujarat, India. https://www.nddb.coop/about/report.

Figure 8. Milk procured and marketed by dairy cooperative societies in India



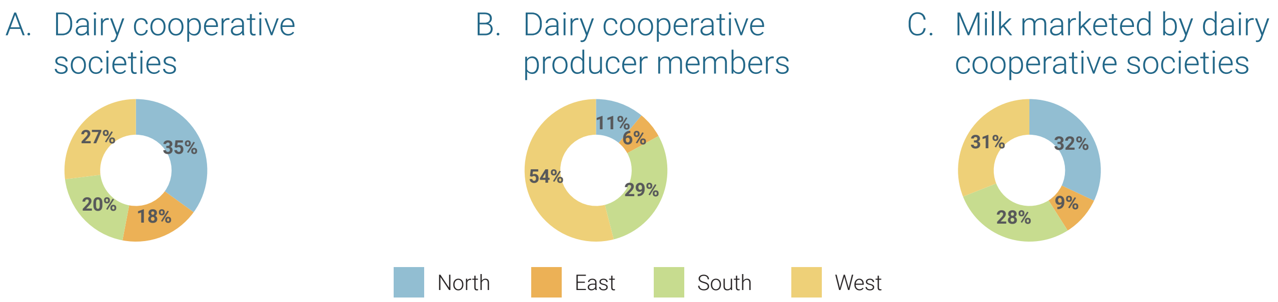
Source: National Dairy Development Board. 2019-20. Annual Report. Anand, Gujarat, India. https://www.nddb.coop/about/report.

[2] India's Operation Flood was a massive dairy development programme launched in 1970 to make India self-sufficient in milk production.

In the past decade, the number of dairy cooperative societies has increased by 36 percent, while the number of their producer members has increased by 19 percent. During the same period, the volumes of milk procured and marketed by dairy cooperatives have increased, respectively, by 83 and 69 percent, also indicating improvements to operational efficiency compared to increased membership. Some successful dairy cooperative societies have seen massive increases in turnover. A key benefit of successful dairy cooperatives is that they tend to offer a higher proportion of each consumer rupee or what consumers pay for dairy products to producers. Shah (2016) highlights the cases of Mulukanoor Women's Cooperative Dairy Union and Payaas in Rajasthan as examples which pay approximately 85 percent of each rupee a consumer pays as producer price. Payments are not the only benefit that attracts dairy cooperatives. In semi arid North Gujarat, the farming system is drought-proofed by strong dairy cooperatives as they allow farmers to concentrate on increasing milk production to counter the income loss from crop failure during droughts (Shah, 2016). While such examples may remain, they nevertheless point to the role of dairy cooperatives in sustaining resilience under challenging market conditions. Despite these benefits, only 27 percent of households with excess milk sell to the dairy cooperatives, while the unorganized sector accounts for 67 percent of the milk sold in the country.

This national dairy cooperative's landscape briefly mentioned above hides significant deviations of dairy cooperatives across dairy zones in India regarding distribution and performance. According to 2019/20, out of all the dairy cooperative societies in India, the North zone has the highest share of 35 percent, while the East zone has the lowest percentage of 18 percent. The East zone also has the lowest share (11 percent) of producer members out of India's 17.2 million total members. The East zone accounts for only a modest 6 percent of the milk procured and only 9 percent of milk sold (**Figure 9**). These figures should be compared to the dairy cooperatives in the North, West and South zones, which account for 32 percent, 31 percent and 28 percent of milk sold, respectively. The anecdotal evidence suggests that dairy cooperatives are prominent in areas with non-significant pandemic impacts.

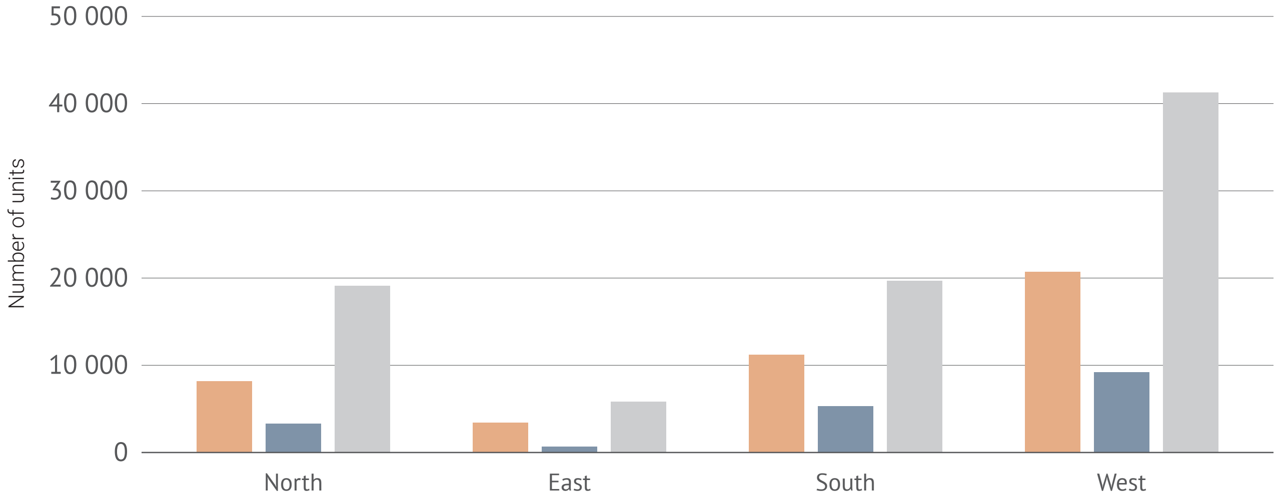
Figure 9. Dairy cooperatives, members, and milk procurement across milk zones in India (2019/20)



Source: National Dairy Development Board. 2020. Diary Knowledge Portal. Anand, Gujarat, India. https://www.dairyknowledge.in/section/iii-dairy-cooperatives.

The availability of cold chain infrastructure and dairy processing facilities played a critical role in the dairy sector's resilience in countries and regions during the pandemic because milk producers could channel excess milk to processing centres. It was observed that countries with the capacity to produce milk powders could weather the market disruptions better. Compared to most other countries, India has widely distributed cooling facilities owing to the widespread dairy cooperatives and their investments. The East zone, however, is again found to have the lowest concentration of chilling facilities in India, with only 3.5 percent of the national chilling units with the capacity for cooling a thousand litres per day (TLPD) (**Figure 10**). The limited capacity to process milk may have contributed to less resilience to market vagaries in the face of the pandemic induced lockdown.

Figure 10. Dairy cooperative cold-chain infrastructure



Source: National Dairy Development Board. 2019-20. Annual Report. Anand, Gujarat, India. https://www.nddb.coop/about/report.

The present study also investigated two dairy cooperatives to understand the mechanisms and factors that may contribute to the resilience of the dairy sector in India.

<u>Kerala Co-operative Milk Marketing Federation (KCMMF):</u>
The KCMMF was established in 1980 while launching the 'Operation Flood' programme under a three tier cooperative system, namely a) milk cooperative societies with local milk producers as its members at the village level; b) cooperative milk producers' unions at the regional level; and c) cooperative federation at the state level. In 2019, the KCMMF had 315 primary milk cooperative societies at the village level with 977 000 dairy farmers as members during 2019, popularly known as 'MILMA.'

Milk sales' data were analysed using a regression model with controls for seasonality (**Table 5**). The results indicate that MILMA procured more milk after the lockdown despite sales falling notably. Although dairy products considered essential, such as paneer, fell only by 3 percent, other products such as butter and ice cream fell by as much as 60 percent. Post-lockdown sales, however, increased across many of these products, suggesting a faster recovery once the lockdown was over. The muted demand due to the shutdown of HORECA[3], schools and hostels led to the fall in sales of milk and milk products. Once the government lifted restrictions on agricultural activities and allowed people to buy milk during restricted hours, the demand and sales began trending up slowly.

3.2.3. The Punjab State Cooperative Milk Producers Federation Limited (MILKFED) MILKFED

came into existence in 1973 and has a three-tier cooperative system: milk federation as the apex body at the state level; milk unions at the district level; and milk producer's cooperative societies at the village level. It promotes milk production, procurement, and processing by providing milk producers with remunerative prices and selling quality milk and milk products. The MILKFED has a network of 7 385 milk producer cooperative societies organized at the village level with around 373 000 producer members in 2019/20 (National Dairy Development Board, 2020). It is popularly known as 'VIRKA.'

Though not statistically significant when controlling for seasonal fixed effects and trends, MILKFED increased procurement when the lockdown was announced (**Table 6**). When controlling only for seasonal fixed effects, procurement shows a statistically significant 21 percent increase. However, controlling for seasonal and other factors (through polynomial trends), the milk procurement by MILKFED shows a 5 percent rise immediately after lockdown. The increased procurement led to an 8 percent decrease in procurement prices. Milk and curd sales were the most affected component among MILKFED sales. Milk sales fell by 25 percent, while curd sales fell by 36 percent immediately post-lockdown. The lockdown did not reduce sales of other milk and milk products like Ghee, Butter, UHT milk, and paneer. Milk procurement prices and sales of UHT milk have been on a significant downward trend since the lockdown.

[3] A strategic buyer to buyer platform for suppliers to network.

4. Summary, conclusions, and recommendations

4.1. Summary and conclusions

The pandemic and the containment measures have led to widespread economic disruption and economic, social and political instability worldwide. The lockdowns imposed by governments across the world to contain the virus spread exacerbated these instabilities. Containment measures also impacted different agricultural sectors and value chain actors in heterogeneous ways and with different intensities.

Anecdotal evidence appeared right after the introduction of the first lockdowns, and a large body of research appeared, subsequently providing insight into the impact of the shock. First, a key insight was that the pandemic differed from other shocks in one key aspect: the inability to use geographical arbitrage because the shock was widespread and affected simultaneously with little time lag. Second, the pandemic disrupted the smooth functioning of markets, leaving behind a trail of insolvent producers that could not adapt fast enough to the unfamiliar environment. Initially, the pandemic caused panic buying among consumers, but subsequently, consumers shifted away from food services such as hotels and restaurants to home consumption. The pandemic significantly stressed the supply chains from farms to markets, including production and logistic services and put a heavy burden on producers. Besides, logistical disruptions due to lockdowns and social distancing requirements made it difficult for producers to secure raw materials and transport products to markets. The unpredictability of consumer demand due to lockdowns and social-distancing requirements magnified these demand and supply changes. Simultaneously, consumers faced supply uncertainties, leading some consumers to hoard 'essential' products, further adding to market disruptions. As a result, small-scale producers with limited financial capacity or access to resources had to scale down operations or ended up insolvent. Third, heterogeneous outcomes across geographical regions were also observed due to differences in access to technologies, institutional arrangements and government assistance. In the dairy sector, milk production reached near normalcy after dropping significantly at the initial stage depending on the availability of resources, including government assistance, increased use of automation, e commerce platforms, direct supply arrangements with supermarkets, etc., thereby minimizing the impact of labour shortages and transport and logistical hurdles. Fourth, notwithstanding significant negative implications on agrifood systems, some sectors have shown remarkable resilience to the market disruptions in some countries.

While there is extensive literature on the impact of shocks on agrifood production systems, studies on resilience are limited, especially quantitative assessments that trace the heterogeneity of effects. The study aimed to fill this vacuum by undertaking quantitative assessments focusing on the Indian dairy sector and explaining the underlying factors of the observed resilience to the shock. The study analysed wholesale and retail prices over time, differentiated by milk-producing 'zones.' For this purpose, the study employed RDiT, and ITSA approaches.

Following an exposition of salient features of the Indian dairy sector, the study used weekly wholesale and retail milk price data available to identify if the lockdown had led to some discontinuities in prices in four milk production zones in India. The study also undertook a detailed analysis of the dairy production arrangement in India, analysed milk procurement and dairy product sales of two prominent dairy cooperatives in India to determine the resilience factors.

The study provides several new insights. First, the study found that lockdown did not have a statistically significant immediate impact on wholesale prices, a proxy for the price received by farmers, across all five milk production zones. Retail prices also did not have significant discontinuities, except for the East zone, confirming a remarkable resilience to the crisis. The same result was confirmed when the price spread between retail and wholesale prices was analysed. In other words, the price spread between retail and wholesale prices rose in the East zone of India, indicating disruptions in milk marketing channels.
Second, retail prices trended upward in all the milk zones during the post lockdown period when a longer time horizon was considered, reflecting the removal of lockdown and other social distancing requirements. This contrasts with a nearly flat or mild increase in wholesale prices post lockdown period.

Third, the study hypothesized that, among other factors, the mobilisation of the vast network of dairy cooperatives has been a factor that contributed to the dairy sector's resilience in India. This is compatible with the finding that the East zone, which was found to have a discontinuous retail price immediately after the lockdown, has the lowest number of active dairy cooperatives and producer members. The region also has the lowest cold-chain infrastructure in the country – a key factor that contributed to the dairy sector's resilience in some countries.

By investigating the issue further using milk procurement data made available to the research team by two dairy cooperatives in India, namely MILMA in Kerala and MILKFED in Panjab, we found that the capacity to absorb financial risk during the lockdown was a key resilience factor. Successful dairy cooperatives continued to procure milk from producers despite steep declines in dairy product sales, assuming high risks at the time under unknown market conditions. This further corroborates the finding cited by Cariappa and Suraj (2021) that a multinational corporation (MNC) in Haryana State in India did not stop dairy processing operations, or payments to their contract farmers during the lockdown, suggesting that milk processing capacity and ability to assume higher risk were instrumental in sustaining dairy production during the pandemic.

4.2. Recommendations for sustaining market resilience

Based on the study's findings, the study offers a few recommendations for sustaining market resilience when faced with external shocks:

1. Building strong institutional infrastructure such as dairy cooperatives is necessary but not sufficient for sustaining market resilience. It is imperative to undertake an evaluation of risk-taking capacity, especially the availability of financial and other resources required to support dairy production processes without interruption, given that dairying is not an activity similar to others that can turn off and on when needed. Dairy processors need resources for assuming higher risks while relaxing certain regulations, such as labour movements, deemed essential for sustaining production.

2. Ensure the availability of inputs for sustaining the dairy industry, which include: feed and veterinary services for maintaining dairy herd numbers; input required for milk processing, including energy for milk processing (for spray drying, ultra high sterilisation, pumps, refrigeration and thermal energy as steam for evaporation and pasteurisation processes) and raw materials; transport facilities to sustain continuity in operations such as consumables, packaging materials, milk and dairy products; the availability of skilled labour force; and efforts to sustain short term milk supply chains (e.g. farmers selling directly to consumers) and integrated food processing industry; and

3. Provide government assistance for those who fail to use other channels for distinct reasons, including lack of training, education and access to markets, or small-scale farmers who operate only in the unorganized sector.

Annex 1. Technical note on Regression Discontinuity in Time (RDiT)

The study uses the Regression Discontinuity in Time (RDiT) design to assess the immediate impact of lockdown on milk prices. The RD design uses three components: score, cutoff, and treatment. While all the observations get a score (Xi), the time variable of the study, the observations above and below the date of lockdown (25 March 2020) are assigned to the treatment group (Ti=1) and control group (Ti=0), respectively (Cattaneo, Idrobo and Titiunik, 2020). As India announced the lockdown suddenly, and measures came into effect immediately and nationwide, the study uses a Sharp RD design, which requires perfect compliance to treatment.

Local polynomial estimators are widely used to estimate and draw inferences from RD designs (Calonico *et al*., 2019). A linear regression model is chosen with a weighting scheme decided by the kernel function K(·) using a bandwidth choice (h) and the neighbourhood of observations on either side of the cutoff. The estimates use a triangular kernel that assigns more weight to observations near the cutoff and lower weight to those farther away. The bandwidth (h), which yields the least mean-squared error (MSE), is selected. Bandwidth (h) and the triangular kernel localise the regression fit around the cutoff. Stata routine 'rdrobust' is used to estimate the standard local linear RD treatment effect (Calonico, Cattaneo and Titiunik, 2014). A weighted least squares (WLS) regression of log milk prices on a constant, Xi, Ti, and TiXi is fit using observations inside the neighbourhood with $\mathrm{Xi} \in [-\mathrm{h}, \mathrm{h}]$ and applying weights $\mathrm{K}(\mathrm{Xi}/\mathrm{h})$ (Calonico *et al*., 2019).

The parameter of interest, Sharp RD average (reduced form) treatment effect, is measured at the cutoff and can be written as,

$$\tau_{SRD} = E[Y_i\,(1) - Y_i\,(0)|X_i = c]$$

Where $Y_i\,(0)$ and $Y_i\,(1)$ are the potential outcomes without and with treatment, respectively, for each time in the sample

$$Y_i = \beta_0 + T_i\,\tau + X_i\,\beta_- + T_i\,X_i\,\beta_+$$

Numerically, τ is equivalent to the difference in intercepts of two separate WLS regressions run on the left and right sides of the cutoff (with the same bandwidth and kernel).

Interrupted time series analysis (ITSA)

Following (Bernal, Cummins and Gasparrini, 2017; Cariappa *et al*., 2020, 2021; Crosbie, 1993; Serumaga *et al*., 2011; Shadish, Cook and Campbell, 2002), the study uses a longitudinal quasi-experimental technique known as the Interrupted Time Series Analysis (ITSA) to evaluate the effects of COVID-19 induced lockdown on milk prices.

$$Y_{it} = \beta_0 + \beta_1 time_t + \beta_2\, level_i + \beta_3\, trend_{it} + \gamma s + \varepsilon_{it}$$

where Y is the wholesale or retail log milk prices; β_0, β_1, β_2 and β_3, respectively, are the existing level (at t=0), pre-intervention trend (changes in outcome over time), level change post-intervention and post-intervention slope change. γs is the seasonal fixed effects of milk supply and prices. Polynomial time variables were also included to further control for nonlinearity in the milk prices. The parameters of interest are β_2 and β_3, as they indicate, respectively, the change in milk prices immediately and in the long term after lockdown. The post-lockdown trend (long-run effects) was also calculated using the linear combination of β_1 and β_3 coefficients.

Once the model uses bandwidth and triangular kernel in RdiT and controls for seasonality and nonlinearity in milk prices in ITSA, the change in milk prices should solely be due to the nationwide lockdown.

Annex 2. Tables with model estimate results

Table 1. Immediate impact on milk prices: RDiT estimates

Model	**-1**	**-2**	**-3**	**-4**	**-5**
Dependent variable	**Natural logarithm of monthly milk prices**				
ZONE	**North**	**West**	**East**	**North-East**	**South**
Panel A. Wholesale prices					
Conventional	0.06	0.012	-0.001	-0.013	0.027
	-0.049	-0.014	-0.03	-0.081	-0.039
Bias-corrected	0.073	0.022	-0.006	-0.046	0.031
	-0.049	-0.014	-0.03	-0.081	-0.039
Robust	0.073	0.022	-0.006	-0.046	0.031
	-0.061	-0.02	-0.032	-0.103	-0.046
Observations	11	11	11	11	15
Conventional Std. Err.	0.049	0.014	0.03	0.081	0.039
Conventional p-value	0.217	0.417	0.976	0.87	0.486
Robust p-value	0.231	0.283	0.858	0.652	0.493
BW Loc. Poly. (h)	5.42	5.4	5.405	5.515	7.498
BW Bias (b)	8.461	5.4	8.149	9.197	11.98
Panel B. Retail prices					
Conventional	0.038	-0.004	0.041***	0.004	0.005
	-0.031	-0.013	-0.016	-0.042	-0.022
Bias-corrected	0.046	-0.006	0.047***	-0.015	0.013
	-0.031	-0.013	-0.016	-0.042	-0.022
Robust	0.046	-0.006	0.047***	-0.015	0.013
	-0.04	-0.018	-0.018	-0.05	-0.027
Observations	11	13	11	11	11
Conventional Std. Err.	0.031	0.013	0.016	0.042	0.022
Conventional p-value	0.219	0.744	0.009	0.918	0.825
Robust p-value	0.256	0.743	0.008	0.762	0.631
BW Loc. Poly. (h)	5.588	6.662	5.967	5.277	5.408
BW Bias (b)	8.628	10.57	9.62	8.475	8.937

Note: Standard errors in parentheses.
* p<0.1, ** p<0.05, *** p<0.01
Source: Author's(s') own elaboration.

Table 2. Falsification test: cutoff at March 2019 instead of March 2020

Model	-1	-2	-3	-4	-5
Dependent variable	Natural logarithm of milk prices				
ZONE	North	West	East	North-East	South
Panel A. Wholesale prices					
Robust	-0.007	0.009	0.006	0.117	0.013
	-0.032	-0.036	-0.031	-0.317	-0.01
Observations	11	11	11	11	15
Conventional Std. Err.	0.023	0.021	0.021	0.088	0.008
Conventional p-value	0.946	0.283	0.276	0.638	0.222
Robust p-value	0.828	0.797	0.833	0.713	0.217
BW Loc. Poly. (h)	5.4	5.4	5.4	5.5	7.5
BW Bias (b)	5.4	5.4	5.4	5.5	7.5
Panel B. Retail prices					
Robust	-0.011	0.004	-0.045	-0.077	-0.02
	-0.042	-0.019	-0.028	-0.243	-0.032
Observations	11	13	11	11	11
Conventional Std. Err.	0.028	0.01	0.021	0.1	0.019
Conventional p-value	0.481	0.39	0.0539	0.354	0.578
Robust p-value	0.796	0.843	0.112	0.751	0.532
BW Loc. Poly. (h)	5.6	6.7	6	5.3	5.4
BW Bias (b)	5.6	6.7	6	5.3	5.4

Note: Standard errors in parentheses.
Source: Author's(s') own elaboration.

Table 3. Additional robustness test: impact on weekly retail prices

Model	-1	-2	-3	-4	-5
Dependent variable	Natural logarithm of weekly retail milk prices				
ZONE	North	West	East	North-East	South
Robust	0.019	0.002	0.030***	0.005	0.002
	-0.012	-0.005	-0.01	-0.005	-0.004
Observations	23	15	37	188	43
Conventional Std. Err.	0.011	0.005	0.009	0.005	0.003
Conventional p-value	0.197	0.875	0	0.318	0.61
Robust p-value	0.116	0.669	0.004	0.318	0.71
BW Loc. Poly. (h)	11.29	7,765	18.69	93.79	21.36
BW Bias (b)	25	7.765	32.3	26.25	34.56

Note: Standard errors in parentheses.
* p<0.1, ** p<0.05, *** p<0.01
Source: Author's(s') own elaboration.

Table 4. Impact on price spread: RDiT estimates

Model	-1	-2	-3	-4	-5
Dependent variable	Natural logarithm of monthly milk prices				
ZONE	North	West	East	North-East	South
Panel A. March 2020 as the cutoff date					
Conventional	-0.2	-0.029	0.683***	0.464	-0.291
	-0.226	-0.085	-0.214	-1.134	-0.67
Bias-corrected	-0.197	-0.004	0.569***	0.916	-0.008
	-0.226	-0.085	-0.214	-1.134	-0.67
Robust	-0.197	-0.004	0.569*	0.916	-0.008
	-0.297	-0.103	-0.326	-1.428	-0.757
Observations	13	11	11	11	11
Conventional Std. Err.	0.226	0.085	0.214	1.134	0.67
Conventional p-value	0.376	0.732	0.001	0.682	0.664
Robust p-value	0.507	0.971	0.081	0.521	0.992
BW Loc. Poly. (h)	6.338	5.03	5.5	5 653	5 191
BW Bias (b)	10.57	7.488	5.5	10.41	8 655
Panel B. Falsification test with March 2019 as cutoff					
Robust	-0.198	-0.064	-1.421*	-4.106	-0.898
	-0.225	-0.117	-0.8	-3.153	-0.915
Observations	13	11	11	11	11
Conventional Std. Err.	0.145	0.082	0.567	1.126	0.464
Conventional p-value	0.03	0.167	0.249	0.336	0.463
Robust p-value	0.377	0.587	0.076	0.193	0.326
BW Loc. Poly. (h)	6.3	5.5	5.5	5.6	5.2
BW Bias (b)	6.3	5.5	5.5	5.6	5.2

Note: Standard errors in parentheses.
Source: Author's(s') own elaboration.

Table 5. Impact of COVID-19 lockdown on Procurement and sales of milk and milk products of MILMA, Kerala

Dependent variable	Natural logarithm of Procurement	Natural logarithm of sales								
		Milk	Ghee	Butter	Paneer	Curd	Peda	Buttermilk	Ice cream	Flavoured milk
Lockdown (March 2020)	-0.02	-0.10 ***	0.15	-0.59	-0.03	-0.25 **	-0.25*	-0.46	-0.62 **	-0.58 **
	-0.04	-0.03	-0.12	-0.39	-0.13	-0.11	-0.13	-0.57	-0.28	-0.28
Post-lockdown	0.06***	0.02**	-0.01	0.35**	0	0.08**	0.12***	0.01	0.14*	0.13**
	0.01	0.01	0.04	0.14	0.05	0.03	0.03	0.14	0.08	0.06
N	*45*	*45*	*44*	*44*	*44*	*44*	*44*	*44*	*44*	*44*
Polynomial order	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*
Season FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
F	*36*	*5.57*	*0.46*	*6.1*	*13.4*	*3.6*	*10.9*	*10.3*	*8.01*	*5.45*

Source: Author's(s') own elaboration.

Table 6. Impact of COVID-19 lockdown on Procurement and sales of milk and milk products VERKA, Punjab

Model	-1	-2	-3	-4	-5
Panel A. Milk procurement (in natural logarithm)					
Lockdown	0.21	0.22*	0.17	0.18	0.05
	-0.18	-0.12	-0.11	-0.14	-0.16
Post-lockdown trend	-0.00	-0.00	-0.00	-0.00	-0.00
Panel B. Milk prices (in natural logarithm)					
Lockdown	-0.11***	-0.13***	-0.18***	-0.18***	-0.08*
	-0.02	-0.03	-0.02	-0.03	-0.03
Post-lockdown trend	-0.00	-0.00	-0.00***	-0.00**	-0.00***
Panel C. Milk sales (in natural logarithm)					
Lockdown	-0.22***	-0.20***	-0.22***	-0.26***	-0.25***
	-0.04	-0.03	-0.03	-0.05	-0.05
Post-lockdown trend	0.00***	0.00***	-0.00	-0.00	-0.00
Panel D. Ultra High Temperature Milk sales (in natural logarithm)					
Lockdown	0.33**	0.36**	0.27*	-0.01	-0.05
	-0.11	-0.11	-0.11	-0.13	-0.14
Post-lockdown trend	0.001***	0.001***	-0.003**	-0.003**	-0.003**
Panel E. Ghee sales (in natural logarithm)					
Lockdown	-0.13	0.035	0.062	0.11	0.22
	-0.11	-0.11	-0.12	-0.15	-0.2
Post-lockdown trend	-0.00	-0.00*	-0.00	0.00	0.00
Panel F. Butter sales (in natural logarithm)					
Lockdown	-0.35**	-0.23*	-0.22*	-0.14	-0.1
	-0.11	-0.096	-0.1	-0.12	-0.16
Post-lockdown trend	0.00	0.00	0.00	0.00	0.00
Panel G. Paneer sales (in natural logarithm)					
Lockdown	-0.04	-0.06*	-0.06*	-0.04	-0.02
	-0.04	-0.03	-0.04	-0.05	-0.05
Post-lockdown trend	-0.00	-0.00	-0.00	-0.00	-0.00
Panel H. Curd sales (in natural logarithm)					
Lockdown	-0.05	-0.30***	-0.34***	-0.48***	-0.36**
	-0.11	-0.09	-0.09	-0.11	-0.15
Post-lockdown trend	0.00***	0.00***	-0.00	-0.00	-0.00

Note: Standard errors in parentheses.
* p<0.1, ** p<0.05, *** p<0.01
Source: Author's(s') own elaboration.

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