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The impact of digitalisation on the agricultural wholesale prices to aid agrarian income

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Abstract: The paper analyses the effect of electronic-trading (e-trading) on the wholesale prices of select commodities in agricultural marketplaces to aid agrarian income levels. Post a literature review, the researcher performed a field survey to get the opinions of 371 farmers and traders. The researcher also conducted the descriptive statistical analysis, the difference in differences analysis, and the *t*-test analysis to show the wholesale price improvement after the e-trading platform implementation. The field survey findings and the statistical analysis suggest an increase in average wholesale prices of select agri-commodities in select markets of India due to the National Agriculture Market (eNAM) e-trading platform effect. The suggestions to practitioners and social policymakers highlight an improvement in the functioning of e-trading in terms of better prices for farmers, lowering transaction costs, increased transaction speed, reduced administrative hurdles, improved infrastructure and eventually higher income for a farmer. The knowledge base developed in this paper will help researchers reduce the knowledge gap in agricultural pricing.

Keywords: e-marketplace; electronic trading; income improvement; national agriculture market; wholesale pricing

Social policymakers across the globe are also interested in increasing the income level of the citizens involved in agriculture. In most developing countries, the agricultural sector remains the major contributor to the economy and employs the majority of the workforce. The increase in the effective farm produce prices is one of the policymakers' main components of the farmers' agricultural income improvement initiatives. So far, most research has focused on productivity increase and cost reduction in this space. Not much research is done on price improvement, resulting in the net income increase equation.

The agriculture sector is undergoing a massive transformation due to digitalisation. The digitalisation effect is not only on the technology side but also has economic fallout. In India, the positive impact of digitalisation [electronic trading (e-trading) and information portals] is augmented by the policymaker's interest in reducing the farmer's over-reliance on subsidies and price support mechanisms (Chand 2016; Chatterjee and Kapur 2016). Digitalising the procurement stage of the agricultural supply chain is a vital initiative in this direction.

Information and communication technology (ICT)-based digital solutions help the buyer (trader/corporate/exporter) in terms of transparency, speed, and efficient transactions. The seller (farmer) benefits from better market access and detailed information (GSMA 2020). Consequently, in procuring agricultural commodities in the agricultural marketplace, sales are progressively shifting from an oral auction mode to a digital e-trading mode.

Empirically, the positive effect of digitalisation, including e-trading, is well documented in the reduced transaction cost sides (Auramo et al. 2005; Francois et al.

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2014). However, the positive impact of e-trading on the net price realised by farmers is still being researched and is a source of inspiration for this article (Fuglie et al. 2019; Liu et al. 2020; Chaudhary and Suri 2022).

The core premise favouring wholesale e-trading platforms is that they are more open and transparent than physical markets, resulting in high demand for produce. The online setup has increased the speed and extent of the procurement process. The positive aspects of openness, transparency, speed and reach are expected to increase the seller's bargaining capability by accessing a broader range of buyers. Consequently, primary sellers, i.e. farmers, are expected to obtain a higher price when they sell products on the e-platform instead of through a limited number of regional agents at the farm gate (Banker et al. 2011).

Research gap. The academic literature gives mixed results on the impact of information technology on rural income, and there is a deficiency of rigorous evidence on the effect of e-trading on the rural community and farmers' income (Guo et al. 2018). There is an academic debate around the impact of e-trading on agricultural commodity wholesale prices in developing countries. Does digitalised e-trading indeed positively impact agricultural wholesale produce prices and market practices? This study addresses the academic debate by providing requisite insight.

The current structure of trading using open auctions is still popularly used in many Indian agricultural marketplaces for various produce. Per se, open auctions pose the risks of trader collusions and even manual errors, the losses of the same being borne by the farmer himself. A contemporary study suggests the need to study the benefits of e-trading and quick payment, obtaining a higher price for the farmers (Chand 2016; Dey 2016). This gap is also addressed in this study of a valid variance of the pricing for the general farming populace and the populace registered on the e-trading platforms using the case of India's National Agricultural Market (eNAM) as a context.

Research objective. The objectives of this research are:

– Analyse the impact of e-trading on the wholesale prices of two agricultural commodities in the select wholesale markets in India.
– Suggest improving the efficiency of wholesale markets to realise better pricing for farmers.

MATERIAL AND METHODS

Methodology. The triangulation of the method attempts to give credibility to the study findings. First, a review of the relevant literature is conducted for empirical evidence about e-trading the wholesale price realised by farmers. Second, the researcher performed a statistical analysis of the secondary data. Third, a statistical analysis of an opinion survey was conducted. The opinion survey encompasses 371 respondents (farmers, traders, and corporate agents). The case of eNAM gives a practical context to the study.

The statistical analysis includes the comparison and difference in differences analysis for the mean between pre- and post-eNAM implementation and wholesale price (wheat and paddy) to see the effect. The researcher also performed paired sample *t*-test analysis.

For comparison analysis, the variables are numeric and continuous. The price observations are independent, as they are collected across the two markets for 2017 and 2015. The variables are normally distributed given the large secondary data sample size of 204, and the data have no outliers. The *t*-test analysis is relevant, as the sample from two crops, two markets, and two years is compared against many combinations.

The opinion survey was conducted to validate the findings of the statistical analysis. The field survey period was from October to November 2018 for two months. Opinion was measured on a Likert scale, with options ranging from 1 to 7. Option 1 means 'negligible', and option 7 means 'to a huge extent'.

The opinion survey respondents were chosen using simple random sampling without replacement. The sampling unit is a registered farmer or trader on eNAM in the Agriculture Produce Market Committee (APMC) wholesale markets. Four hundred participants were picked using a lottery system and called for questionnaire responses from the sampling frame (registered users list at APMC). The data cleaning found the 371 answers valid for descriptive statistical analysis of the primary data.

The survey and interviews (for suggestions) were conducted in the four regulated APMC markets of Meerut, Aligarh, Nadbai and Nagar (India). These APMCs were chosen based on the following criteria: trading in similar commodities, the large size of markets (in terms of transactions and eNAM users), geographical proximity, and researcher familiarity with the culture and local language of the farmers.

Wheat and rice (paddy) are India's two top kinds of cereals. These two types of grains are taken as representative agri-products for this study, as they constitute 78% of the total agricultural production in India. These two grains also get the maximum government procurement under the minimum support price (MSP) (Ministry of Statistics and Programme Implementation 2010).

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Hypotheses. The null (H_0) and alternative (H_1) hypotheses are conceptualised as follows:

H_0: e-trading does not affect the wholesale prices of two agricultural commodities (wheat and paddy) in the select wholesale markets in India.

H_1: e-trading affects the wholesale prices of two agricultural commodities (wheat and paddy) in the select wholesale markets in India.

Agriculture marketing and wholesale prices. Agriculture marketing in India is a state subject regulated under the APMC act. India has twenty-eight states. Each state is divided into distinct geographic market areas; each has a separate APMC market or sub-market yard. Across India, farmers sell their products primarily in these markets at auction through licensed traders and agents. Recently, several reforms in private markets, contract farming, and e-trading are under various stages of implementation.

Due to non-integrated markets, information asymmetry and multiple intermediaries result in the wide gap between farmer wholesale prices and consumer retail prices in India. Another critical issue is the low level of integration among agricultural markets. It is evident from a finding that agri-produce prices in select other markets across India varied plus and minus 28% of Delhi. In some cases, it even goes to plus 300% (Banana, Shillong market) and 88.50% (Potato, Panipat market) (Thomas et al. 2017; Boffa and Vaerla 2019).

Thus, the value chain's marketing aspect needs improvement so that the farmer gets a higher share of the end consumer price. An ICT led digital mechanism is an effective tool to improve the agri-supply chains.

From the policy point of view, the floor price for twenty-four mandated crops and sugarcane is under the MSP procurement mechanism of the Indian Government. Other policy initiatives include a selective market intervention scheme for agriculture commodities not covered under MSP, the imposition of a levy on rice millers and sugar factories, maintenance of buffer stock of wheat and rice, distribution of food grains and sugar at subsidised prices under public distribution system, and open market sale at fixed prices by public agencies. The policy initiatives are also meant to reduce the market price and quantity volatility (Swaminathan 2006; Subramanian 2016).

The effect of government procurement on actual market prices is positive in India but negative in the case of non-periodic revisions of MSP. It is also to be noted that the difference between target and actual procurement and farmer reach shows a high variation among states. An active public-private partnership may complement it and make it more useful (Chatterjee and Kapur 2016).

State levies and other market charges also vary considerably between states. Such a variation is a significant source of market distortion and has a cascading effect on commodity prices as the commodity moves through the supply chain across states.

A national e-trading platform, eNAM is perceived as a game-changer in addressing the price gap and availability issues (Chand 2016).

Case context: eNAM platform. The eNAM platform provides the requisite context for the study. The eNAM (started in April 2016) operates in 1 000 regulated APMC markets across India. By 2022, it envisions connecting all 2 477 APMCs into a unified state and national market for trading in agricultural commodities. It is the largest and de-facto pan-country integrated e-trading platform in India. However, several small private sector e-trading platforms have emerged in the last five years.

As of April 30, 2022, the eNAM has registered 17.3 million farmers, 0.22 million traders, and 2 140 farmer producer organisations (FPOs) in 21 states and union territories. As of January 2022, the platform has recorded overall transactions of agricultural produce worth USD 26.82 billion. Under the eNAM platform, the inter-market and interstate trade of 175 commodities are also possible (Press Information Bureau 2021; Ministry of Agriculture and Farmers Welfare 2022).

Open auctions may be susceptible to trader collusion, whereas manual tendering is prone to quote manipulation and entry errors. Due to a lack of competition, the direct sale system reduces a farmer's bargaining power. The e-trading process (Figure 1) is simple, transparent and quick. The farmer and the trader know the prices in real-time. These are disseminated quickly using electronic means, e.g. messages and mobile. Thus, a farmer may get a higher price than selling their produce at the farm gate (Banker et al. 2011; Chand 2016; Dey 2016).

Compared to eNAM, other e-trading initiatives in India are small but have shown positive results. A private sector e-trading platform for wholesale coffee shows that a farmer gets an estimated 6% higher price on the e-trading platform vis-à-vis a trade on the farm-gate. A study in the Indian state of Karnataka quotes that e-trading helped farmers get up to 9% better prices in 2016 over the previous year. Additional perceived benefits mentioned by 98% of farmers covered in the field survey are that it is impossible to manipulate prices in e-trading, and 76% cite direct transfer of pay-

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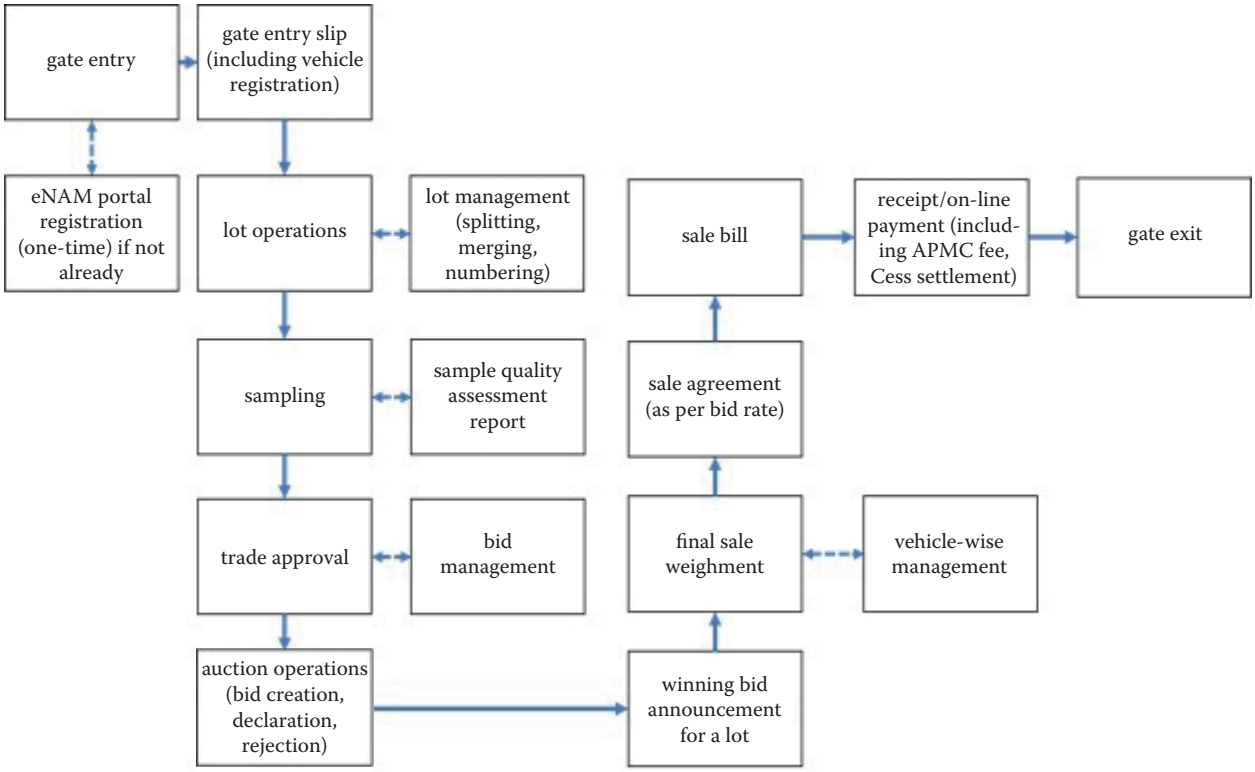

Figure 1. Electronic trading (e-trading) process

APMC – Agriculture Produce Market Committee; eNAM – National Agriculture Market
Source: Author's own elaboration

ment as better than cash payment (Banker et al. 2011; Pavithra et al. 2018; Gowda et al. 2018).

While there are numerous positive effects of the e-trading platform, it may be prudent also to consider some of the negative aspects of e-trading.

The critics of e-trading quote the inability to verify quality (multiple quality specifications in agri-commodities) and lack of physical interaction, resulting in low confidence. E-trading in high-volume lots is quoted as a put-off. The perceived risk (loss expectations) in e-trading increases due to a high level of illiteracy among the farmers, low ICT skills, lack of vernacular/visual content, and lack of training. At the same time, the low level of trust concerning the non-delivery of e-traded produce and the digital payment from unseen buyers adds to the perceived risk (Pavlou and Gefen 2004; Brush and McIntosh 2010; Roy et al. 2018; Qalati et al. 2021).

A combination of strategies can reduce the adverse effects; altering the structure of the value chain (including third-party/ancillary service providers, aggregators, FPOs, and local agri-community), using expertise (market know-how, commodity knowledge, risk profile), proper functioning of facilities (assaying, grading, sorting, delivery, and quality check) and improving organisational readiness (training, customer care, awareness camps, and knowledge sharing) (Leroux et al. 2001). For example, if the delivered agri-produce does not meet the quality standard specified in the terms and conditions. In that case, a penalty or payment reversal from the escrow account may be levied on an errant farmer/trader. Similarly, the dispute settlement may be formalised for inter-state trade, and the warehouse receipt trading process may be detailed. Also, the banks may not use e-payments from e-trading remitted to a bank account to settle loan equated monthly instalments (EMIs) unless the farmers give written consent. The secure application programming interface (API) open to partners may lead to several innovative applications linked to the e-trading platform for the benefit of the ecosystem.

The e-trading transaction flow (Figure 2) is predominantly online. Post agricultural market gate entry, weighment and quality assaying, the registered farmers (own/assisted by market staff) enter trade details (quantity, quality, ask price) on the eNAM portal/mobile application. Online bidding of lots is held on the

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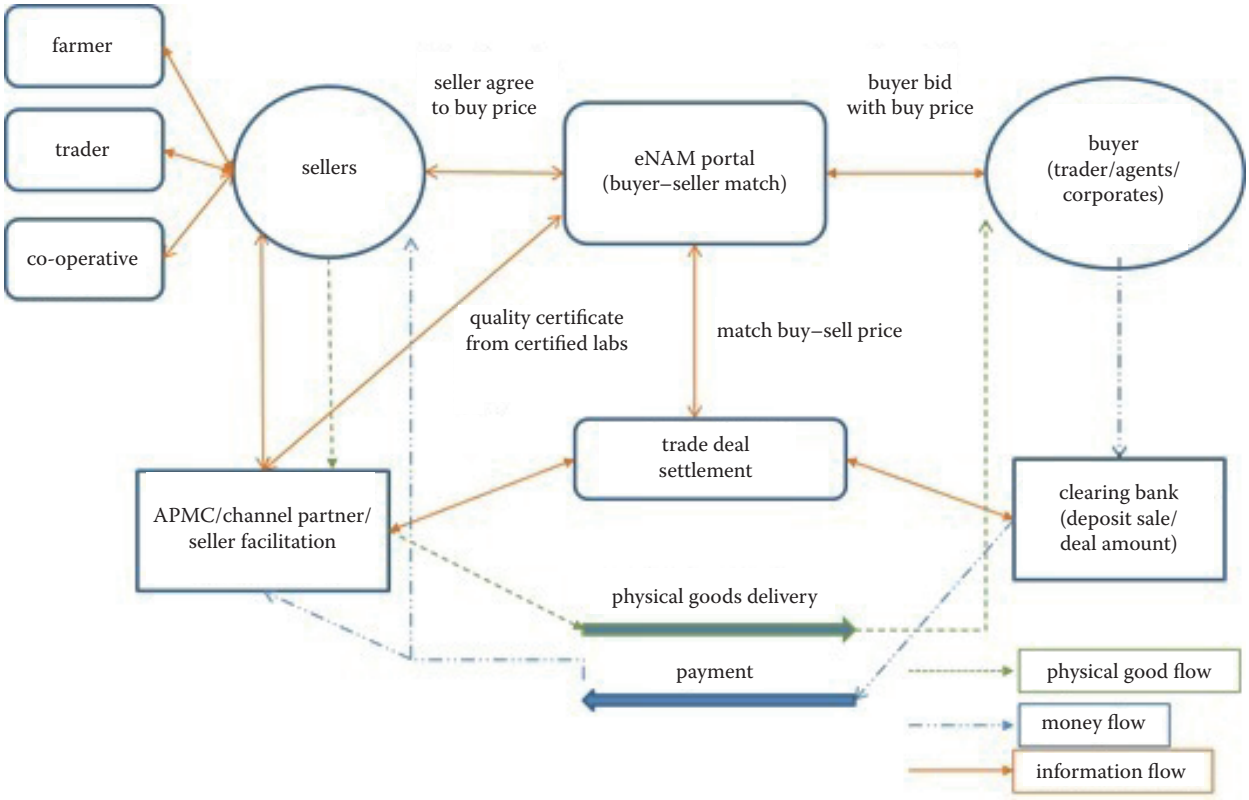

Figure 2. eNAM electronic trading (e-trading) transaction flow

APMC – Agriculture Produce Market Committee; eNAM – National Agriculture Market
Source: Author's own elaboration

portal. Post competitive deal (intra- or inter-market) confirmation on a price, an initial invoice is generated for traders. The deal winner also gets an email/message confirmation. Post deposit of the requisite deal amount online (via payment gateway)/offline plus other requisite market charges, the final confirmation is sent to both farmer and trader/agent. The delivery happens as per deal terms and conditions. It is either on the spot at the market or through a logistics service provider (arranged by the supplier/buyer) listed on the portal. The payment is electronically released to the farmer/trader/agent on delivery acceptance.

Early results from eNAM implementation indicate that farmers are now more concerned with quality. There has been an increase in online transactions, electronic fund transfers, and online banking literacy. Since the Mandi records are now computerised, the transaction flow is more transparent. Farmers receive a clear sale bill and quick payment due to transparent online e-trading and worry less about trade collusion. The payment cycle is one day compared to the earlier 1 to 2 weeks (National Bank For Agriculture And Rural Development 2018; Nirmal 2019).

As per experts' opinion, the e-trading platform (eNAM) is expected to digitalise all organised Indian agricultural markets in future. It is expanding its scope by enlisting logistics service providers, ancillary service providers, and other private e-trading platform providers. Eventually, it is seen to emerge as a platform of platforms for e-trading and associated e-transactions.

The multi-stakeholder open consultation process is ongoing for the common national platform for Agriculture 4.0, open for data exchange and provisioning of end-user applications by public or private companies in India. The open digital platform is intended to be interoperable to serve solution providers, start-ups, agribusiness companies, service providers, technology developers, users (farmers, general users, traders), and other systems (IDEA 2022).

RESULTS AND DISCUSSION

The comparison (Table 1) was conducted using the yearly mean values of the daily wholesale prices of wheat [adjusted for the wholesale price index (WPI)] for the post-implementation period (the year 2017) and pre-im-

https://doi.org/10.17221/113/2022-AGRICECON

Table 1. Comparison of wholesale prices (pre- and post--eNAM implementation)

Wholesale price (adjusted for WPI)	2015	2017	2018
	(USD per 100 kg)		
Wheat at Meerut APMC	24.29	24.77	25.21
Paddy at Aligarh APMC	32.84	37.69	41.28

APMC– Agriculture Produce Market Committee; eNAM – National Agriculture Market; WPI – wholesale price index
Source: Author's own computations based on data from Agmarknet (2019)

plementation period (the year 2015) at Meerut APMC. The constant exchange rate during 2015 of 1 USD equals 64.13 Indian rupees (INR) is used.

The weekly modal (most common) wholesale prices for 2015 and 2017 were taken for basmati paddy (at Aligarh APMC) and wheat (at Meerut) from the Government provisioned Agmarknet website. The year 2015 was considered the pre-implementation year, 2016 was considered the year when the eNAM was implemented, and 2017 was considered the post-implementation year when the usage of eNAM started.

WPI has been used to measure inflation in the Indian economy (Ministry of Statistics and Programme Implementation 2010). The other effects, such as market fixed effects (fixed infrastructure, soil quality, and market size) and monthly fixed effects (world prices, sudden demand change, seasonality, or sudden climate change), do not hold relevant for this analysis since the comparison is for the same commodity in the same market (or neighbouring market of same type and size) for a yearly period.

After adjusting for the WPI increase during the corresponding years, the wholesale price means in 2017 are found to be higher than the 2015 mean price by USD 0.47, showing a positive effect attributable to eNAM. The increase in the price level was lowered to USD 0.45 in 2018 when early gains of eNAM subsided, but the effective trading volume on eNAM increased.

Similarly, the yearly mean values of basmati paddy prices in Aligarh APMC are compared (Table 1). After adjusting for the WPI increase during the corresponding years, the wholesale price average in 2017 was higher than the 2015 average price by USD 4.85, showing a positive effect attributable to eNAM. The WPI--adjusted wholesale price of the paddy increase lowered to USD 3.59 in 2018 as early gains of eNAM subsided.

To cross verify, we compared the difference in the wholesale modal price of wheat in 2015 and 2017 between the eNAM-enabled Meerut APMC and neighbouring Bijnor APMC in Uttar Pradesh, India, where eNAM has yet to be implemented (Table 2). The difference-in-differences estimator analysis (Abadie 2005; Fredriksson and Oliveira 2019) found that the mean difference in a wholesale modal price between these two markets in 2015 was USD 0.46, which increased to USD 0.62 in 2017. This increase in indifference may be attributed to e-trading on eNAM at Meerut APMC since each neighbouring Mandi has similar weather, area, size, arrivals, and agricultural productivity.

The quality of trade (QT) was measured as the per cent of trade in a year settling near the maximum price. The QT of wheat in the Meerut APMC increased after implementing eNAM in 2016. The relative variation of the modal price shown in Table 3 shows the gap between the maximum price and modal trade price relative to the price gap between the maximum and least price of the trade settlement. The variation decreased, showing that most of the trade on eNAM settled near the maximum rate, thus showing the increased quality of wheat wholesale trade at APMC.

The paired sample *t*-test analysis (Table 4) shows a statistically significant difference between the aver-

Table 2. Difference-in-differences analysis of Meerut and Bijnor APMC wholesale price

Difference between APMC wholesale price (USD per 100 kg)	Mean
Meerut–Bijnor APMC (2015)	0.46
Meerut–Bijnor APMC (2017)	0.62

APMC – Agriculture Produce Market Committee
Source: Author's own computations based on data from Agmarknet (2019)

Table 3. Improving the quality of trade (QT)

APMC	Commodity	Year	Relative variation of modal price from the maximum price
Meerut	wheat	2015	0.59
		2016	N/A
		2017	0.56
		2018	0.50
		2019	0.40

APMC – Agriculture Produce Market Committee; N/A – not available
Source: Author's own computations based on data from Agmarknet (2019)

https://doi.org/10.17221/113/2022-AGRICECON

Table 4. Paired sample *t*-test for the adjusted wholesale prices

Wholesale price	Paired differences mean (USD)	*t*	d*f*	Significance*
Wheat (adjusted for WPI) at Meerut APMC (2017 *vs.* 2015)	0.47	5.21	257	significant
Paddy (adjusted for WPI) at Aligarh APMC (2017 *vs.* 2015)	4.85	14.32	273	significant

*99% confidence interval [(2-tailed) significance < 0.01]; APMC – Agriculture Produce Market Committee; WPI – wholesale price index

Source: Author's own computations based on data from Agmarknet (2019)

Table 5. Univariate statistical analysis of user opinion survey (n = 371)

Serial No.	Question*	Mean	SD	Median	Mode
1	eNAM increases the potential profit	5.06	1.37	5	6
2	eNAM has lesser transaction costs than offline trade	4.82	1.28	5	5
3	eNAM prices are better than offline deal	4.47	1.25	5	5
4	if one gets a better price, one may take produce to other APMC	4.51	1.27	5	5
5	satisfied with transportation, storage, and quality lab reports at APMC	4.31	1.39	4	4

*Scale: 1 – no influence, 2 – very small influence, 3 – small influence, 4 – medium influence, 5 – high influence, 6 – very high influence, 7 – extreme influence; APMC – Agriculture Produce Market Committee; eNAM – National Agriculture Market

Source: Author's own computations

age wholesale price of wheat and paddy between pre- and post-eNAM implementation. The WPI-adjusted wholesale price means in 2017 was higher than the 2015 mean price. The *t*-test is also significant, thus supporting the alternate hypothesis that 'e-trading' via eNAM does affect the wholesale prices of two agricultural commodities (wheat and paddy) in the select wholesale markets in India.

In the opinion survey, the internal consistency of constructs was assessed using Cronbach's alpha value for each construct. At more than 0.65, internal consistency was considered acceptable for empirical research of this nature (Hair et al. 2006). The descriptive statistics of the opinion survey are presented in Table 5.

At 5.06 and 5.00, the mean and the median value of the opinion 'eNAM increases the potential profit' is relatively high. Once the users start using the electronic platform, familiarity, quick response, and fast processes (e.g. electronic payment) impress them and increase their expectations to obtain more profit from eNAM. The respondent also feels that eNAM has a lower transaction cost than offline trade (mean value 4.82), which helps them obtain the best net price. At a mean opinion value of 4.47 out of a maximum of seven, there is a belief that on eNAM, the prices for produce are better than offline trade due to price linkage to quality and competition between an increased number of potential buyers.

In the opinion survey, farmers were also inclined to inter-Mandi trade on eNAM. Marketplace managers have recently addressed practitioners' concerns, and necessary FPO registration, logistics modules, and warehouse receipt modules are integrated with the e-trading portal. The practical and quick dispute resolution mechanism for inter-market e-trade and regular monitoring from APMC officials may stop the market from being manipulated by price cartels.

Small farmers have shown an encouraging trend, especially after the mobile application's availability for e-trading in vernacular language. The trend is expected to increase by allowing for lot consolidation for e-trading, credit facilities, and requisite training for e-trading. The participation of farmers' producer organisations for collective bargaining, waste reduction via excess supply offloading in inter-market e-trade and reduction in cartel/price-fixing are some of the aspects that are helping in e-trading adoption.

CONCLUSION

The study shows the positive effect of eNAM on the weekly adjusted wholesale prices of basmati paddy and wheat at the select APMC markets. In the case of paddy and wheat, wholesale markets demonstrate a high degree of integration, and the price signals reach across markets. Thus, it is expected that any increase

https://doi.org/10.17221/113/2022-AGRICECON

in price realised by farmers in major markets will help increase the price realised by farmers across all markets (Acharya et al. 2012).

As e-trading is getting implemented in all seven thousand plus APMC market yards of India, it might increase the farmer's wholesale price across India. The empirical studies have already shown the effect of e-trading on transaction cost reduction and consumption increase (Francois et al. 2014; Zeng et al. 2017; Cho et al. 2019). Thus, large-scale e-trading initiatives in public and private sectors may help raise the net income level of the agricultural community.

The eNAM e-trading platform has integrated agricultural marketplaces across geographies and expedited e-trading adoption by private marketplaces adoption. In private e-trading platforms, there is no effective benefit sharing, risk sharing and interest linking mechanism between upstream and downstream users on one platform and among different platforms. The regulator may provide guidelines for a modal mechanism for the various aspects of e-trading, e-commerce platforms and the Agriculture 4.0 ecosystem.

At the same time, due to the variance in agricultural e-trading laws between a few states in India and evolving regulations, compliance is a serious concern. The platform providers must ensure a robust compliance framework and vigorous enforcement of ethical/no-corruption sourcing and vendor management practices. Information security and privacy are also a concern. Thus, strong authentication, encryption, data protection/firewall, and anti-virus solutions must be the de facto requirements for e-trading platforms. However, in the last three years, advances in internet technology adaptation to user context and user-friendliness of e-trade platforms have lowered the perceived risk of e-transactions (Zia et al. 2022).

In a conventional setup, farmers are compelled to trust/involve the commission agents because of financial support (e.g. loans during off-season) and cash payments for products sold. The quick digital payment directly into the farmer's bank account, providing easy access to bank credit by registered farmers and friendly credit terms to traders for buying and selling on e-trading platforms, may be introduced to compete against commission agents' informal credit systems and cartels.

Policymakers should be interested since the e-trading initiative reduces farmers' overreliance on the price subsidy mechanism and the circular economy effect. Overall, e-trading initiatives by the public and private sectors may turn the agriculture sector's production growth story into a much-needed marketing growth era. Recently small and marginal farmers are organising themselves in the FPOs and collectively e-trading in the agricultural markets for a better bargain. From the practitioner's point of view, such development helps in the desired digital economic transformation to a better socio-economic future. The policymakers of other developing countries may also take a cue from the India case and go for e-trading and information portals as the initiator of agricultural digitalisation.

Referring to the academic debate, the study's triangulated findings suggest that e-trading could level up farmer profitability through a cohesive approach toward gradual implementation in the digitalisation of agri-marketplaces. The results of this research add to the existing knowledge base of a digitalisation-led agricultural economy. It is expected to help researchers by reducing the knowledge gap concerning the effects of the digital platform on trade economics.

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