Towards One Agricultural Market in India: Does the ICT Help?

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Abstract The current phase of economic reforms in agriculture is oriented to help farmers reach out to a larger all India market in order to fetch the best prices and earn higher incomes. The government has already been relaxing regulations to clean the market of imperfections and improve its efficiency, but moving towards 'one' Indian market has become a more targeted objective of reforms. The paper reviews the fast-changing scenario of institutional reforms and application of ICT as a facilitator of reforms. Empirical analysis with data on pulses reveals a convergence of prices in states towards a national-level price enabled by information flow from major markets but cannot confirm the role of trade in equalizing prices nor the benefit of higher prices reaching the producers. This transition period still shows signs of selective market integration and asymmetrical market responses mostly observed in consuming states.

India's agriculture, now in a new transition, is targeted towards a nationally integrated market (MoA 2013).[1] Market integration can support farmers to take advantage of demand arising in any part of the country for fetching the best prices for their products. It also will help the sector to face the world market as a strong player in the global competition, enabling farmers to adjust their production patterns in line with their comparative advantages. Central to this transformation is not just notional knowledge of reality elsewhere to aid local transactions but also realized trade across the country. Experiences show it is not easy to promote cross-state trade in grains in a large politically diverse country, but what arouses optimism is the advent of communication technology in the wider world that can be used to aid the process in unprecedented ways.

[1] States are encouraged to reform markets in order to provide a barrier-free national market for the benefit of farmers and consumers.

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In the absence of trade and information, any potential market can be seen as composed of smaller fragmented markets with their price signals. Swift transmission of information from one sub-market to another is a precondition for removing market imperfection and attaining an integrated 'one' competitive market where theoretically, any residual price difference persisting post-trade would signify only the transportation ordeals. Larger the geographic extent of the market, greater would be the role of information and brisk trade to sustain its integrity. The process of price equalization is not instantaneous, and the speed of price response to potential demand or supply would depend on the efficiency of the market. Information and communication technology (ICT), which enables exchanges of knowledge, finance and contracts between distant locations, is becoming an integral part of the ongoing transformation of Indian agriculture.

Exploring the criticality of information transmission for an efficient market in a large, federal and geographically diverse country, this paper revisits market transformation in Indian agriculture, tracing the rise, the entry and the assimilation of ICT into India's agricultural markets which have been independently evolving under economic reforms of the time. Application of ICT in agriculture relates to using extraneous and evolving technology, while market reforms relate only to the institutional restructuring of rules and regulations to allow more flexibility of operations. Having discussed the evolution of ICT and its induction in Indian agriculture (Sect. 1), the paper addresses the ongoing reforms which have begun to draw from the ICT options (Sect. 2). Conducted over a historic transition, the study takes a view of the present state of Indian agricultural markets which are anticipated to increasingly become interlinked by trade until they compositely constitute the Indian market. Using alternative quantitative methods, the paper probes how far state markets of India diverge and how strongly they are tied up at this juncture of ICT dynamics (Sect. 3). The market considered is for pulses that have drawn government promotion only during the study period but have historically felt less government interference than other food grains. The study, therefore, has a focus on pulses, specifically two crops gram and arhar.

1 Entry of ICT in the Agricultural Domain of India

Green revolution (GR) amply demonstrated the significance of 'knowledge' as a critical resource with public extension transferring agrarian technology to producers. While it is not surprising that ICT became an important vehicle for extension in the post-GR age, its potentials for marketing is only a growing realization even now. ICT's overtures with agricultural marketing have a short history in India. Entering the realms in the 2000s mostly as trials, ICT picked up steam within agriculture post-2010 when the sector also gained relative emphasis in public policy. Targeting the integration of Indian markets using the power of ICT began as late as 2017.

The world's ICT revolution started in the early nineteenth century when communication was based purely on physical proximity. By the 2000s, disrupted successively

by innovations, tools generated in the fields of computer science and telecommunication were found to be converging (Andrews 2013). They were become increasingly smaller, mobile and interactive. ICT and its synergies even at this point are not static. Integrated with another powerful source of data, the satellite it serves in weather forecasting, television broadcasting, radio and Internet communications, and geo-referencing. ICT compliant softwares are helping in timely and accurate collection of socio-economic data for policy-making. Convenience is being offered by 'cloud' for accessing data and software only on demand. Artificial intelligence, machine learning, Internet of things, unmanned aerial technology and financial applications promise to further enrich ICT's capabilities.

Only in 1985, telecommunication became important enough in India to be detached as a separate department.[2] Manufacture of electronic exchanges was initiated in the end 1980s, and years after India's telecom system had begun feeling the need of technology overhauling. Computerization was progressing sluggishly in the 1980s, and Internet was an even slower process, first available to only academic institutions (ERNET), expanding into inter-government uses (Nic.net), and reaching out to the public only in the late 1990s but with slow speed. The vast rural sector and agriculture remained dependent on posts and telegraphs for connectivity creating a digital devide.

For the Indian economy, the decade of the 2000s was transformative when the telecom sector was opened up to the private but regulated competition.[3] The historic broadband policy of 2004 attended to people's growing need for Internet, and the last-minute connectivity became mobile with the auction of 3G spectrum in 2010 by when the simple wireline telephone was already giving way to innovations culminating in the cellular phone and the smartphone converging with other emerging technologies.

Evident in the inflexion in Fig. 1a, telephones changed from a luxury to a necessity in Indian psyche from 2010, as the idea of a phone gave way to the lightweight and multi-purpose mobile phones. Internet subscription was picking up gradually since 2004, but a larger leap was seen in 2014–15, marking the visible beginning of rural connectivity (Fig. 1b). As will be seen later, at that time, the government intent of transforming the rural economy using ICT began to appear as a green shoot for India's development. Rural areas of the country have historically been secluded from the mainstream economy by poor road networks, lack of telecommunications, and above all, by poverty and ignorance. Farmers had very little resources by way of market intelligence to support them in deciding the crops they grew and marketed. Unorganized traders, who were themselves outdated in their practices, served as the main link with other regions and were highly influential in the pricing of products in a region. Their trade coverage was bound by poor infrastructure, scarce information and their inward looking approach complemented by their lack of resources. ICT seemed

[2]To start with, the telegraph (1850) and the formal telephone (1882) only supplemented the postal system of the government which was the core component for long distance communication in India.

[3]Moving telecom away being a government monopoly, the National Telecommunication Policy (NTP) 1994, for the first time, showed respect for private participation and investment as well as for checks on unfair practices to institute and enact the Telecom Regulatory Authority of India (TRAI) in 1997.

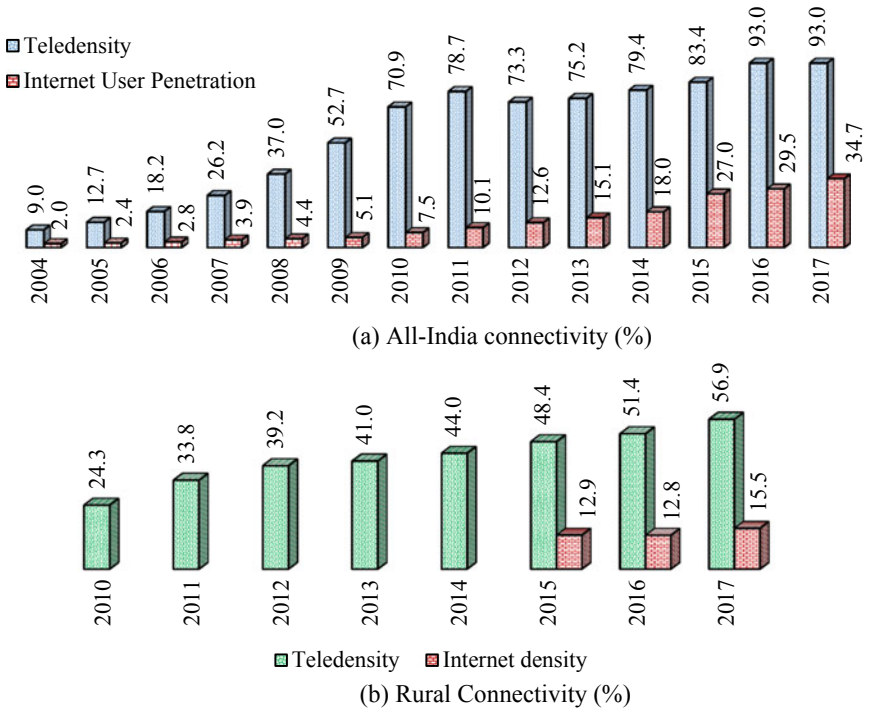

Fig. 1 Communication by telephones and Internet among Indian population. *Note* Internet use is reported by calendar year in all India and other data by financial year. *Source* MoC (2018), FAO, Website

to offer ways to overcome the communicational barriers with equity and symmetry in the new millennium. Unlike in industry, the central and state governments took active role in making this happen.

Tele-density in India rose phenomenally from 9 to 93% between 2004 and 2017 when Internet subscription also increased from 2 to 35% (Fig. 1a). An ICT indicator (share of people with ICT facility) is calculated as the simple average of ICT facilities per hundred population: tele-density wireline and tele-density wireless, Internet subscription broadband, Internet subscription narrowband, wire line and wireless telephones, village public telephones (VPT) and public call office (PCO). While both tele-density and Internet density by wireline as well as public telephones diminished in number between sub-periods 2010–2013 to 2014–2016 balanced by remarkable increases in wireless connections (Table 1), the composite indicator of ICT improved from 12.4 to 17.8%. More remarkably, tele-density in rural areas doubled between 2010 and 2015 in steady growth and despite its late entry, Internet intensity continued increasing after 2015 (Fig. 1b).

The ICT budget for agriculture (DoA&FW, Website) in nominal terms was only Rs. 16 crores in 2004–05, the early stage of ICT in India, but it rose by 16% per annum

Table 1 ICT indicators per 100 population (average)

	Tele-density		Internet density						IT Indicator
Year	Wireline	Wireless	Narrow-band	Broad-band	Wireline	Wireless	VPT*	PCO	
1	2	3	4	5	6	7	8	9	10
2010–11–2013–14	2.60	72.51	4.30	2.09	1.64	15.73	0.07	0.23	12.4
2014–15–2016–17	2.02	83.99	14.36	13.86	1.62	26.60	0.06	0.07	17.8

Note *Per 100 rural population, IT indicator is the simple mean of columns 2–9
Source MoC (2018)

up to the 2010–13 and then by another more moderate 6.4% per annum by 2014–16 (Table 2). Expressed at constant prices (2011–12) the ICT budget in agriculture (Fig. 2) had shot up in after 2004, became depressed up to 2012 and again peaked in 2014 but the real budget remained largely stagnant except for the spurts, but its pattern changed. In 2004–05 highest allocation, 63% was marked under the heading other agricultural programmes (major head) which mainly constituted expenses on marketing and market information (see Table 4). Since then that allocation diminished almost to extinction, but 'other expenditure (Minor)', meant for strengthening the department's capacity continuously gained share up to 2013–14. In the period 2014–16, a substantial share of 41% went to the states as grants in aid. Market intelligence, highlighted in the AMIS efforts of G20, has been identified as an important resource for designing efficient markets (AMIS, Website).

ICT has become a game-changer (Box 1) for agriculture, aimed to reach farmers with timely weather alerts and market information, relief and insurance claims although the effectiveness requires more evaluation. It was supporting data collection and informed policy-making and was monitoring production to avoid a crisis. Qualitative dimensions like user-friendly interface, language compatibility, two-way

Table 2 ICT budget in agriculture sector in India (Rs. Crore)

Year	2004–05	2010–13*	2014–16*
Crop husbandry (Major Head)	1.03	0.47	0.62
Agricultural Economics and Statistics (Minor Head)		0.04	0.02
Other Expenditure (Minor Head)	4.95	36.64	35.40
Other Agricultural Programmes (Major Head)	10.05	1.02	
Grants-in-aid to State Government (Major Head)		1.50	20.38
Other Agricultural Programmes–Marketing Facilities (Minor Head)		0.20	
Total	16.03	38.57	49.42
WPI—All Commodities (2011 – 12 = 1)	0.64	1.03	1.12

Note *Average
Source DoA&FW (Website)

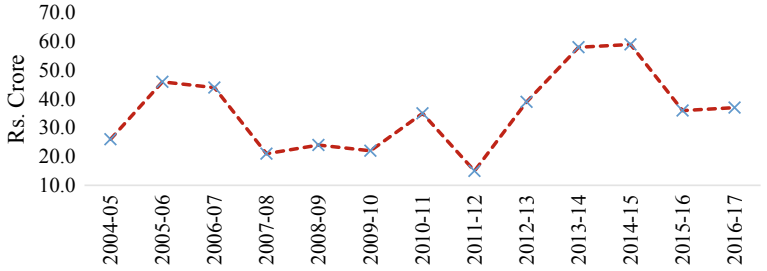

Fig. 2 Agriculture IT budget (2011–12 prices)

query-based communication, use of multiple mediums supported rural penetration of ICT (Shalendra and Sharma 2011) and the Kisan Call Centre served as a useful instruments. Satellite-based monitoring of production, drought assessment and digital money transfer, under trials and pilots in 2000s, showed a success. Now ICT is enabling payment from public funds to target beneficiaries with least diversion through Direct Benifit Transfer (DBT) on subsidiaries of fertilizer, other inputs, support price and welfare payments to bank accounts of farmers. Integration of meteorology, satellite imagery and computer-aided crop modelling in an umbrella multidisciplinary FASAL project, launched in 2006 and further revamped in 2012, was providing an early outlook of production, but ICT use can lead to more frequent and real-time monitoring of crop prices and production than ground-level insights allow. A dynamic Atlas of agricultural markets, designed on the GIS platform (MoA 2013), facilitates both public and private sectors in planning marketing strategies.

Harnessing the advancements in (ICT) a Central Sector Scheme of Agricultural Marketing Information Network (AGMARKNET) was already working since March, 2000 to link important produce markets spread all over the country with the technical support of National Informatics Centre (NIC). The AGMARKNET portal has linkage with futures prices and international price trends available on the FAO website are also accessible through the portal. In 2014–15, allocation was made under Market Research and Information Network (MRIN) to strengthen market linkages and inter-market information with ICT power. Finally, the Union Government's e-NAM starting in 2016 is a major step towards harnessing the power of ICT in Indian agriculture to integrate the fragmented markets. It is a pan-India electronic trading portal which networks the existing regulated mandis (Sect. 2.2) to create a unified national market for agricultural commodities. Moving beyond making marketing data of the country universally available, the platform enables e-trading across the country by all-India electronic-auctioning. To reduce financial and supervisory cost, procurement operation is conducted in pockets, decisions about which are made consultatively between state and Centre to avoid overlaps and exclusions while the ICT enabled trio schemes Jan Dhan, Aadhar and mobile comprehensively called JAM enable payments to be made directly by government to recipient's bank account by DBT.

Box 1: How ICT is usable for Indian Agriculture

Global Positioning System (GPS): A satellite-based navigation system to locate positions, made available for civilian use in the 1980s, can be useful for identifying location for intervention in agriculture.

Global Information System (GIS): is a computerized data storage and retrieval system, used to manage and analyse spatial data relating to crop productivity and agronomic factors.

Remote Sensing (RS) Technique, the science of making an inference from measurements, made at a distance without coming into physical contact. RS

has been used for monitoring land use and crop production from the 1980 s but has been more actively used from 2012.

AKASHGANGA, established in 1996 in the private sector, showed that even illiterates or semi-illiterate people can adopt IT-based systems.

E-Chaupal-ITCs launched Agri-Business Division of a private company in June 2000. E-Sagu-ICT based personalized agro-advisory system is being developed since 2004.

ICTs and Farmers' Advisory Service: The online phone-based expert advice service, Kisan Call Centres (KCC), launched by Government of India is available for all within the country since January 2004 with a toll-free telephone number is operational on all days from 6:00 a.m. to 10:00 p.m., KCC—that makes agriculture knowledge available free of cost to the farmers as and when desired.

Decision Support System (DSS): Interactive software-based system intended to help decision-makers to compile useful information from raw data, documents, personal knowledge and/or business models to identify and solve problems and make decisions.

Decision Supportive System for Agro-technology Transfer (DSSAT): A software package integrating the effects of soil, crop phenotype, weather and management options that allow users to ask 'what if' questions.

AGMARKNET: Agricultural Marketing Information Network (AGMARKNET) was launched in March 2000 by the Union Ministry of Agriculture. The Directorate of Marketing and Inspection (DMI), under the Ministry, links around 7000 agricultural wholesale markets in India with the State Agricultural Marketing Boards and Directorates for effective information exchange. This e-governance portal AGMARKNET, implemented by National Informatics Centre (NIC), facilitates generation and transmission of prices, commodity arrival information from agricultural produce markets and web-based dissemination to producers, consumers, traders and policy-makers transparently and quickly.

Market Research and Information Network (MRIN): Under an umbrella scheme ISAM launched in 2014, creation of improved marketing infrastructure, scientific storage and integrated value chains was aimed to be supported by trained personnel in ICT and a strong nationwide information network by which a large number of wholesale markets were planned to be linked using computers, mobile phones and SMS

FASAL: Well-planned programmes for crop acreage and production forecasts (Forecasting Agricultural Output using Space, Agro-meteorology and Land-based Observations) culminated in the establishment of a dedicated Mahalanobis National Crop Forecasting Centre (MNCFC) by Ministry of Agriculture (GoI), for crop inventorying and drought assessment. Advanced methods of remote sensing, meteorology and econometrics are used for forecasting production.

PMFBY: Pradhan Mantri Fasal Bima Yojana is a new crop insurance scheme that was announced by the Government on 13 January 2016. It provides a comprehensive insurance cover to all food, oilseeds and commercial/horticultural crops against the failure of the crop, thus helping in stabilizing the income of the farmers. Availability of past yield data is from General Crop Estimation Survey (GCES) which is important, but modern ICT methods are encouraged for timely collection of data for assessment and release of claims.

e-NAM: National Agriculture Market is an online trading platform for agricultural commodities in India to facilitate farmers, traders and buyers with transparent online trading in commodities. e-NAM is helping in better price discovery with smooth marketing facilities. Launched by Ministry of Agriculture, Government of India on April 2016, the electronic market pilot across India is managed by Small Farmers' Agribusiness Consortium (SFAC) with a technology provider, NFCL's iKisan division. Before it was rolled out nationally, a similar project in the State of Karnataka had proved successful. It also removes the information asymmetry between states and markets within a state.

2 Marketing Reforms and the Application of ICT

Retrospection shows that events of food shortage that still haunt India's memory resulted from failures not just of weather but also of the markets and government strategies.[4] Enquiry committees[5] in colonial and newly independent India rejected free trade as a policy (Kahlon 1991). In the 1960s and 1970s decades, the food market was therefore highly regulated and even nationalized briefly. Even reforms in the larger economy from the 1990s had only meagre outreach to agriculture where government intervention continued. When ICT offered new ways of the transaction, market reforms in agriculture became an easier option. Latecomer in the arena of India's economic reform, agricultural marketing is yet in its early stage. It is probably

[4]Famines at different locations owing to local rainfall failure were a common event from early times resulting in tax waivers, public works and economic relief, three Famine Commissions (1878–1900) having been set up in colonial times owing to pressure. Though irrigation was treated as a solution, failure of the distribution system emerged as a greater concern than production failure at the national level leading to the construction of railways as a mode of transport beyond the cheaper roads and canals but without attacking economic poverty at its root even this large investment had limited effect (Sweeney 2008; Naoroji 1901; Sen 1981). Recent soil findings have suggested that the disastrous famine of 1943 was linked more with government strategies than production losses (Scroll 2019). Government's entrance into the food market for rationing and procuring grains in post-independence times was related to spatial disparities of production and demand and the inadequacy of private traders to bridge the gap.

[5]Food Policy Committee in 1943, the Food grain Procurement Committee (1950), the Food Grain Enquiry Committee (1957) and the Agricultural Prices Commission (APC) (1965).

the most challenging part of economic reforms that are known to be politically sensitive and difficult as they affect various sections in dissimilar ways in the short run and long run.

The Commission for Agricultural Costs and Prices (CACP) formed in 1985 advises the union government on food prices.[6] Minimum support prices (MSP) is offered to ensure that farmers get remunerative returns above the cost of production.[7] India's food policy, designed to achieve food security was executed by Food Corporation of India (FCI), a large central agency established in 1965 (Ghosh and Khasnobis 2008) though the food market remained dualistic as private traders remained free to compete with government agencies. Although MSP was announced for 25 crops (DES, Website), open-ended procurement supported only cereals.

Since 1980 FCI's operations became confined to rice and wheat and National Agricultural Cooperative Marketing Federation (NAFED), founded in 1958 for promoting cooperative marketing among farmers, started operating in perishable items[8] but even then, rice and wheat remained the main beneficiaries of public intervention. The rather unstructured price support scheme (PSS) faced further transition after 2010 when pulses, so long under market forces began to receive protection from the government. To arrest price volatility under international influences, a new central agency called Small Farmers Agri-Business Consortium (SFAC) which, unlike FCI and NAFED also draws on private investment, was established in 1994 (PIB 2017b). NAFED and SFAC are leading the central agencies for procuring of pulses.

Marketing policy, rooted in the findings of the Royal Commission on Agriculture (1928) and continued through the enactment of legislation for Agricultural Produce Marketing (APMC Acts) in states, was meant to protect the interests of the farmers. Prices in regulated (APMC) markets were determined by open auctions, but the regulations of the APMC markets began to appear stifling in the era of reforms (Acharya 2004). The central government in 2002 circulated a model bill in response to which the states began amending their APMC regulations at varied speeds. New players were invited into an even playing field. The reform was also expected to draw investment, modern methods and technology, all of which would reduce the cost of the transaction and product wastage and discover prices transparently. Further, limits and permits for stocking 'essential' commodities were relaxed when the Essential Commodities Act (ECA 1955) was reviewed in 1990 and 2002.

[6]Initially, the government announced procurement price (PP) and minimum support prices (MSP) separately for two distinct purposes. Though both were calculated to allow some profit, the PP tended to fall below the prevailing market price, while the guaranteed MSP in principle served as a floor price for the market. Since the early 1970s, only the MSP has been announced, and all the products offered by farmers were guaranteed to be purchased by the government.

[7]The Ministry of Agriculture had been collecting primary information on cost of cultivation since 1970–71 on the recommendation of a Technical Committee.

[8]Besides FCI and NAFED, Cotton Corporation of India (CCI), Jute Corporation of India (JCI) and Central Warehousing Corporation (CWC) are some of the other organizations that help the government procure from farmers.

2.1 A policy shift

The year 2014–15, agro-marketing policy shifted towards farmers' interests. A price stabilization fund (PSF) was set up in 2014–15 under the Department of Agriculture, Cooperation & Famers Welfare (DAC&FW), later transferred to the Department of Consumer Affairs (DOCA) in 2016, to moderate the prices of important agri-horticultural commodities (PIB 2017a). Public support to pulses using PSF was a new development started in 2014 which expectedly would raise prices above what market itself would realize. The AGMARKNET was already in operation since 2000 for linking important agricultural produce markets and the national and state marketing departments. The union budget allocated funds for computers and the necessary software. At the end of 2014, to strengthen this endeavour, an Integrated Scheme for Agricultural Marketing (ISAM) was brought under a single umbrella all Central Sector Schemes aiming to improve the efficiency of marketing, keeping the farmers at the heart of it. It emphasized infrastructure and ICT to expand a market's outreach. The ISAM was a further recognition of the potentials of ICT to form a nationwide information network for speedy collection and dissemination of market information to help timely price realization. Minimum, maximum and modal prices of varieties and qualities transacted were posted. At the start of the XII Plan (2013), 3241, i.e. 45% of the wholesale markets of the country had online facilities, and the ISAM targeted 3700 new markets to be covered through computers, mobiles and SMS facilities.

An intention of doubling farmer's income by the year 2022 was announced in 2015, making it clear that the priority of agricultural policy is shifting from producing more to delivering more to the producer. Empirical evidence of low farm incomes in a growing economy (NABARD 2018) had already been drawing political attention. The Ministry of Agriculture was renamed Ministry of Agriculture and Farmers Welfare in 2015. Rural markets were getting ready for the technology-enabled methods like electronic auctioning, computerized market intelligence, spot and futures markets, mobile 'apps', specialized call centres and anticipated forecasting algorithms (Union Budget on demand forecasting 2018) for demand and price discovery.

2.2 Innovative Reforms 2016–2018

Karnataka government was implementing a unified market platform jointly through a private company ReMS from 2014. It demonstrated how, supported by facilities for grading and standardization, a common platform for a transparent and integrated e-trading mechanism can be successful in expanding the market within and beyond the state for fetching remunerative producer prices. Following the ReMS model, a central sector scheme created a common e-platform at the national level aimed to link 585 selected wholesale markets across the country to which free software and funds for hardware and equipment would be given by the central government.

The electronic trading platform for e-NAM was launched in 2016. The e-NAM, to be monitored intensely, is expected to draw private investment and benefit farmer directly and indirectly with competitiveness, efficiency, lower price spreads and better price realization and to reduce their dependence on MSP, but the success will depend greatly on state cooperation (Chand 2016). The national e-market platform allows transparent sale transactions and price discovery initially only in regulated markets in willing states that have a liberal licensing policy for traders without any precondition of physical presence. Harmonization of quality standards of agricultural produce with infrastructure for assaying (quality testing) is essential for informed bidding by buyers for trade to follow and still proves to be a challenge. Recent data (2019) shows a limited coverage of only 14% farmers under e-NAM (BL 2019).

In the way forward in reforms, PSS imposes a costly administrative burden, leakages of scarce public funds targeted for farmers and possibility of price distortion. An umbrella scheme 'Pradhan Mantri Annadata Aay Sanrakshan Abhiyan or the PM-AASHA' approved in 2018 brought together the conventional procurement scheme and an option of purchase from farmers by private traders against DBT by government. It followed the model 'price deficiency scheme' which was already in operation in Madhya Pradesh. Replacement of actual physical public purchases by the government could over time diminish price and production distortion that MSP implicates and simplify the administration of PSS. In the latest move to secure farmer's welfare, a financial transfer to farmers dissociated from nature or quantity of crop is grown is implemented as a token measure under the Kisan Samman Nidhi Yojana (PM-Kisan) in 2019, similar in spirit to Rythu Bandhu scheme in Telangana. The innovations started in 2016 are rudimentary in development.

2.3 Production and Public Operations in Pulses

Pulses are consumed across the country, but production fell short historically. Gram and arhar are the two dominant crops, accounting for 40 and 20% of India's pulses production, respectively. Production is concentrated towards Maharashtra, Madhya Pradesh and Karnataka in case of arhar and towards Madhya Pradesh, Maharashtra and Rajasthan in case of gram (Table 3), but Gujarat, Uttar Pradesh and Andhra Pradesh are minor producers of arhar and Karnataka, Andhra Pradesh and Uttar Pradesh of gram. Between the two periods, 2010–13 and 2014–16, Madhya Pradesh gained share in both gram and arhar, but Maharashtra lost share in arhar whose production became more spatially concentrated in Madhya Pradesh. More than 1.5 million tonnes of pulses out of the 23 million tonnes produced was procured in 2016–17. Among the agencies procuring gram and arhar, NAFED was by far the largest followed by SFAC. Arhar and gram were prominent items of procurement.

Plots of annual price indices of major producer states show differential behaviour of markets (Fig. 3a, b). Gram price, reaching an upper bound in end 2012, was arrested thereafter but rose steadily subsequently. Arhar, on the contrary, showed plateauing at two levels, but like gram the price in all growing states increased sharply from 2014

Table 3 Production distribution of gram and arhar across states (%) in India

States	Gram		Arhar	
	Period-I	Period-II	Period-I	Period-II
Madhya Pradesh	38.2	41.5	10.1	18.7
Maharashtra	13.4	15.1	32.8	27.1
Rajasthan	16.3	13.3	-	-
Karnataka	7.1	8.1	15.7	15.9
Andhra Pradesh	8.3	6.5	7.7	8.0
Uttar Pradesh	6.9	4.9	10.6	7.0
Jharkhand	-	-	5.0	6.0
Gujarat	-	-	8.6	8.7
Other states	9.8	10.6	9.5	8.6
India (Million Tonnes)	8.57	7.92	2.93	3.41

Note Period-I: 2010–11 to 2013–14, Period-II: 2014–15 to 2016–17. Andhra Pradesh includes Telangana
Source DES (Website)

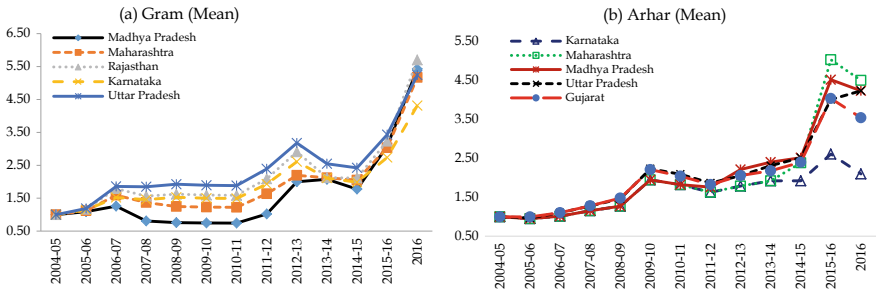

Fig. 3 Movements of mean of annual price indices (base 2004–05) across states 2004–5 to 2016–17

till it reached a crisis point in 2016 when the curve takes an inverted U-shape due to unprecedentedly high production of 4.9 million tonnes against 2.6 million tonnes in 2015–16 followed by imports adding to the stock. The steady decline of producer price thereafter has been a cause of greater concern for the economy.

3 Moving Towards an Integrated Agricultural Market

An idealized 'perfectly competitive' market allows space to numerous agents as buyers (traders) and sellers (farmers) to transact with chosen partners and an open option to enter or leave the trade. Theoretically, the market generates a representative 'one' price, which leaves no super-normal profit. The perfect competition also implies efficiency, which means that the equilibrium price incorporates all possible information (Samuelson 1964). In practice, trade theory (Balassa 1964; Samuelson 1964) has its gaps attributed to quality differences, demand patterns and costs imposed by non-traded goods. Differential market behaviour (Hallak and Schott 2011; Feenstra and Romalis 2014) is also manifested in empirical correspondence between income and price level (Bekker et al. 2012; Melchoir 2016). The geographic ambit of the market bound by roads, ports and trade laws is important for any analysis of markets (Samuelson 1964; Enke 1951; Samuelson 1952; Takayama and Judge 1971). As a concept, market integration is an extension of the theory of general competitive equilibrium to the spatial context where a number of locations are conceived to be tied by trade relations through the law of one price across markets which has been questioned and tested empirically in a broad discourse (Goodwin 1992; Goodwin and Wohlgenant 1990; Crougy-Veyrac et al. 1981).

Influenced by geography, production is seldom found to be distributed with uniformity and even government interventions, constrained by administrative and fiscal constraints, cannot be uniformly dispersed across producing regions. In a free market, integration is essential for preventing localized famines in consuming areas (Ravallion 1986), but when a positive shock is created by PSS in one location, trading responses of surrounding states will convey its benefit across state borders. The large gap between prices that consumers pay and what producers receive has been a matter of concern, but it is also important to note that prices that farmers get for the same commodity can be widely variant among locations (Chatterjee and Kapur 2016). ICT can influence the convergence of markets not only by disseminating price information across wholesale markets swiftly to enable price benchmarking in smaller markets but more importantly, also by stimulating trade to match demand and supply across the nation.

The regulated (APMC) market of India, which served agricultural marketing for decades, was designed with a strong mechanism of price discovery. The economic reforms, by relaxing the entry barriers to traders expanded the options available to farmers to choose their buyers (Ghosh 2013) and reduced the role of the APMC market. As price discovery in the absence of an auction became a challenge, regulated markets, especially the larger ones with numerous transactions in the specific products, continued to provide benchmark prices to others. Thus, despite critical reports, even at the extreme, the regulated APMC market can not be seen as an 'auction mechanism' grounded on competition laws (Reddy and Rajshekhar 2014). The AGMARKNET initiative of the government (see Box 1) was aimed at disseminating price information from relevant wholesale markets so that benchmark prices can be

drawn from across India and even international markets. The effectiveness and outreach to farmers and small traders remained limited so long as access to the Internet was scarce.

The year 2014–15 could therefore be seen as a watershed. The MRIN under ISAM (Sects. 1 and 2) was linking wholesale markets with locally accessible information using modern technologies under ICT. The year was a departure also because pulses came under the ambit of PSS. The public policy of PSS is expected to enhance market prices in areas of concentrated procurement. In the short run, procurement can widen price differentials with other producing regions, but at a reasonably longer time scale, so long as private trade flows are uninhibited, PSS, by attracting supplies from other producing areas, can only widen the outreach of public benefit to farmers across the country. The government's intervention in pricing is a distortion in the market, but the PSS of 2014 was a recognition of the distressfully low pulses prices determined in producers' markets. The sharp rise in prices in the producing states with converging tendencies seen in Fig. 3 is a further affirmation of the distress caused by local market forces in the absense of state intervention and the increased role of information networking across the markets where producers sold pulses. Concurrently undertaken public intervention with PSS and ICT linkage will reflect on both price level and their differentials. Analysis of monthly price data at the state level in the whole study period is expected to show enhancement of prices due to procurement in the Sub-Period-II along with increased convergence of state prices owing to ICT-enabled market networking.

3.1 Methodological Approaches

The approach taken to assess market integration is neither unique nor has it been static. Food price differences across countries and within large and heterogeneous counties have been under research lens (Melchior 2016; Deaton and Dupriez 2011; Li and Gibson 2014) to identify border effects (USA and China), convergence of fragmented markets (China, Russia), segmentation (Russia), their implications for poverty (India) and their determinants (India). The bivariate correlation coefficient is another simple quantitative measure of market integration. It has been applied to show that Indian markets tended to be increasingly integrated with the development of roads and aberrations were attributed to price controls in cereals (Cummings 1967; Lele 1967, 1971; Kainth 1982; Gupta 1973; Palaskas and Hariss 1993). However, any observed correlation may be spurious when the price is affected by another traded good (Blyn 1973; Hariss 1979). The role of trade in handling bulky consignments across distances is not explicitly patent in results based on this analysis. An alternative method, hinging on long-run convergence of markets, is to track the spatial variances of prices across markets, but this method too is not spared from criticisms (Hurd 1975; Ravallion 1986). Gini coefficients are computed with the population as weights also to analyse unit values of products, their wholesale and retail prices across states, but price differentials are explained by standard regressions of pooled

price data on the state-level and supply-side variables as proxies because interstate trade data is not available, state level and supply side variables are taken as proxies (Melchior 2016). Focus on the role of trade is also placed in examining the effect of highway construction in India (Atkin 2013), which is expected to reduce trading cost. Imports from other states are apprehended to make farmer's income volatile. Compiling micro-data from 308 districts in 19 states over 40 years and 15 major crops, distributions of the mean and variance of prices were plotted at decadal levels for comparison, but structured econometric methods showed that portfolio reallocation across crops helped farmers to minimize risk and amplify gains from trade. Implicitly information proved important in this argument.

A more popular as also evolving procedure is the dynamic bivariate or multivariate regression-based method of measuring price cointegration that allows local dynamic structures to be incorporated in the measurement (Johansen 1988). Using a radial framework with a single central urban market and six satellite markets, Ravallion (1986) identified two highly restricted rice markets in Bangladesh in a period of price turbulences. An important insight gained in this study is the preference for a linear rather than a logarithmic form to allow transport cost to affect price differentials. In one critical application, Gonzalez-Rivera and Helfand (2001) also searched for geographical boundaries of markets in Brazil, attributing any non-exclusion to factors like remoteness, trade reversals and non-stationary transaction costs, but in the same paper (p. 579), statistical limitations of the procedure in large dimensioned data have been cautioned by the authors. Gonzalo and Granger (1995) also isolated an unobserved common factor between two cointegrated variables. In a step ahead of the cointegration analysis, an error correction model (ECM) takes account of the possible reactions of each location to disequilibria elsewhere. The launch of market reforms and methodological advances intensified the applied research interest in the flow of price signals. Application of cointegration analysis and ECM on price data expanded. Johansen method was commonly used to show improvement of spatial integration of wholesale markets for wheat, rice and other products in India (Wilson 2001; Acharya 2004; Kumar and Sharma 2000; Bathla 2008).

3.2 Data and Method Used in This Study

The analyses that follow primarily examine the association of price levels and their movements between pairs of states treated as markets using monthly wholesale data. The sample period starts with 2010 when ICT application entered agriculture marketing (see discussion in Sect. 2) but, limited by access to data at the time of analysis the sample period is truncated at the end of 2016. In reality, the sample period 2010–16 covers a gestation period for the reforms targeting market expansion and is dynamic with the years 2014–15 marked a watershed when policy emphasis in various ways shifted to farmers' welfare. Subsequently, the years 2016 was another watershed when the objective was oriented specifically towards expanding farmers' reach to spatially distant buyers. Given that the sample is a period marked by dynamics in

policy and ICT, two sub-periods are compared to track the tendencies in the entire period.

The number of states covered is 10 each for arhar and gram which include both producer and consuming states and Sub-Period-I: 2010:04–2014:03 and Sub-Period-II: 2014:04–2016:12 with 2014 as a break point. The state price is represented as the average of the nominal mandi (wholesale market) prices in the state reported officially (DES, Website, MoA&FW, Various). The time series sample sizes in Sub-Period-I and Sub-Period-II are 48 and 33, respectively, reasonably adequate for time series analysis.

Simple correlation analysis of prices is made for both sub-periods anticipating improved correlation among prices in Sub-Period-II compared to Sub-Period-I as markets get increasing linked by trade. The standard deviation among the prices in any market measures the spread of prices from the mean. To correct for inflation, the deviation is standardized by the mean to get the coefficient of variation (CV) which can be compared and tracked by the two sub-periods. Finally, prices are also analysed by modelling for cointegration and ECM across markets for the two consecutive sub-periods. If non-stationary random variables have a stationary linear combination, the variables are said to be cointegrated in the sense that they have a long-run linear relation. When prices in two markets do not have a long-run linear relation, the markets are not integrated and have their price determination processes as separate markets. Cointegration and ECM are estimated to assess if any pair of markets (states) are integrated by trade and whether the price in one market catches up with a movement in another within a time frame of one month which seems reasonable for a food product that is perishable only in the medium term. The ECM, in its dynamic approach, allows lags in responding to disequilibrium.

First, each price series is subjected to unit root analysis using ADF (augmented Dickey–Fuller) test choosing lags based on AIC (Akaike information criterion) and alternatively the SIC (Bayesian information, Schwarz criterion). An alternative to ADF test is the PP test (Phillips–Perron test) which can be used with Newey–West bandwidth to choose lags. Time trend is considered only if statistically significant. The ADF and PP tests help identify the order of integration $I(k)$ which implies that the kth difference in price data is stationary. If the series is stationary at level, it is $I(0)$ and if the series at the level has a unit root, the first difference is tested and so on. If two series are $I(k)$ and $I(j)$ where orders k and j are not equal, they are not cointegrated. Further cointegration analysis is continued only if the order of integration is the same. Johansen's method is used to find the cointegrating relation and the error correction in prices in a bivariate process between states.

A long-run equilibrium or a cointegrating relation between two price series is given by the equation

$$P_i = \alpha + \beta P_j + \in_i \tag{1}$$

where β the long is run coefficient of adjustment and α is a constant and the error $\in_i$ is stationary, expressed as

$$\in_i = P_i - \alpha - \beta P_j \tag{2}$$

measuring the extent of short-run disequilibrium which stimulates trade flows from market-*j* to market-*i*. When $\in_i > 0$ which means that the price in the *i*th market exceeds the target set by the price in the *j*th market through the hypothetical long-run cointegrating relation (1), the traders' responses tend to raise the price in market-*j* and bring down the price in market-*i* in an equilibrating move in the short run represented by the error correction equation as follows

$$\Delta P_{it} = \theta_i \in_{it-1} + \alpha_{1i} \Delta P_{i_{t-1}} + \alpha_{2i} \Delta P_{i_{t-2}} \cdots + \beta_{1i} \Delta P_{j_{t-1}} + \beta_{2i} \Delta P_{j_{t-2}} \cdots + \varepsilon_t, \tag{3}$$

where

θ_i is treated as the ECM coefficient.

3.3 Have Markets for Pulses Integrated Over Time?

Prices in Maharashtra and Madhya Pradesh, both dominant pulses producers, are consistently low (Tables 5 and 6). Within the sub-periods, temporally the price was relatively stable in the first period in arhar, but in both crops, intra-period variation increased over time. Inflation made prices much higher in the second period, the ordering of states did not always remain consistent and the prices became temporally more unstable in both crops. Comparisons of the prices and their variations based on range, correlation and CV suggest that state prices at levels are converging through it must be admitted that the results do not present robust confirmation. The literature (see Sect. 3.2) is clear about specific flaws in these indicators.

3.4 Prices and Their Interstate Variations

Compared to the sample average, gram prices are low in producing states Madhya Pradesh, Maharashtra and Rajasthan in all of which public procurement is also reported. In Sub-Period-I, gram price is lowest in Madhya Pradesh, but the price is high in Tamil Nadu, Karnataka and Bihar, all-consuming or minor producer states. In Sub-Period-II, the price of gram in the consuming state Tamil Nadu is higher by Rs. 32 than the lowest price state Madhya Pradesh. The range of gram price fell from 148 to 74%, and its CV fell from 26 to 21% from Sub-Period-I to Sub-Period-II. The curve for the CV of state prices of gram (Fig. 4a) showed no convergence to start with, there was a mild rise in 2013 followed by a distinct reversal.

In Sub-Period-I, arhar price is particularly low in major producing states Madhya Pradesh and Maharashtra and also in minor producing states Rajasthan and

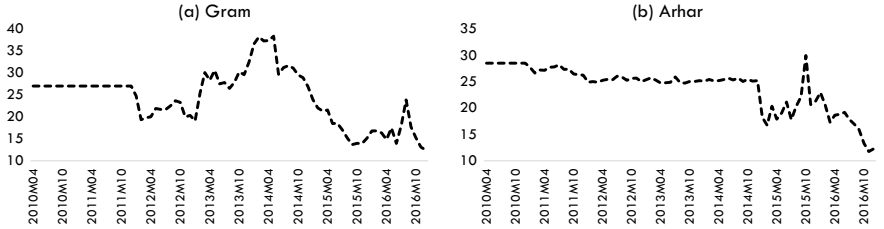

Fig. 4 Tendency of interstate price variation (coefficient of variation %)

Uttar Pradesh but paradoxically, not in Karnataka which also produces the crop, attributable arguably to some extent to quality difference, demand factors related to dietary patterns and probably also to initiation of policy experiments with online marketing (Sect. 2.2). In the second period, Madhya Pradesh, Rajasthan and Maharashtra were still left with relatively low prices. Between the two periods, the interstate range reduced from 113 to 86%, and the CV is less in Sub-Period-II at 23% compared to 27% in the Sub-Period-1. Interstate price variances seem to be static in most of Sub-Period-I, showing some volatility in 2014 but falling mostly in Sub-Period-II (Fig. 4b).

3.5 Correlation

If the bivariate correlation coefficient is considered as an indication of integration, Tables 7 and 8 suggest that transmission of price movements has improved in Sub-Period-II over Sub-Period-I for gram, but for arhar the result is mixed. For gram in Sub-Period-I prices in producing states, Maharashtra and Madhya Pradesh have low correlation with states Gujarat, Haryana and Rajasthan despite the proximity and Rajasthan prices are weakly correlated with prices in other two producing states and Tamil Nadu, while Bihar prices have a relatively high correlation with producing states. In Sub-Period-II on the contrary, coefficients are mostly 99–100% except between Bihar and the three major producing states and between Rajasthan and Tamil Nadu. In the case of arhar, correlation of prices with Karnataka actually reduces for all cases except Tamil Nadu and West Bengal. The result may signify that Madhya Pradesh, the major producer integrated into a larger market, unlike Karnataka, where the price clings to its high level.

3.6 Cointegration and Error Correction Analysis

Cointegration is indicative of a long-run price relation suggestive of trade. All the price series have a unit root at levels (Table 9), but at first difference, mixed results emerge from alternative methods because choosing lags based on AIC, the ADF tests show non-stationarity in several cases in both sub-periods for gram and only

in Sub-Period-II for arhar. Since the second differences prove to be stationary, these price series are deemed to be I(2) in 11 out of the total 42 cases and I(1) in others (Table 10). If these results are accepted, long-run cointegration can be examined only for states with I(1) series and for states with I(2) series separately.

On finer scrutiny, the results are observed to be highly sensitive to the number of lags. AIC and SIC criteria often differ in the indication of model selection, and the literature is not clear on the choice, leaving much to judgment. While SIC is parsimonious, the longer lag structure of a typical AIC-based model can be more representative of the dynamic process of price changes in the different states. The PP test is more robust, and the lags are chosen by the method itself (Newey–West bandwidth). ADF test by choosing lags based on SIC reduces the I(2) to only 2 cases and applying the PP test eliminates them. Assuming all series to be I(1) to allow space to alternative methods, bivariate cointegration tests are conducted though the findings from ADF-AIC methodology suggest some caution in dealing with the results. Seasonality in monthly time series data is a possibility, gram being a rabi crop and arhar being grown in the kharif season. Plots of the monthly prices are not conspicuous for seasonality. Nevertheless, as a trial, the ADF analysis was conducted on prices corrected for seasonality (not reported).[9] The results remained same except that gram price in Gujarat with ADF-AIC method (Table 10) changed from I(2) to I(1) which is assumed in this study anyway based on the other methods. Although AIC is used for model selection, sensitivity test is conducted for varying lags to ensure consistency between AIC and SIC.

When prices between two markets are found to be cointegrated, the two markets are treated as integrated or linked together as a larger market, whereas segmented markets are expected to be not integrated. In both crop cases, profound changes are seen in market pairing (Table 11). More the number of states any producer state is integrated with, larger is its potential market. However, even if two markets are integrated, despite the trade links implied, price transmission may not be mutual or significant in one month. To the extent a producing state remains unresponsive, it serves as an exogenous influence to another consuming or producing state and remains insulated from the benefit coming from consumer demand or public procurement.

Considering price cointegration as a sign of market integration and error correction to be suggestive of the direction of causality and the strength of adjustment to short-term disequilibrium, the two crops differ in price behaviour though producer states in both cases tend to be cointegrated. Gram markets in Maharashtra and Rajasthan, in general, appear to be relatively large sprawling across the country and Rajasthan's arhar market covered as many as five states from different regions. There appears to be a shift in the trading partners of Maharashtra from eastern states to northern and

[9] Admittedly, seasonal adjustment may produce mistaken inference of economic relationship and loss of valuable information, and application of new methods (Franses 1991; Johansen and Schaumburg 1999; Darne 2004) is found in the literature. The analysis in this study also could not correct for seasonality in Sub-Period-II owing to the small size of the sample. Use of monthly data is common in cointegration analysis of agricultural prices (Ahmed and Singla 2017; Shreshtha et al. 2014; Singh et al. 2018).

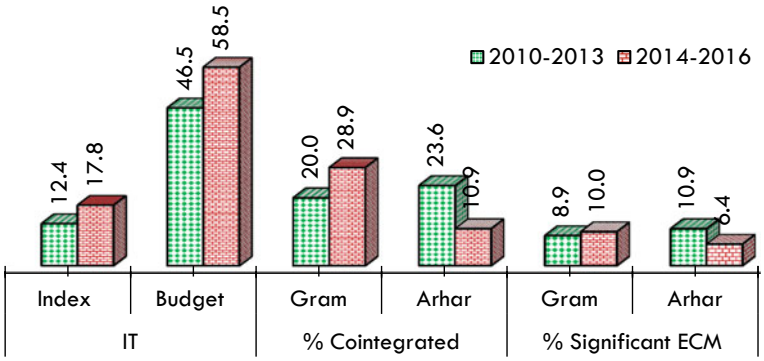

Fig. 5 Change in IT index (%) and budget (Rs. per 100) and market expansion

western neighbours. The ECM coefficient showed limited and mostly asymmetrical responses of gram producing states in Sub-Period-II. In particular, gram price in Maharashtra did not respond to differentials with producing or consuming states, Madhya Pradesh responded only to Maharashtra, while Rajasthan was insulated to price differentials with all other states. Prices in producer states, however, were found to cause price changes in consumer states. Compared to gram, markets for arhar performed poorly in integration and the responses of producer states (Fig. 5). Producing states generally have low prices but some developed integration with consuming states such as Gujarat with West Bengal, Maharashtra with Rajasthan, Madhya Pradesh with Bihar, but in all these cases, the latter showed price responses asymmetrically. Maharashtra, a major producer, did not expand its market and did not respond to price differential though consuming states adjusted prices in response.

4 Conclusion

India's agricultural markets are being reformed to enable farmers to take advantage of market opportunities and earn higher incomes. The direction taken is towards supporting farmers with higher incomes without distorting the market. Currently, the policy emphasis of the central government is moving towards creating a larger national-level market for agro-products beyond state borders so that with improved supply chains farmers fetch best prices for their products. By relaxing regulations and simplifying administration, entry barriers are removed, and new and resourceful trading agents are allowed to enter the market as buyers.

Market reforms implemented by tinkering with institutional rules aim to clear markets of imperfections and expand the market through competitive means but the entry of ICT into the domains of reforms can be expected to facilitate the process at every step by enabling easy financial transfers, forecasting early outlooks of production, monitoring prices and above all by supporting farmers, traders and consumers

across the country to transact at efficient prices. A review of the transition process in the new millennium demonstrates that the large array of uses that ICT has found in moving Indian agriculture into a new technology-enabled age. ICT, as a facilitator of reforms, seems to offer a way to transform agriculture into a modern, adaptive and lucrative sector.

A leading objective of current reforms is to integrate the segmented state-level markets of India into a 'one' market where interstate arbitrage will make prices move in line. Empirical assessments made at this crucial stage can provide a baseline for measuring progress on this front. At the levels, pulses prices continue to be widely different across states, but they have come closer with reduced divergence in the 2010–2016 period as indicators like range and coefficient of variation suggest. The year 2014–15 marked by price support on pulses and a large budget on linking markets by information (ICT) started proved to be a departure. Prices of both crops in producing states started rising due to public support, and while dispersions in prices began declining sooner in the case of gram, arhar which is increasingly concentrated in Madhya Pradesh saw price convergence only later in 2015 attributable largely to ICT.

Though mere access to ICT may have helped in price discovery by accessing benchmark prices at major centres elsewhere, which tend to be production centres and large wholesale markets, these methods cannot capture the role of trade in price movements that involve dynamics. The correlation coefficient between prices across markets has not also shown any clear sign in this regard with price movements being contemporaneously even becoming less correlated in the case of arhar, but this indicator says little about trade and causality.

The cointegration and error correction methods, by modelling the price behaviour econometrically accounting for local dynamics and the theory of price adjustment to disequilibrium, show that market coverages are limited and variable in the study period. Even if two markets are integrated, more often, the consuming states responded to price differential with producing states bringing down their prices. With rare exceptions, the producing states were seen to lead the market, largely remaining exogenous. Also, during this time high prices of pulses happened to be the dominant concern of the country, invoking varied policy responses and the market response observed seem to be the fulfilment of the aspiration of the time although arguably it added to farmer's distress. Segmentation was not uniformly observed in the sub-periods though a few pairs of states lost their linkages, but there is no evidence that distances stood in the way of trade.

ICT can be anticipated to support the supply chains with information and operational efficiency, enable government to support farmers without distorting the market and help farmers and traders to expand markets with modern marketing methods defeating the imposed barriers with its own universality. The recent origin of the e-NAM which actually facilitates auctioning and trade on ICT portals across the country has much more to offer but the effects are awaited. Prerequisite to physical goods movements, are however freight pathways bolstered by suitable storage facilities, minimal transaction cost of flow (rules, toll gates, restrictions, harassment etc.). The speed of trading responses is contingent on the presence and readiness of

a well equipped, willing and forward looking trading community. Further, the ICT budget for agriculture marketing has not retained its share throughout. In a federal nation despite the Union government's intentions, market expansion and responses are largely outcomes of the political economy reactions and capabilities of states to restrain grain movements across borders. Market exchange is not costless and outdated supply chains can add to unproductive costs associated with trading. The government instituted ICT system for agro-marketing may also have biases towards harnessing information specifically from larger producer markets when similar attention from consumer markets can be more helpful to farmers

Acknowledgements The authors thank Dr. Sangeeta Chakravarty, Institute of Economic Growth, Delhi, for her advice on the empirical analysis.

Appendix

See Tables 4, 5, 6, 7, 8, 9, 10, 11 and 12.

Table 4 ICT budget classification in agriculture sector

Crop Husbandry (Major Head)
Farm Information Bureau (Non-Plan)
Information Support/Management Information System
Agricultural Economics and Statistics (Minor Head)
Commission for Agricultural Costs and Prices
Other Expenditure (Minor Head)
Strengthening of IT and Information Net Work in DAC
Strengthening/Promoting Agricultural Information System
National E-Governance Plan-Agriculture
Other Agricultural Programmes (Major Head)
Marketing Research, Survey and Marketing Information Network
Grants-in-aid to State Government (Major Head)
Crop Husbandry—Other Grants (Minor Head)
Promotion/strengthening of IT in Agriculture
National E-Governance Plan-Agriculture
Other Agricultural Programmes–Marketing Facilities (Minor Head)
Marketing Research, Survey and Marketing Information Network

Table 5 Mean and variations in of wholesale prices (Rs./kg) of gram in India

	Temporal average and variation within states										Spatial average and variation across states	
	BH	GJ	HR	KRN	MH	MP	RJ	TN	UP	WB	Mean	CV
Sub-Period-I												
Mean	37.8	29.4	30.2	38.7	27.4	20.1	29.2	49.8	35.3	36.0	33.4	26
CV	19	26	23	22	26	44	25	28	21	22	23	
Sub-Period-II												
Mean	51.2	46.4	49.1	55.0	49.7	44.8	46.9	77.8	50.2	55.8	52.7	21
CV	29	46	46	36	42	49	45	33	35	38	39	

Note Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12. Calculations are based on monthly data
Source MoA&FW (various), DES, Website

Table 6 Mean (Rs./kg) and variations (%) in of wholesale prices of arhar in India

	Temporal average and variation within states										Spatial average and variation across states	
	AP	BH	GJ	KRN	MH	MP	RJ	TN	UP	WB	Mean	CV
Sub-Period-I												
Mean	37.6	34.3	52.1	59.5	28.0	30.7	29.4	41.3	35.5	42.9	39.1	27
CV	9	8	8	8	8	15	8	11	10	13	8	
Sub-Period-II												
Mean	67.4	53.2	85.0	73.8	61.3	55.6	45.7	58.9	60.3	64.1	62.5	23
CV	29	22	30	22	37	30	22	18	25	30	25	

Note Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12. Calculations are based on monthly data
Source MoA&FW (various), DES, Website

Table 7 Correlation of monthly wholesale price of gram

	BR	GJ	HR	KR	MH	MP	RJ	TN	UP	WB
Sub-Period-I										
MH	0.88	0.66	0.69	0.80	1.00	0.80	0.73	0.82	0.80	0.73
MP	0.82	0.65	0.64	0.79	0.80	1.00	0.67	0.90	0.77	0.85
RJ	0.88	0.98	0.99	0.97	0.73	0.67	1.00	0.65	0.92	0.84
Sub-Period II										
MH	0.95	0.98	0.99	0.99	1.00	0.99	0.99	0.96	0.98	0.98
MP	0.95	0.99	0.99	0.99	0.99	1.00	0.99	0.94	0.97	0.99
RJ	0.95	0.98	0.99	0.99	0.99	0.99	1.00	0.95	0.97	0.98

Note Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12
Source MoA&FW (various), DES, Website

Table 8 Correlation of monthly wholesale price of arhar

	AP	BR	GJ	KR	MH	MP	RJ	TN	UP	WB
Sub-Period-I										
KR	0.89	1.00	0.92	1.00	1.00	0.68	1.00	0.68	0.94	0.63
MH	0.89	1.00	0.92	1.00	1.00	0.68	1.00	0.68	0.94	0.63
MP	0.65	0.68	0.71	0.68	0.68	1.00	0.68	0.64	0.70	0.29
Sub-Period-II										
KR	0.85	0.66	0.82	1.00	0.71	0.78	0.66	0.82	0.61	0.79
MH	0.93	0.95	0.92	0.71	1.00	0.93	0.95	0.88	0.91	0.91
MP	0.93	0.94	0.93	0.78	0.93	1.00	0.94	0.86	0.91	0.93

Note Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12
Source MoA&FW (various), DES, Website

Table 9 Unit root test of monthly price data

	Sub-Period-I				Sub-Period-II			
	Level		First difference		Level		First difference	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP
Gram								
BR	−1.59	−1.48	−4.63	−4.63	1.88	7.01	−1.72[a]	−6.50[a]
GJ	−1.92	−0.13	−2.52	−6.27	−1.24	−2.66	−3.81[a]	−7.49
HR	−1.40	−1.49	−6.31	−6.38	−1.58	−1.43	−5.55[a]	−6.52[a]
KR	−1.73	−1.47	−3.49	−3.43	1.48	3.18	−3.18[a]	−4.53[a]
MH	−3.16	−2.49	−5.89	−9.44	−1.93	−1.70	−3.88	−3.86
MP	−1.62	−1.32	−1.76	−9.22	−1.74	3.09	−6.63[a]	−6.64[a]
RJ	−2.02	−1.45	−2.32	−5.44	−1.58	−1.80	−2.09	−4.74
TN	−1.97	−2.58	−4.34	−5.34	−1.69	−1.76	−4.78	−4.87
UP	−1.57	−1.57	−5.41	−5.49	3.51	3.51	−5.78[a]	−5.81[a]
WB	−1.30	−1.25	−4.63	−5.51	−2.64	−1.67	−3.83[a]	−4.75
Arhar								
AP	−2.38	−2.11	−5.15	−5.08	−1.51	−1.57	−6.25[a]	−6.25[a]
BR	−1.89	−1.65	−5.05	−5.05	−1.84	−1.37	−3.44	−3.38
GJ	−2.78	−2.23	−4.91	−4.88	−1.58	−1.58	−7.77	−7.83
KR	−1.89	−1.65	−5.06	−5.05	−1.53	−1.62	−6.42	−6.43
MH	−1.89	−1.65	−5.06	−5.05	−0.15	−0.19	−5.76[a]	−5.76[a]
MP	−2.40	−2.31	−8.02	−8.07	−2.53	−1.52	−2.10	−8.08
RJ	−1.89	−1.65	−5.06	−5.05	−1.84	−1.37	−1.10	−3.38
TN	−1.97	−1.84	−8.54	−8.53	−1.37	−1.49	−5.47	−5.52
UP	−1.89	−1.74	−6.64	−6.65	−1.39	−1.28	−3.31	−3.28
WB	2.15	−2.17	6.76	−6.77	−0.29	−0.29	−4.92	−4.93

Note Lags are chosen using AIC for ADF test and Newey–West bandwidth for PP test. Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12

[a]Denotes having time trend

Source MoA&FW (various), DES, Website

Table 10 Order of integration of monthly prices

	Sub-Period-I			Sub-Period-II		
States	ADF–AIC tests	ADF–SIC tests	PP–BK tests	ADF–AIC tests	ADF–SIC tests	PP–BK tests
Gram						
BR	I(1)	I(1)	I(1)	I(2)	I(1)	I(1)
GJ	I(2)	I(1)	I(1)	I(1)	I(1)	I(1)
HR	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
KR	I(1)	I(1)	I(1)	I(2)	I(2)	I(1)
MH	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
MP	I(2)	I(1)	I(1)	I(2)	I(1)	I(1)
RJ	I(2)	I(1)	I(1)	I(2)	I(2)	I(1)
TN	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
UP	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
WB	I(1)	I(1)	I(1)	I(2)	I(1)	I(1)
Arhar						
AP	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
BR	I(1)	I(1)	I(1)	I(2)	I(1)	I(1)
GJ	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
KR	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
MH	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
MP	I(1)	I(1)	I(1)	I(2)	I(1)	I(1)
RJ	I(1)	I(1)	I(1)	I(2)	I(1)	I(1)
TN	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
UP	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
WB	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

Note Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12
Source Based on estimated model

Table 11 Bivariate cointegration analysis of markets integration using monthly wholesale prices

States		Sub-Period-I			Sub-Period-II		
I	J	Lag	AIC	Coeff.	Lag	AIC	Coeff.
Arhar							
AP	BR	1	24.60	−1.17*			–
AP	RJ	1	24.29	−1.36*			–
BR	RJ	1	8.71	−1.16*			–
GJ	BR	5	9.08	−1.52*			–
GJ	RJ	5	9.09	−1.77*			–
GJ	WB			–	5	33.07	−1.52*
KR	AP	1	25.70	−1.48*			–
KR	GJ	5	9.56	−1.14*			–
MH	AP	1	24.19	−0.70*			–
MH	BR			–	5	28.95	−1.93*
MH	GJ	5	8.80	−0.54*			–
MH	RJ	1	8.18	−0.95*	5	28.64	−2.24*
MP	BR			–	1	29.01	−1.39*
MP	TN			–	1	30.74	−1.55*
RJ	KR	1	9.14	−0.49*			–
TN	WB			–	1	31.01	−0.63*
UP	AP	1	25.77	−1.11*			–
UP	GJ	1	25.23	−0.91*			–
Gram							
BR	TN			–	5	30.33	−0.49*
GJ	WB			–	4	29.08	−0.97*
HR	UP			–	5	29.76	−0.93*
KR	WB	5	26.09	−1.19*			–
MH	BR	1	26.30	−0.89*			–
MH	HR			–	1	29.40	−0.89*
MH	KR	1	26.71	−0.74*	2	27.84	−0.95*
MH	MP	5	28.17	−0.83*	1	29.31	−0.89*
MH	RJ			–	2	28.95	−0.94*
MH	WB	3	28.40	−0.92*			–
MP	BR	4	26.42	−1.12*			–
MP	HR			–	1	29.73	−0.97*
MP	RJ			–	1	29.38	−1.12*
MP	WB			–	4	28.89	−0.96*
RJ	BR			–	5	29.34	−0.21

(continued)

Table 11 (continued)

States		Sub-Period-I			Sub-Period-II		
I	J	Lag	AIC	Coeff.	Lag	AIC	Coeff.
RJ	HR	4	24.74	−1.05*	1	28.88	−0.89*
RJ	KR	5	23.90	−0.79*	4	27.57	−0.99*
RJ	WB	5	26.42	−0.91*			–

Note *Significant at 5%. Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12
Source MoA&FW (various), DES, Website

Table 12 Error correction coefficients (ECM) of monthly prices in the cointegrated pairs of States

States		Sub-Period-I		Sub-Period-II	
I	J	State I	State J	State I	State J
Arhar					
AP	BR	−0.37	0.24*	–	–
AP	RJ	−0.37	0.21*	–	–
BR	RJ	160.56	138.98	–	–
GJ	BR	−104.00	0.51*	–	–
GJ	RJ	−102.85	0.53*	–	–
GJ	WB	–	–	1.91	1.33*
KR	AP	−0.28*	0.25	–	–
KR	GJ	−0.81*	72.11	–	–
MH	AP	−0.28*	0.53	–	–
MH	BR	–	–	0.78	0.49*
MH	GJ	−0.97*	370.37	–	–
MH	RJ	−435.94	−457.52	0.78	0.42*
MP	BR	–	–	−0.55	0.49*
MP	TN	–	–	−0.71*	−0.07
RJ	KR	638.28	1291.94	–	–
TN	WB	–	–	0.14	0.99*
UP	AP	−0.23*	0.40*	–	–
UP	GJ	−0.36*	0.35*	–	–
Gram					
BR	TN	–	–	−0.08	1.00
GJ	WB	–	–	0.26	1.08*

(continued)

Table 12 (continued)

States		Sub-Period-I		Sub-Period-II	
I	J	State I	State J	State I	State J
HR	UP	–	–	−1.04	0.65*
KR	WB	0.19	0.82*	–	–
MH	BR	−0.69*	0.02	–	–
MH	HR	–	–	0.18	1.31*
MH	KR	−0.42*	0.02	0.14	0.87*
MH	MP	−0.08	0.66*	−0.24	0.64*
MH	RJ	–	–	−0.40	0.83
MH	WB	−0.37*	0.36*	–	–
MP	BR	−0.39*	0.01	–	–
MP	HR	–	–	0.38	1.13*
MP	RJ	–	–	−0.49	0.16
MP	WB	–	–	0.19	1.42*
RJ	BR	–	–	0.43	0.12
RJ	HR	−0.11	1.93	0.54	1.36*
RJ	KR	−0.27	0.20	0.77	1.26*
RJ	WB	0.03	0.51*	–	–

Note *Significant at 5%. ECM is standardized in State I. Sub-Period-I: 2010:04 to 2014:03, Sub-Period-II: 2014:04 to 2016:12
Source MoA&FW (various), DES, Website

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