Has Open Innovation Taken Root in India? Evidence from Startups Working in Food Value Chains

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Abstract

Open innovation represents a paradigm shift in the technology development process in the New Millennium with potential positive implications for helping the food system in addressing grand challenges formalized through the SDGs. Though evidenced mainly in technology-intensive sectors of developed countries, several ‘erosion factors’ and their interplay catalyse open innovation in relatively traditional sectors of developing countries. The rise of startups with supplementary venture capital industry is hypothesized to play this role in the Indian food system. Our paper examines this hypothesis by leveraging a large database of startups. Several types of startups have come up in the last decade and are introducing innovations, apart from filling the gaps in the food value chains in infrastructure-deficit regions. It classifies the startups working in food value chains based on the main purpose of each of its functioning, though there can be several interventions at different nodes of the value chain and overlap of functions. The interconnections between startups themselves and their business partnerships with input companies, processors, aggregators, traders, hotels and restaurants, supermarkets, e-commerce companies, research organizations, various governments, international institutions like the World Bank and various crop associations like the tea growers association constitute a complex web. The knowledge flows are both outbound from the startups to the companies and other actors and sometimes in the opposite direction as well as bi-directional. These fast expanding knowledge flows have brought several innovations that could not be imagined just a few years back in developing countries. The emergence of open innovation bodes well to food value chain flows and to harness the higher level of technologies. There is a need to internalize these innovations in the national food policy for addressing issues of inclusion. The paradigm shift also calls for rigorous research on the business models and collaboration and licensing agreements between companies, universities, and governmental agencies.

Keywords Open innovation · Startups · India · Food system · Knowledge flows
Introduction

Open innovation has been permeating every field of economic activity all over the world in the last two decades, more consciously and as a planned development process, after the word ‘open innovation’ was coined and formalized as a new paradigm of creating and profiting from technology by Chesbrough [1] in his celebrated book entitled Open Innovation: The New Imperatives for Creating and Profiting from Technologies. Initially, he called it the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively [2]. As the learning curve moved up with intensive debates and extensive applications after the first decade, more details are added to say that open innovation is ‘a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization’s business model’ [3].

The knowledge flows leading to open innovation can be outside or outbound depending on the needs of innovation and the business models of the respective actors. While initial evidence showed that primarily the large companies initiate and move the process forward, the subsequent experience proved that small- and medium-sized companies including startups, non-profit foundations, collective community actions and individual consumers can also catalyse significant transformations [4–6].

The objectives of this paper are to examine the relevance of open innovation in food system in a developing country context and then to analyse startup operations empirically with main focus on resulting innovation and some focus on the knowledge flows. It employs an open innovation framework to understand the operations of a large number of agri-tech startups in India across various activities to fully make sense of their activities in totality. It classifies the startups working in food value chains based on the main purpose of each of its functioning, though there can be several interventions at different nodes of the value chain and overlap of functions. Then, it analyses the innovations and brings out salient features including the level of investments. It harnesses a large database of startups from Tracxn Technologies Pvt Ltd. and also collates with other published as well as news items in business dailies. Being an exploratory study on this evolving ecosystem, this paper confines to the broad delineation of the functions and interoperability mechanisms without going deeper into the technological products and associated marketing strategies.

Open Innovation in Food System to Address SDGs

This organization of innovation with multiple actors across multiple sectors is initially hypothesized to occur only in economic activities having high level of sophistication and complex processes [3]. However, the evolving experience in disparate industries showed that this can have traction in relatively conventional industries too [7, 8]. As the volume of transactions in midstream and downstream of food value chains reached two-thirds magnitude in most of the world [9] including India [10], the ramping up of technology with newer innovations has been spurring transitions in the food industry. Open innovation arises in food system because of the multiple actors in the long chains with heterogeneous needs [11] and an assortment of technologies required to produce changing consumer demands [12]. The convergence of findings can also be seen in studies in agricultural economics showing the diffusion of innovations across all the actors in the entire chain when the processing firms bring in new technologies [13]. However, the new paradigm goes beyond joint diffusion and involves heterogeneous actors in both the development and diffusion of innovations.
Startups specifically need external knowledge sources given the scarcity of internal resources and competencies (Di [14]). The food system is ideally suited to combine the knowledge specificities of many actors including startups in the open innovation framework ([15], pp 109-110). Moreover, food system is crucial in achieving grand challenges of the contemporary world like hunger, malnutrition, poverty, inequalities and climate change—all combined as Sustainable Development Goals (SDGs) with specific targets to be achieved by 2030 [16]. It is worth noting that food production activities account for 40% of the land use, 30% of greenhouse gas emission and 70% of fresh water usage on the planet. In other words, food system has the onerous task of dealing with some of the problems of its own production system as well as provide solutions to the grand challenges mentioned above [17]. However, governments around the world lack the political will as well as the means to pump in necessary financial resources for this task. Bogers et al. [18] demonstrate empirically how sustainable open innovation methods prove useful in generating public private partnerships in dealing with sustainability issues simultaneously with profit motives. This synchronized targeting of financial, social and environmental goals is in line with the recent developments in sustainability and related concepts such as the circular economy as envisaged in Geissdoerfer et al. [19].

Open innovation 4.0 that combines firms, institutions, government, civil society, end users and machines is possible through coordinated and collaborative effort of multiple actors in food system and beyond in co-creative and co-sharing innovation processes [20]. It also helps in adopting a long-term perspective oriented to close, slow, intensify, dematerialise and narrow resource loops and in that sense achieves circular business model goals as explained by Tunn et al. [21]. Reducing food waste through the innovations of startups slows the resource loops, while startups offering mechanization services intensify the resource loops by reducing the need to own the machines. Leveraging cutting-edge digital technologies like IoT, AI and cloud computing dematerializes the resource loops. Finally, startups coming up with smart solution for precision agriculture in smallholder farming in India drive down resource use and narrow the resource loops. Several of these initiatives by startups are discussed in the next section. These startups can exploit the opportunity of co-creation of co-sharing with other actors in the food value chain including the large companies, institutions, policymakers, civil society and end users. Startups have been proliferating across the countries not only in the developed, but also in the developing countries of Asia, Africa and Latin America [22, 23]. As growth accelerates with large software exports and consequent cultural attitudes change facilitating willingness to fail among youth, the last decade witnessed entry of a large number of these micro-firms in India [24–26]. It is by now well-known that entrepreneurial micro-firms called startups have the potential to bring in innovations to address the gaps in production and marketing of goods and services [27–30]. Harnessing the rapidly developing cutting-edge technologies in the information and communication revolution including machine learning, Internet of things (IoT), deep learning, big data analytics, blockchain technologies and so on [31–35] has been made possible by the explosion of startups in India. These startups are hypothesized to bring open innovation through new business models in association with established companies and other players [36, 37].

Nature of Innovations in Food Value Chains with Startups and Implications

Several types of startups have come up in the last decade that are filling the gaps in the food value chains in infrastructure-deficit regions of the country. Farmers in developing countries
face multiple risks on several fronts [38], and these startups endeavour to address them using
new generation tools of information and communication technologies. Many of these startups
in India operate in tandem with various other related companies in downstream with the
supermarkets, retailers and hoteliers; in the midstream with the processors, wholesalers and
logistic firms; and in the upstream with the input companies; and so on. It is here the open
innovation framework is employed to discern the nature of emerging innovations and their
diffusion through an inbound and outbound as well as bi-directional knowledge flows as
shown by Bogers et al. [39]. An effort is made to classify them based on their main line of
activity, though they can have other initiatives too so that the nature of arising startup
initiatives can be analysed to unravel the mechanisms of knowledge flows for innovation.
The six broad categories of startup innovations identified are those providing output market
linkages; facilitating input supply; enabling mechanization, irrigation control and financial
support; helping in quality maintenance, monitoring, traceability and output predictions
(software as a service [SaaS]); post-harvest management and farming as a service (FaaS);
and those supporting animal husbandry farmers. All these groups are discussed below with
more details and analysis with interconnections. Finally, the nature of knowledge flows
leading to the complicated web of open innovation networks is examined.

Output Market Linkages

Accumulated evidence shows that reducing the chain of intermediaries between the farmer-
producer and consumer can benefit the former through higher price realization [40–42]. A
large number of startups focus on innovations for linking the farmers in far-flung areas with the
buyers of their produce (Table 1). The important players among them include Udaan, BigBasket, Swiggy, Zomato, Grofers, Ninjacart, WayCool, ZopNow, ShopKirana, Jumbotail, DeHaat, AgriBazaar, Bijak, Farmpal and MilkBasket. The first five of these startups are
unicorns involved in direct procurement from farmers and selling to other supermarket chains
and other downstream actors. Udaan is the fastest-growing B2B full-stack platform dealing in
several items like electronics, garments, footwear, kitchen and home appliances along with
staples and fruit and vegetables [43]. Despite being the direct sellers of food, the other four
unicorns, viz. BigBasket, Grofers, Swiggy and Zomato, engage directly with the farming
community and procure through their own collection centres. By September 2020, large
investments are attracted by these startups to the tune of 5.5 billion USD, which is invested
in building the long-neglected modernization of the value chains as well as for associated
innovations. Significant investments are in Swiggy (1.6 billion), Zomato (972 million),
BigBasket (1.02 billion) and Udaan (900 million). Some of the other startups raising consid-
erable investments include Grofers (548 million USD), Ninjacart (163 million), WayCool (66
million), Jumbotail (25 mn) and Bijak (15 mn).

While BigBasket has been procuring directly from the farmers for the last several years
[44], several startups embarked on direct procurement in recent years, and the quantities are
significant and increasing. For example, Udaan is procuring fruits and vegetables in Delhi and
Karnataka and dealing with a quantity of 500 tons per day, apart from 5000 tons of staples
[43]. Ninjacart supplies fresh produce to Flipkart for its Flipkart Quick and deals with 1500
tons a day [45]. Zomato acquired Bangalore-based WOTU in 2018 and renamed as ‘Hyper-
pure’ for starting direct procurement from farmers through operations in B2B foodtech space
[46, 47], while Swiggy entered hyperlocal grocery delivery recently and is also procuring from
farmers directly [48]. Leveraging e-mandi model, Agribazaar works with 200,000 farmers and
Table 1  Startups leveraging innovative fork-to-farm model to connect farmers with output markets through direct procurement from farmers in villages along with a host of services

| Startup name               | Overview                                                                 | Founded year | City       | Funding Mn. USD | Company stage | Revenue Mn. USD |
|----------------------------|---------------------------------------------------------------------------|--------------|------------|-----------------|---------------|----------------|
| Bigbasket (unicorn)        | Online marketplace of grocery products                                   | 2011         | Bangalore  | Yes             | Series F      | 366.077        |
| Zomato (unicorn)          | Online platform enabling food ordering and delivery                      | 2008         | Gurgaon    | Yes             | Series J      | 169.140        |
| Swiggy (unicorn)          | Online platform for food ordering and delivery                            | 2014         | Bangalore  | Yes             | Series I      | 159.332        |
| Udaan (unicorn)           | Online B2B marketplace for multi-category products                       | 2016         | Bangalore  | Yes             | Series D      | 7.760          |
| Grofers (unicorn)         | Online retail store offering groceries                                   | 2013         | Gurgaon    | Yes             | Series F      | 11.121         |
| Ninjacart (soonicorn)      | App-based B2B platform offering vegetables and fruits                    | 2015         | Bangalore  | Yes             | Series C      | 17.110         |
| WayCool (soonicorn)        | E-distributor of farm products                                           | 2015         | Chennai    | Yes             | Series C      | 22.693         |
| ZopNow (soonicorn)         | Online grocery platform with a 3-h delivery promise (acquired by More and Amazon) | 2011     | Bangalore  | Yes             | Series A      | 2.943          |
| Agrevolution (DeHaat)      | Provider of end-to-end farming services to the farming communities       | 2012         | Patna      | Yes             | Series A      | 5.417          |
| Bijak                     | Online B2B marketplace to trade agriculture commodities                 | 2019         | Gurgaon    | Yes             | Series A      | 5.417          |
| Jumbotail                 | Online B2B platform for packaged food, fruits and vegetables             | 2015         | Bangalore  | Yes             | Series B      | 29.233         |
| ShopKirana                | Mobile-based B2B marketplace for groceries                                | 2015         | Indore     | Yes             | Series B      | 3.011          |
| Otipy                     | App-based platform offering fruits and vegetables                        | 2019         | Delhi      | Yes             | Seed          | 0.000          |
| Kisan Network             | B2B marketplace for farmers, bulk buyers                                  | 2015         | Delhi      | Yes             | Seed          | 0.867          |
| Crofarm                   | Digital supply chain of fruits and vegetables from farm to business      | 2016         | Gurgaon    | Yes             | Seed          | 1.476          |
| Aibono                    | Services for farm data collection and analytics and mobile appln.        | 2013         | Bangalore  | Yes             | Seed          | 0.244          |
| Clover Ventures           | Provider of supply chain solution for fruits and vegetables              | 2017         | Bangalore  | Yes             | Series A      | 0.148          |
| Teabox                    | Online retailer of tea                                                   | 2012         | Bangalore  | Yes             | Series B      | 2.689          |
| Satvacart                 | Online platform offering multi-category grocery products                 | 2014         | Gurgaon    | Yes             | Seed          | 0.184          |
| Tokri                     | Online platform to buy fresh produce and groceries                       | 2014         | Pune       | Yes             | Seed          | 0.056          |
| Milkbasket                | Subscription-based daily need items delivery (milk and F&V)             | 2015         | Gurgaon    | Yes             | Series B      | 10.349         |
| Farmpal                   | Online platform delivering farm produce to businesses                    | 2017         | Pune       | Yes             | Seed          | 0.179          |
| MeraKisan                 | Online marketplace that connects consumers with local farmers            | 2014         | Pune       | Yes             | Seed          | 0.819          |
| VNF                       | Online platform to purchase fruits and vegetables                        | 2018         | Mumbai     | Yes             | Seed          | 0.423          |
| Inl Farms                 | Provider of farming services to horticulture industries                  | 2009         | Mumbai     | Yes             | Series A      | 14.404         |
| FarmTaaza                 | Manages supply chain of fruits and vegetables from farm to business      | 2015         | Bangalore  | Yes             | Series A      | 10.693         |
| Daily Ninja               | Hyper-local subscription-based delivery service (acquired by Big Basket) | 2015         | Bangalore  | Yes             | Acquired      | 0.414          |
| Smerkato                  | Online B2B platform offering multi-category grocery products             | 2016         | Bangalore  | Yes             | Funded        |               |
| GeeCom                    | Online E-commerce platform offering agricultural products and supplies    | 2018         | Indore     | No              | Unfunded      |               |
| Startup name       | Overview                                                                 | Founded year | City    | Funding Mn. USD | Company stage | Revenue Mn. USD |
|-------------------|--------------------------------------------------------------------------|--------------|---------|----------------|---------------|----------------|
| Mn. USD            |                                                                          |              |         |                |               |                |
| Farmley           | Online platform linking farmers with customers (earlier called Technify Biz) | 2016         | Delhi   | Yes            | Funded        | 1.683          |
| KiranaMonk        | App-based B2B marketplace offering farm produce                          | 2018         | Sonipat | No             | na            | Unfunded 0.000 |
| Atomaday          | App-based video shopping platform offering fruits and vegetables         | 2017         | Bangalore | No             | na            | Unfunded        |
| GreenNGood        | Online retailer of organic products                                       | 2012         | Jaipur  | Yes            | na            | Funded          |
| Organofresh Solutions | B2B wholesaler of fruits and vegetables                              | 2017         | Chandigarh | No             | na            | Unfunded        |
| Farmcon           | Online B2B marketplace for agriculture products                          | 2017         | Pune     | No             | na            | Unfunded 0.874 |
| LivLush           | B2B platform to procure fresh fruits and vegetables(Sabziwala and LivLush merged as Kamatan) | 2016         | Bangalore | Yes            | na            | Series A 0.874 |
| Brownsoil         | Online B2B platform offering farm produce                               | 2018         | Bangalore | No             | na            | Unfunded 5.531 |

Source: Compiled from Tracxn database as of February 2020

Note: Seed funding, first equity funding usually by angel investors to finance its first steps including market research and product development; series A, usually by venture capital firms to further optimise its user base and product offering by putting in place a business model for marketing the ideas; series B is to expand market reach by expanding the team to meet the levels of demand; series C, to develop new products, expand into new markets or acquire new companies and prepare for IPO; series D, to increase value before going to IPO or to remain private for longer; startups that are successful but not making enough revenues to be self-sustainable go to later stages of funding like series E, F, G, H and above. Funded indicates lack of information on stage of funding, though the startup received some funding. Unfunded indicates not receiving any outside funding other than family, friends and personal supporters.
connects them with procurement agencies and food processing companies like Britannia and AgroPure at no cost, though it collects transaction fees from buyers [49]. DeHaat, based on the franchise model, connects farmers with traders, institutional financiers and buyers like Reliance Fresh, Zomato and Udaan on one platform in 20 regional hubs in eastern India and serves 210,000 farmers [50]. It is noteworthy that several of the active startups work in the states with poor agricultural marketing infrastructure in central and north India. While several startups fail to survive or make it to the bigger leagues, some are acquired by bigger companies. For example, ZopNow was acquired by More and later Amazon; FarmTaaza by WayCool and DailyNinja by BigBasket. Pivoting from B2C to B2B, as done by Ninjacart, WayCool, has been a trend recently, and B2B startups seem to get higher funding chances relatively [51].

**Startups Facilitating Input Supply**

Several studies showed that availability and quality of inputs to the farmers are a serious problem impinging productivity and profitability of farmers, where fly-by-night operators make quick money by selling spurious seeds, fertilisers and pesticides [52]. The transformation of input industries and delivery systems is critical in this regard [53].

Several startups have been offering solutions to optimize the use and enable the delivery of assured quality inputs to farmers (Table 2). These online services have been of particular help in the times of pandemic to follow social distancing and purchase inputs from home using smartphone. Agrostar is the largest startup in input supply to farmers and is expected to be a unicorn soon. It has mobilized 47 million USD in funding and reached series C funding so far. It has been serving farmers in Gujarat, Maharashtra and Rajasthan with 400,000 active users and one million downloads of its app. By partnering with leading national and multinational companies to sell their products through AgroStar, it enables farmers in buying seeds, nutrients, crop protection as well as hardware products from its platform and app [54]. Similar services are provided by BigHaat, Khetinext, Gramophone and several others. Many of them combine input provision with agri-advisory and other services.

**Startups for Mechanization, Irrigation and Financial Services**

Farming in the Indian context has been becoming difficult for lack of suitable equipment especially for small farmers, enormous drudgery in irrigation fields, wastage of water and lack of financial services. Startups have been filling these gaps and operating efficient services across the length and breadth of the country (Table 3). Several startups focus on mechanisation of farming activities through renting easy to use machines or aggregating companies that can rent machines. FarMart, EM3 Agri Services, M.I.T.R.A and others have been providing these services at a lower cost, and some of them are finding good traction among farmers [55]. Sickle innovations, Distinct Horizon, Tractor Junction, Khetibadi and J Farm service are some of the other startups in mechanization services. Kamal Kisan develops farm equipment for small farm owners to reduce labour dependence and has rental services in Karnataka, Jharkhand and Andhra Pradesh [56].

Some of them focus on the accurate and timely assessment of soil moisture and developing data-driven controlled irrigation models (Table 3). Kisan Raja is an innovative device that allows farmers to remotely control the irrigation motor using their mobile or landline and used by 34,200 farmers in India [57], apart from being harnessed by the World Bank for a project on saving water in rice. Bangalore-based FlyBird installs sensors in the soil to detect moisture content and controls irrigation at a low cost to the farmers, and this can be of use especially for
| Company name          | Overview                                                                 | Founded year | City       | Funding | Total funding Mn USD | Stage | Annual revenue Mn USD |
|----------------------|--------------------------------------------------------------------------|--------------|------------|---------|----------------------|-------|------------------------|
| Agrostar (soonicorn) | Online platform offering agri-inputs, content and advice                | 2008         | Pune       | Yes     | 47.183               | Series C | 11.618                 |
| Khethinext           | Mobile app that enables procurement of farm inputs and provides information | 2017         | Hyderabad  | Yes     | 5.386                | Series A | na                     |
| Gramophone           | App-based platform providing farm input products and information to the farmers | 2016         | Indore     | Yes     | 8.062                | Series A | 0.578                  |
| Marut Drones         | Provides drone-based precision agriculture services                      | 2019         | Guwahati   | Yes     | 0.100                | Seed   | na                     |
| LeanAgri             | Technology solutions for farmers                                         | 2017         | Pune       | Yes     | 0.567                | Seed   | 0.093                  |
| BharatAgri          | Platform that provides crop management solutions for farmers             | 2017         | Pune       | Yes     | 1.292                | Seed   | 0.093                  |
| BigHaat              | Online marketplace offering farm inputs                                  | 2015         | Bangalore  | Yes     | 2.570                | Seed   | 0.104                  |
| A-One Seed           | Online B2B marketplace of seeds                                          | 2019         | Hisar      | No      | na                   | Unfunded | na                     |
| Terra Agro Biotech   | Manufacturer and supplier of biological farm inputs                      | 2016         | Jaipur     | No      | na                   | Unfunded | na                     |
| AgriApp              | Online marketplace for agriculture farm inputs                           | 2016         | Bangalore  | Yes     | na                   | Funded  | na                     |
| SmartFarms           | Online B2B distributor of agricultural input products                    | 2019         | Gurgoan    | Yes     | na                   | Seed   | na                     |
| FarmGuru             | Online platform for group buying of farm inputs                          | 2015         | Pune       | No      | na                   | Unfunded | na                     |
| Behtar Zindagi       | Online marketplace for agri supplies                                     | 2016         | Delhi      | No      | na                   | Unfunded | na                     |
| Unnati               | Unnati                                                                    | 2016         | Noida      | Yes     | 0.452                | Seed   | 10.129                 |

Source: Compiled from Tracxn database as of February 2020

Note: Seed funding, first equity funding usually by angel investors to finance its first steps including market research and product development; series A, usually by venture capital firms to further optimise its user base and product offering by putting in place a business model for marketing the ideas; series B is to expand market reach by expanding the team to meet the levels of demand; series C, to develop new products, expand into new markets or acquire new companies and prepare for IPO; series D, to increase value before going to IPO or to remain private for longer, startups that are successful but not making enough revenues to be self-sustainable go to later stages of funding like series E, F, G, H and above. Funded indicates lack of information on stage of funding, though the startup received some funding. Unfunded indicates not receiving any outside funding other than family, friends and personal supporters.
high-value crops [58]. There are others like Intech Harness that provide solutions for water pump controller and Sense It Out, Kritssnam, Agrirain, Manna Irrigation.

As we move from traditional marketing services to modern marketing channels, the lack of support structures to provide handholding through credit is a handicap for the farmers. Some of the startups resolve this issue by making credit available in a transparent online procedure at lower rates of interest, along with other services. Apart from Jai Kisan, SG Agtech and Safal Fasal shown in Table 3, there are others like Samunnati, FarMart, PayAgri, Kissht, SatSure, Farmguide and Niruthi. GramCover acts an insurtech platform too. Some of the startups with market linkage also provide loans. For example, there are the startups like Udaan, Bijak and Clover.

**Startups for Quality Maintenance, Monitoring, Traceability and Output Predictions**

Several innovative products have been developed and popularised by startups in this area for quality assaying, quality maintenance through advisories, traceability and yield predictions through mobile imagery, digitization and advanced software (Table 4). One of the most popular startups in this category seems to be CropIn that has clients in 30 countries and chosen by the World Bank as a project on sustainable livelihoods and adaptation to climate change. Basically a farm-to-fork traceability business model, it collects information from various sources like weather, satellite and ground data and delivers targeted solutions to the agribusinesses on a B2B model and at the same time has a unique farmer application for the companies to interact directly with the farmers [59]. The Government of India has also roped in CropIn to streamline crop cutting experiments¹ and their accuracy.

Saas startups such as Intellolabs, Agricxlab, qZense and Raav Techlabs focus on quality assessment of agri-commodities. Intellolabs developed an app to test, grade and analyse the visual quality parameters of agri-commodities to enable better prices for the farming community and had been working with the Government of Rajasthan to grade grains in mandis [60]. Agricxlab harnessed deep learning technology to grade a gri-commodity and certify in 30 s and acts as a bridge between cold storages and procurement companies [61]. On the other hand, women entrepreneurs who founded qZense employs a unique combination of near-infrared spectral sensors and olfactory sensors for analysis of internal spoilage, ripeness, sweetness and shelf life that can be used at any stage of the supply chain. However, it was initially deployed by retailers to gauge and maintain quality for driving down inventory losses and spur margins [62]. Soil and groundwater sensing and analytics products are brought out by OneWater, while an innovative paddy quality tester for rice mills came out from AmviCube. Another useful innovation is by Krishitantra from Udupi, Karnataka, for rapid soil testing in 35 min, and that can be shared in cloud and SMS with advisory. Cheruvu also enables soil testing facilities and advisory along with comparisons to neighbour’s field. TartanSense developed technologies to assess the health of plants through drone imageries.

The game-changing precision agriculture technologies, using advanced analytics and prediction platforms, are supposed to be the exclusive preserve of top six companies and likely to be bypassed for the developing world [63]. However, startups enter this segment of the value chain and make them possible through their innovations at a cost-effective manner for the smallholder farmers in developing country contexts such as in India. Precision agriculture solutions are provided by

¹ Large number of crop-cutting experiments are conducted every year in the country to estimate the productivity and production of crops. The quality of these experiments has been questioned by many scholars including the National Statistical Commission.
| Company name | Overview | Founded year | City | Funding stage | Total funding Mn. USD | Company stage | Annual revenue Mn. USD |
|--------------|----------|--------------|------|---------------|-----------------------|--------------|-----------------------|
| **Mechanization** | | | | | | | |
| FarMart | Web and mobile-based application for renting farm equipment | 2015 | Gurgaon | Yes | 0.740 | Seed | 0.035 |
| EM3 Agri Services | Provider of farming services to the farming communities | 2013 | Noida | Yes | 17.022 | Series B | 1.174 |
| RAVGO | Digital farm and construction equipment rentals marketplace | 2015 | Gurgaon | No | na | Unfunded | na |
| JFarm Services | Online marketplace platform for equipment rental | 2017 | Chennai | No | na | Unfunded | na |
| Tringo | Mobile-based app offering farming equipment on rent | 2016 | Mumbai | No | na | Unfunded | 0.240 |
| **Irrigation** | | | | | | | |
| FlyBird Innovations | Manufactures irrigation controllers | 2013 | Bangalore | Yes | 0.223 | Seed | 0.066 |
| Intech Harness | Provider of an IoT-based automated water pump controller | 2018 | Pune | Yes | na | Funded | na |
| Sense It Out (F6s) | IoT controller for greenhouse management deployed as a service | 2015 | Pune | Yes | na | Funded | na |
| KisanRaja | Technology solutions for agriculture | 2006 | Bangalore | No | na | Unfunded | na |
| Satyukt | Data and analytics solutions for earth observations | 2018 | Bangalore | No | na | Unfunded | na |
| Kritsnam | IOT-based solutions for water monitoring and management | 2015 | Kanpur | Yes | 0.0701 | Seed | na |
| **Financial services** | | | | | | | |
| Jai Kisan | Online supply chain platform for farmers | 2017 | Mumbai | Yes | 6.0140 | Seed | 0.098 |
| SG Agtech Innovations | Online platform for providing digital and financial solutions to farmers | 2018 | Chennai | No | na | Unfunded | na |
| Safal Fasal | Online marketplace for agricultural products | 2019 | Mumbai | No | na | Unfunded | na |
| Jai Kisan | Online supply chain platform for farmers | 2017 | Mumbai | Yes | 6.014 | Seed | 0.098 |
| Niruthi Technologies | Location-specific crop monitoring and yield prediction solution provider | 2005 | Hyderabad | No | na | Unfunded | 0.341 |
| Gramcover | Insurance marketplace focused on rural areas | 2015 | Noida | Yes | 1.181 | Seed | 0.318 |
| SatSure | Data services for crop health monitoring and assessment | 2016 | Bangalore | Yes | na | Funded | 0.03 |
| Company name | Overview                                                                 | Founded year | City       | Funding | Total funding Mn. USD | Company stage | Annual revenue Mn. USD |
|--------------|---------------------------------------------------------------------------|--------------|------------|---------|-----------------------|---------------|------------------------|
| PayAgri      | Online platform to bring cashless ecosystem in Agriculture                | 2017         | Chennai    | Yes     | 0.348                 | Seed          | 0.01                   |
| Farmguide    | Digitizing agri supply chain and services                                 | 2014         | Gurgaon    | Yes     | 15.708                | Seed          | 0.157                  |
| AgRisk Tech  | Core banking, payments, transaction banking and financial inclusion solution provider | 2009         | Mumbai     | No      | na                    | Unfunded      | na                     |

Source: Compiled from Tracxn database as of February 2020

Note: Seed funding, first equity funding usually by angel investors to finance its first steps including market research and product development; series A, usually by venture capital firms to further optimise its user base and product offering by putting in place a business model for marketing the ideas; series B is to expand market reach by expanding the team to meet the levels of demand; series C, to develop new products, expand into new markets, or acquire new companies and prepare for IPO; series D, to increase value before going to IPO or to remain private for longer; startups that are successful but not making enough revenues to be self-sustainable go to later stages of funding like series E, F, G, H, and above. Funded indicates lack of information on stage of funding, though the startup received some funding. Unfunded indicates not receiving any outside funding other than family, friends and personal supporters.
| Company name     | Overview                                                                 | Founded year | City       | Funding stage | Total funding Mn.USD | Company stage | Annual revenue Mn.USD |
|------------------|---------------------------------------------------------------------------|--------------|------------|---------------|----------------------|---------------|-----------------------|
| CropIn           | Provider of SaaS-based farming solutions to agribusinesses               | 2010         | Bangalore  | Yes           | 15.624               | Series B      | 1.623                 |
| Intello Labs     | Image recognition–based solutions for multiple industries                | 2016         | Bangalore  | Yes           | 8.751                | Series A      | 0.157                 |
| FarmERP          | Software suite for control over farm operations and traceability         | 2005         | Pune       | Yes           | 14.389               | Series A      | 0.312                 |
| Jivabhumi        | Connecting consumers to farmer groups/cooperatives. Uses blockchain      | 2015         | Bangalore  | Yes           | na                   | Funded        | 0.316                 |
| Agricx           | Provider of AI-based stack solutions for grading                        | 2016         | Thane      | Yes           | 0.775                | Seed          | 0.0411                |
| qZense Labs      | Provider of an IoT device for food quality check for grading             | 2019         | Bangalore  | Yes           | 0.254                | Seed          | na                    |
| AgNext           | Platform for monitoring and improving agricultural food quality for      | 2016         | Mohali     | Yes           | 4.337                | Seed          | 0.097                 |
| RAAV Techlabs    | Provider of AI-powered food quality analysers                           | 2018         | Delhi      | na            | Funded               | na            | 0.001                 |
| OneWater         | Soil and groundwater sensing and analytics product                       | 2015         | Ahmedabad  | No            | na                   | Unfunded      | na                    |
| Amvicube         | Developer of paddy quality tester for rice mills                         | 2014         | Raichur    | Yes           | na                   | Funded        | na                    |
| Amnex            | Provider of precision agriculture solutions                               | 2008         | Ahmedabad  | Yes           | na                   | Funded        | 18.783                |
| AS Agri Systems  | Develops integrated hardware and software platform for precision         | 2017         | Bangalore  | No            | na                   | Unfunded      | na                    |
| BKC              | Precision agriculture solutions provider                                  | 2018         | Delhi      | No            | na                   | Unfunded      | na                    |
| Aggregator       | Provides smart agriculture solutions                                     | 2019         | Gandhinagar| Yes           | na                   | Funded        | na                    |
| NEERx Technovation| Provides smart agriculture solutions                                      | 2019         | Gandhinagar| Yes           | na                   | Funded        | na                    |
| RML AgTech       | Online portal for agriculture information sharing                        | 2007         | Mumbai     | Yes           | 4.000                | Series A      | 0.779                 |
| FarmBee          | Online platform providing data-driven agricultural solutions             | 2006         | Pune       | Yes           | 9.099                | Seed          | 0.560                 |
| MyCrop Technologies| Provider of information, expertise and resources for agriculture sector  | 2016         | Ahmedabad  | Yes           | na                   | Funded        | na                    |
| Agrojay          | Online information dissemination platform for agriculture farmers        | 2019         | Nashik     | No            | na                   | Unfunded      | na                    |
| Namma            | Online agriculture information dissemination platform for farmers        | 2018         | Coimbatore | No            | na                   | Unfunded      | na                    |
| Uzhavan          | Crop quality assessment system                                           | 2016         | Jaipur     | Yes           | 0.295                | Seed          | 0.141                 |
| Nebulaa's Matt   | Crop quality assessment system                                           | 2016         | Jaipur     | Yes           | 0.295                | Seed          | 0.141                 |
| TartanSense      | Analysing health of plants using drones                                  | 2015         | Bangalore  | Yes           | 2.139                | Seed          | 0.002                 |
| Yuktix           | Technology sensor products for remote monitoring and control of devices | 2013         | Bangalore  | Yes           | 0.133                | Seed          | 0.077                 |
| Fasal            | AI-powered IoT platform for precision agriculture                       | 2018         | Bangalore  | Yes           | 1.720                | Seed          | na                    |
| Blooom           | AI-powered IoT platform for precision agriculture                       | 2009         | Delhi      | No            | na                   | Unfunded      | na                    |
| Company name | Overview                                                                 | Founded year | City     | Funding | Total funding Mn.USD | Company stage | Annual revenue Mn.USD |
|--------------|---------------------------------------------------------------------------|--------------|----------|---------|-----------------------|---------------|---------------------|
| Skymet Weather | Crop insurance and weather forecasting data services                      | 2003         | Noida    | Yes     | 11.768                | Series C      | 5.827               |

Source: Compiled from Tracxn database as of February 2020

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software platforms of Amnex, AS Agri Systems, BKC Aggregator and NeerX Technovation. Agricultural information sharing has few startups attending, and they include RML Agtech, FArmBee, MyCrop Technologies, Agrojay and Namma Uzhavan. Crop yield predictions are facilitated by Fasal, Yuktix, Bloom and Skymet. Many of these startups leverage satellite images to geotag farms, assess crop health and estimate output. Fasal captures real-time data on growing conditions from on-farm sensors and delivers farm-specific, crop-specific actionable advisories to farmers via mobile in vernacular languages. Likely to be unicorn soon is SourceTrace that operates in 26 countries with a digital platform to capture information regarding agriculture, financial services and retail through existing mobile and wireless networks in developing economies and also a two-way interactive digital platform [64].

**Startups for Postharvest Management and Farming as a Service**

As the value chains become elongated with nearly two-thirds of food being consumed in urban areas in India [10], the requirements for processing, logistics, wholesaling and associated services have been increasing over the past few decades. Startups have been crucial in the segment of logistics with several of them acting as third-party logistic partners for other startups as well as established food companies like Britannia and several others. Apart from that, few startups made innovative products for cold storage and saving the produce from post-harvest damage before being transported. Table 5 examines the startups in midstream of the value chain.

The solar-powered small-size cold storage unit of Ecozen Solutions and low-cost storage cum transportation solution called Sabjikothi, developed by Saptakrishi, for extending shelf-life of vegetables from 7 to 30 days have tremendous potential to cover the shortcomings for smallholder farmers. Another area many startups have been playing a considerable role in is storage of agri-produce. In a country where it is estimated that there is storage gap of around 35%, their role can play a crucial role in reducing food damage. A2Z Godaam of Arya Collateral is foremost among them. It is a digital platform for the search, discovery and fulfillment of warehousing for farmers, FPOs, corporate and other stakeholders. It goes beyond storage by integrating with other services like financial and market linkages [65]. Similar post-harvest services are provided by another startup called Origo with 3.5 million tons of storage capacity in 500 warehouses across 15 states.

Farming as a service (FaaS) has been growing with several urban people wishing to engage in the cultivation of fruits and vegetables often in organic modes on the one hand and on the other several smallholders wishing to have support in several related services to make their farming profitable. Several startups have been testing this area and seem to get a good response. Farmizen and Hoshachiguru provide mini-farms to be rented by prospective cultivators and can also opt to take services from them for technically sound and cost-effective cultivation [66]. These startups collect rent and also fee for their services. On the other hand, startups like Vegrow and EMB partner with smallholders for profitable cultivation that might also lead to the aggregation of fragmented farms for achieving economies of scale [67]. Rooftop gardening by Khetify, indoor hydroponics by Agro2o and end-to-end farm enabling services for greenhouses by Kheyti represent the other emerging areas for startup ventures.

**Startups for Farmers in Animal Husbandry**

The animal husbandry sector, with one-third of the gross value added in the agriculture, does attract startup ventures though not in proportion to its contribution to value added and support to smallholder cultivators (Table 6). The leaders in this segment are Licious and FreshtoHome that
| Company name                        | Overview                                                                 | Founded year | City        | Funding Total funding | Company stage | Annual revenue |
|-------------------------------------|---------------------------------------------------------------------------|--------------|-------------|-----------------------|---------------|---------------|
| **Post-harvest management**         |                                                                           | **Overview** | **Founded** | **Funding** | **Company** | **Annual**   |
| Ecozen Solutions                    | Manufactures and supplies solar-powered irrigation pump controllers      | 2009         | Pune        | Yes                    | Series A      | 9.800         |
| SaptaKrishi (Sabjikothi)            | Provider of a micro-climate storage solution for farmers                 | 2018         | Kanpur      | na                     | Funded        | na            |
| New Leaf Dynamic Technologies       | Off-grid refrigeration                                                  | 2012         | Delhi       | Yes                    | na            | na            |
| AgriGator                           | Provider of agricultural logistics platform connecting grain shippers and carriers | 2019         | Bhopal      | Yes                    | Funded        | na            |
| Star Agriwarehousing & Collateral Management | Agricultural warehousing and post-harvest supply chain solutions            | 2006         | Mumbai      | Yes                    | Series C      | 42.600        |
| Arya Collateral Warehousing Services | Warehousing and collateral management services for agri-commodities       | 1982         | Noida       | Yes                    | Series A      | 11.956        |
| **Farming as a service (FaaS)**     |                                                                           |              |             |                        |               |               |
| Farmizen                            | Develops and operates digital application for community-supported farming | 2017         | Bangalore   | Yes                    | Seed          | 0.047         |
| Triton Foodworks                    | Integrated business for soil-less cultivation of fruits and vegetables and supply of produce | 2014         | Delhi       | na                     | Seed          | na            |
| Agro2o                              | Manufacturer and supplier of indoor hydroponics system                    | 2017         | Delhi       | na                     | Seed          | na            |
| Kheyt                              | Greenhouse and end-to-end farm enabling services                         | 2015         | Hyderabad   | Yes                    | Seed          | 0.105         |
| Khetify                            | Roofop farming and gardening kits                                         | 2016         | Delhi       | No                     | Unfunded      | na            |
| Hosa Chiguru                        | Agri Infrastructure and developer                                         | 2006         | Bangalore   | No                     | Unfunded      | na            |
| Vegrow                              | Provider of tech-enabled farming services to farmers                      | 2020         | Hyderabad   | Yes                    | Seed          | na            |

Source: Compiled from Tracxn database as of February 2020

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| Company name       | Overview                                                                 | Founded year | City         | Funding Total funding Mn. USD | Company stage | Annual revenue Mn. USD |
|--------------------|---------------------------------------------------------------------------|--------------|--------------|------------------------------|---------------|------------------------|
| Licious (soonicorn) | Online platform for delivery of meat and seafood                          | 2015         | Bangalore    | Yes                          | 94.500        | 9.133                  |
| Fresh to home      | Manages supply chain of meat and seafood from farm/fishermen to home      | 2012         | Bangalore    | Yes                          | 47.200        | 0.930                  |
| ZappFresh (soonicorn) | Online fresh meat delivery service                                        | 2015         | Delhi        | Yes                          | 9.059         | 4.087                  |
| Caprabook          | Software for goat farm management                                         | 2015         | Satara       | No                           | na            | na                     |
| Eggoz              | Full-stack egg producer using advanced technology, IoT-based poultry farming techniques | 2017         | Bihar Sharif | Yes                          | 0.752         | 0.363                  |
| PoultryMon         | Hatchery management solutions for poultry farms                           | 2018         | Hyderabad    | Yes                          | na            | na                     |
| Aquaconnect        | Developer of products for data-driven farming in shrimp ecosystem          | 2017         | Chennai      | Yes                          | 1.102         | 0.204                  |
| INCEVE             | Provider of SONARs for catching fishes                                     | 2016         | Bangalore    | Yes                          | na            | na                     |
| Stellapps          | Provider of farm optimization and monitoring support for milk              | 2011         | Bangalore    | Yes                          | 19.009        | 6.896                  |
| Country Delight    | Online retailer of dairy products                                          | 2015         | Gurgaon      | Yes                          | 19.636        | 7.965                  |
| Prompt AMCS        | Automatic milk collection system for dairy industry                        | 2011         | Ahmedabad    | No                           | na            | na                     |
| Meri Dairy         | Provider of dairy management software for milk collection centres         | 2008         | Jaipur       | No                           | na            | na                     |
| Farmery            | Production, marketing and delivery of raw cow milk                        | 2015         | Delhi        | No                           | na            | 0.766                  |
| Eruvaka            | Provider of IoT-based on-farm diagnostic equipment. Animal nutrition and aqua feed | 2012         | Vijayawada   | Yes                          | 6.781         | 1.360                  |
| Krimanshi          | Developer and supplier of sustainable feed for livestock animals          | 2018         | Bangalore    | Yes                          | na            | na                     |
| Tropical Animal Genetics (TAG) | Developer of in vitro animal breeding platform | 2014         | Gurgaon      | Yes                          | na            | 0.262                  |
| Aquaconnect        | Developer of products for data-driven farming in shrimp ecosystem          | 2017         | Chennai      | Yes                          | 1.102         | 0.204                  |

Source: Compiled from Traxcn database as of February 2020

Note: Seed funding, first equity funding usually by angel investors to finance its first steps including market research and product development; series A, usually by venture capital firms to further optimise its user base and product offering by putting in place a business model for marketing the ideas; series B is to expand market reach by expanding the team to meet the levels of demand; series C, to develop new products, expand into new markets, or acquire new companies and prepare for IPO; series D, to increase value before going to IPO or to remain private for longer; startups that are successful but not making enough revenues to be self-sustainable go to later stages of funding like series E, F, G, H and above. Funded indicates lack of information on stage of funding, though the startup received some funding. Unfunded indicates not receiving any outside funding other than family, friends and personal supporters.
engage in a farm-to-fork model and supply to the consumers directly. They received funding to the tune of 95 million (series E funding) and 47 million (series B funding), respectively. Apart from them, large ticket investments are in dairy sector startups CountryDelight (20 million) and Stellaps (19 million) and fishery startup Aquaconnect (11 million). Both Licious and FreshToHome procure directly from farmers. While Caprabook is for goat farm management, PoultryMon is for hatchery management solutions. The dairy sector has few startups in Stellaps, Country Delight, Prompt AMCS, Meri Dairy and Farmery. Eruvaka and Krimanshi deal with sustainable feed solutions, while Eruvaka has developed AI-based on-farm diagnostic equipment. Listed as one of the 100 Technology Pioneers of 2020 by the World Economic Forum 2020, Stellaps digitizes farm-to-consumer chain and enables dairy ecosystem partnerships including facilitating digital payments and hassle-free credit and insurance to marginal dairy farmers, apart from better milk quality and traceability [68]. It works with its innovative software solutions for dairies to enable contactless procurement and for adhering to sanitary guidelines. It has been managing 10 million litres of milk per day and covers two million farmers in 30,000 villages.

Open Innovation Knowledge Flows

The foregoing analysis reveals that open innovation as explained by Chesbrough [1] has been taking root in Indian agriculture by joint development and diffusion of innovations by startups and other actors in the food value chain. The factors leading to open innovation, termed erosion factors by Chesbrough and Bogers [3], significantly influence the evolution of this innovation system. Most of these erosion factors including startups getting venture capital, the rise of the Internet with 700 million Internet users, the widespread use of social media, universities becoming innovation hubs and mobility of employees are present in India, and they combine to create this open innovation system. Venture capital has grown over the years, and India has become one of the favoured destinations [69, 70]. After a long period of stagnation and ‘technology fatigue’ [71], Indian food system is in transition and moving towards a higher level of technologies with better and faster linkages among various food chain actors. As experience in other countries demonstrated, open innovation is required during the transition stage to a higher level of technologies, and the innovations will be less radical without knowledge flows [8]. The limited and available evidence points to the startup innovations accessible more to the larger farmers [72, 73]. Also, preliminary studies in the Netherlands show that mediating and moderating factors are important to be kept in mind⁴ to enable wider diffusion of these innovations and to resource poor farmers [74].

The entry of startups has accelerated flows between food chain actors in regard to making and diffusing innovations to the end users, as the foregoing analysis shows. The knowledge flows are both outbound from the startups to the companies and other actors and sometimes in the opposite direction as well as bi-directional, as brought out in the cases above. Some of the companies have founded their own startups for various knowledge generation and use⁵. For example, Godrej Agrovet instituted a venture capital fund in the name of Omnivore as an anchor investor for investing in startups. It is a leading agribusiness company in poultry feed.

⁴ The policymakers in Europe have internalised the three core principles of open innovation (open science, open innovation and open to the world) in its Mission-oriented Innovation Policy (MIP) as the core of the Horizon Europe programme.

⁵ Large companies in tech industry are the forerunners in leveraging startups for innovations (Weiblen and Chesbrough, 2015).
dairy products, vegetable oil and processed foods (joint venture with Tyson Foods of the USA for processed foods). This company has so far completed two funds with 40 million and 97 million and about to start the third one [75]. Among its investments are startups working in various segments of the food value chain and include DeHaat (full-stack marketplace), Stellapps (dairy platform), GramCover (rural fintech and farm finance) and Bijak (B2B agricultural commodity platform). The company has also acquired two startups for digital supply chain solutions for farm business [76].

One of the largest processing company ITC has upgraded its eChoupal to a more collaborative mobile platform in the name of eChoupal 4.0, and other companies like Bayer are harnessing the same [77]. ITC has invested in alternative investment funds (AIF) those that fund startups and is also investing directly in startups to aid in improving the business [78]. Reliance, which started JioMart e-commerce company recently, has backed or acquired startups like Grab A Grub (last-mile logistics company), C-Square Info Solutions (software for managing logistics of distribution and retail operations), Fynd (e-commerce company), Reverie Language Technologies (language localisation technology platform), Haptik (AI-backed B2B chatbot maker) and Netradyne (driver and commercial vehicle safety). Reliance continues to scout for many more startups as partners in innovations for the food chain [79]. Walmart-owned Flipkart launched a venture fund with 100 million to support early-stage startups and also a startup accelerator called Flipkart Leap for deep engagement with B2C and B2B startups with supply chain solutions [80]. It has also been leveraging supply solutions of Ninjacart for its grocery delivery initiative ‘Flipkart Quick’ to procure directly from farmers and committed to investing 50 million to strengthen Ninjacart [45]. Similarly, Amazon acquired the e-commerce grocery startup ZopNow in 2018. On the other hand, a startup by name StarAgri floated its own initiative for market linkages in the form of Agrobazaar.

The interconnections between startups themselves and their business partnerships with input companies, processors, aggregators, traders, hotels and restaurants, supermarkets, ecommerce companies, research organisations, various governments (federal as well as provincial), international institutions like the World Bank and various crop associations like tea growers association constitute a complex web. These fast-expanding knowledge flows have brought several innovations that could not be imagined just a few years back. The vibrancy of the food value chains in India during the pandemic can be attributed to some extent to the activities of these startups [49, 81, 82]. The ecosystem has been bringing to the ready access of the farming community several innovative products including online marketing of farmers’ produce, precision agriculture solutions for crop and animal husbandry, traceability solutions, storage solutions, online financing, innovative field level cold storages, irrigation control, customised mechanisation solutions on rent, rapid quality assessment and grading and third-party logistic solutions. Most of the innovations explained above are innovations flowing from the startups to other actors in the value chain, which itself has been accelerated and invigorated with missing links covered up. It needs to be highlighted here that innovations in value chain organisation can accelerate technology adoption by the farming community [83].

Innovation creation in open innovation raises significant issues in proprietary management to the co-created products and needs intellectual property rights management keeping in view the co-sharing principle. According to Chesbrough [2], it requires open innovation mindset to meet the singularities of the innovation types and involvement of multiple partners in the process [20]. The intricacies of evolving business models is fraught with serious challenges as open innovation involves generation of new intellectual property in cooperation between different partners and therefore transfer of IPRs among the co-creating companies. The main
focus of IPR management in the closed innovation model is to obtain legal protection of in-house research results in order to be able to exclude competitors; IPR management in open innovation has to be able to balance the needs and interests of several independent parties [84]. There is a need to find a balance between closed innovation programmes of the company on its own and the creation, maintenance and enhancement of capabilities that can be shared through open programmes by adopting a case-by-case approach [85].

Summary and Conclusions

Open innovation is a paradigm shift in technology development and benefit sharing in the New Millennium with potential positive implications for achieving SDGs through addressing grand challenges like poverty, food and nutrition security and climate change. This kind of organisation of innovation starts with the kind of economic activities with a high level of sophistication and complex processes. The rapid evolution of the food system with diverse actors and an assortment of technologies makes open innovation possible in agriculture. This paper harnesses a large database of startup data in India and examines the nature of innovations in the startups working in food and agriculture in open innovation framework and analyses startups according to their roles in the value chain, funding and investment and revenue.

Several types of startups have come up in the last decade and are filling the gaps in the food value chains in infrastructure-deficit regions of the country and introducing innovations. Our estimates show that they mobilised investments to the tune of six billion USD into the food and agriculture sector producing five unicorns and three soonicorns by the end of 2020. Most of these startups operate in tandem with various other related companies in downstream with the supermarkets, retailers and hoteliers; in the midstream with the processors, wholesalers and logistic firms; in the upstream with the input companies; and so on. The entry of startups has accelerated flows between food chain actors in regard to making and diffusing innovations to the end users. The knowledge flows are both outbound from the startups to the companies and other actors and sometimes in the opposite direction as well as bi-directional.

The interconnections between startups themselves and their business partnerships with input companies, processors, aggregators, traders, hotels and restaurants, supermarkets, e-commerce companies, research organisations, various governments (federal as well as provincial), international institutions like the World Bank and various crop associations like tea growers association constitute a complex web. These fast expanding knowledge flows have brought several innovations that could not be imagined just a few years back in developing countries. The ecosystem has been bringing to the ready access of the farming community several innovative products including online marketing of farmers’ produce, precision agriculture solutions for crop and animal husbandry, traceability solutions, storage solutions, online financing, innovative field level cold storages, irrigation control, customised mechanisation solutions on rent, rapid quality assessment and grading and third-party logistic solutions. These innovations are from the startups to other actors in the value chain, which itself has been accelerated and invigorated with the missing links covered up. Many of these innovations have the positive impact of contributing to the goals of sustainability and circular economy by slowing, intensification, dematerialization and narrowing of the resource loops in the food system. On the whole, the emergence of open innovation in agriculture augurs well to food value chain flows and to harness higher levels of technologies. Food chain actors resisting these open flows will be worse off in terms of net welfare gains, and this will be much more
problematic if the smallholders are bypassed by these innovations. Limited available evidence points to this possibility and necessitate policy attention.

The Indian government needs to learn from the forward-looking policy intervention by the European Union by internalising open science, open innovation and open to the world in its Horizon Europe Programme. It may develop a policy framework to create the necessary enabling environment for the development of the startup ecosystem that includes venture capital industry and associated policy changes. It is worth highlighting few key measures like early-stage support through seed fund, encouragement to angel investors, mass incubators and a level playing field for non-technical startups. Enabling the moderating factors is warranted as startups and chain actors interact with others keeping their interests rather than the wider interests, and therefore this innovation has to be internalised and mainstreamed into the agricultural development planning, mindful of the twin objectives of growth and equity [24, 25].

The nascent stage of development of this open innovation needs dispassionate research on these developments from the purview of equity and the possibility of scaling up these ventures. Also required is a research focus on the type of business models and collaboration and licencing agreements between companies, universities and governmental agencies. The entry of open innovation calls for wider engagement by economists in research related to the factors leading to this innovation in terms of business mechanisms, socioeconomic contexts, technological drivers and both supply and demand-side factors.

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Code Availability  Yes

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References

1. Chesbrough H (2003) Open innovation: the new imperatives for creating and profiting from technologies. Harvard Business School Press, Boston, MA
2. Chesbrough H (2006) Open innovation: a new paradigm for understanding industrial innovation. In: Chesbrough H, Vanhaverbeke W, West J (eds) Open innovation: researching a new paradigm. Oxford University Press, Oxford, pp 1–12
3. Chesbrough H M Bogers (2014) “Explicating open innovation: clarifying an emerging paradigm for understanding innovation”, in H.Chesbrough, W.Vanhaverbeke and J.West (Eds) New Frontiers in Open Innovation, Oxford University Press, pp.3-28
4. Keswani Chetan (Ed.) (2021) Agri-based bioeconomy: reintegrating trans-disciplinary research and Sustainable Development Goals. CRC Press, Boca Raton, Florida, USA 384 pages
5. Keswani Chetan (Ed.) (2019) Bioeconomy for sustainable development. Springer-Nature, Singapore. 392 pages
6. Sarkar S, Costa AIA (2008) Dynamics of open innovation in the food industry. Trends Food Sci Technol 19:574–580
7. Bigliardi B, Galati F (2013) Innovation trends in the food industry: the case of functional foods. Trends Food Sci Technol 31(2013):118–129
8. Zilberman D, Lu L, Reardon T (2019) Innovation-induced food supply chain design. Food Policy 83:289–297
9. Pietro D, Francesca AP, Majchrzak A (2018) Crowd equity investors: an underutilized asset for open innovation in startups. Calif Manag Rev 60(2):43–70
10. Bernardi D, Paola DA (2020) Innovation in food ecosystems. Springer Nature, Switzerland
11. Nuthalapati, Chandra S.R., Seema Bathla, Anjani Kumar, and Girish Jha (2018), “Agriculture and sustainable development goals: an overview and issues”. Agricultural Economics Research Review, 31(Conference Number): 1-7.
12. Medeiros G, Binotto E, Caleman S, Florindo D (2016) Open innovation in agrifood chain: a systematic review. J Technol Manag Innov 11(3):108–116
13. Reardon T, Echeverría R, Berdegué J, Minten B, Liverpool-Tasie S, Tschiley D, Zilberman D (2019) Rapid transformation of food systems in developing regions: highlighting the role of agricultural research and innovations. Agric Syst 172:47–59
14. Nuthalapati, Chandra S.R., Seema Bathla, Anjani Kumar, and Girish Jha (2018), “Agriculture and sustainable development goals: an overview and issues”. Agricultural Economics Research Review, 31(Conference Number): 1-7.
15. Medeiros G, Binotto E, Caleman S, Florindo D (2016) Open innovation in agrifood chain: a systematic review. J Technol Manag Innov 11(3):108–116
16. Keswani Chetan (Ed.) (2021) Agri-based bioeconomy: reintegrating trans-disciplinary research and Sustainable Development Goals. CRC Press, Boca Raton, Florida, USA 384 pages
17. Korreck, Sabrina (2019), “The Indian startup ecosystem: drivers, challenges and pillars of support”, ORF Occasional Paper No. 219, September 2019, Observer Research Foundation. Available at: https://www.orfonline.org/research/the-indian-startup-ecosystem-drivers-challenges-and-pillars-of-support-55387/
18. de Angelis (2016) Italy and startups: harnessing a country of innovators: a policy analysis of the Italian Startup Act and its effects on the startup ecosystem, Harvard Kennedy School, Available at: https://www.hks.harvard.edu/sites/default/files/degree%20programs/MPP/files/17%207%2010%20MPP_PAE_Luca%20de%20Angelis_Italy%20and%20Startups.pdf. Accessed on 17.3.2018
19. Korreck, Sabrina (2019), “The Indian startup ecosystem: drivers, challenges and pillars of support”, ORF Occasional Paper No. 219, September 2019, Observer Research Foundation. Available at: https://www.orfonline.org/research/the-indian-startup-ecosystem-drivers-challenges-and-pillars-of-support-55387/
20. Singh, Vijay Kumar (2020), Policy and regulatory changes for a successful startup revolution: experiences from the startup action plan in India, Working Paper No. 1146, Asian Development Bank Institute, Tokyo.
21. Tunn VSC, Bocken NMP, van den Hende EA, Schoormans JPL (2019) Business models for sustainable consumption in the circular economy: An expert study. J Clean Prod 212:324–333
22. Tunn VSC, Bocken NMP, van den Hende EA, Schoormans JPL (2019) Business models for sustainable consumption in the circular economy: An expert study. J Clean Prod 212:324–333
23. Nanda R, Rhodes-Kropf (2013) Investment cycles and startup innovation. J Financ Econ 110:403–418
24. Korreck, Sabrina (2019), “The Indian startup ecosystem: drivers, challenges and pillars of support”, ORF Occasional Paper No. 219, September 2019, Observer Research Foundation. Available at: https://www.orfonline.org/research/the-indian-startup-ecosystem-drivers-challenges-and-pillars-of-support-55387/
25. Singh, Vijay Kumar (2020), Policy and regulatory changes for a successful startup revolution: experiences from the startup action plan in India, Working Paper No. 1146, Asian Development Bank Institute, Tokyo.
26. Subramanya MHB (2015) New generation start-ups in India: what lessons can we learn from the past? Econ Polit Wkly 50(12):56–63
27. Acs ZJ, Audretsch DB, Braunerhjelm P, Carlsson B (2004) The missing link: the knowledge filter and endogenous growth (discussion paper). Center for Business and Policy Studies, Stockholm
28. Audretsch DB, Santarelli E, Vivarelli M (1999) Start-up size and industrial dynamics: some evidence from Italian manufacturing. Int J Ind Organ 17:965–983
29. Audretsch DB (2009) The entrepreneurial society. J Technol Transfer 34:245–254. https://doi.org/10.1007/s10961-008-9101-3
30. Ries E (2011) The lean startup: how today’s entrepreneurs use continuous innovation to create radically successful businesses. Crown Business, New York
31. Deichmann U, Goyal A Mishra D (2016) “Will digital technologies transform agriculture in developing countries?” World Bank Policy Research Working Paper no. 7669
32. Jha K, Doshi A, Patel P, Shah M (2019) A comprehensive review on automation in agriculture using artificial intelligence. Artificial Intelligence in Agriculture 2:1–12
33. Lele U, Goswami S (2017) The fourth industrial revolution, agricultural and rural innovation, and implications for public policy and investments: a case of India. Agric Econ 48(S1):87–100
34. Tripoli, M and J. Schmidhuber, (2018), "Emerging opportunities for the application of blockchain in the agri-food industry” (FAO and ICTSD: Rome and Geneva, License: CC BY-NC-SA 3 2018).
35. World Bank (2019) Future of Food: Harnessing Digital Technologies to Improve Food System Outcomes, International Bank for Reconstruction and Development, Washington DC
36. Chesbrough H (2020) Open innovation results: going beyond the hype & getting down to business. Oxford University Press, New York
37. Poojary, Thimmaya (2019), Bridging the gap: how B2B ecommerce startup Udaan seamlessly connects India and Bharat, September 30, Yourstory, Available at: https://yourstory.com/2019/09/startup-b2b-ecommerce-retail-udaan
38. Kashyap, Sindhu (2020), "Why these Ola and Zomato Hyperpure execs chose to launch an agritech Startup", Yourstory, June 7. Available at: https://m.dailyhunt.in/news/india/english/yourstory-epaper/why+these+ola+and+zomato+hyperpure+execs+chose+to+launch+an+agritech+startup-newsid-n189588982.
39. Garg Saurab (2020) “Improving farmer incomes with Odisha model: better produce prices thanks to Zomato, Swiggy”, Financial Express, August 21. Available at: https://www.financialexpress.com/economy/improving-farmer-incomes-with-odisha-model-better-produce-prices-thanks-to-zomato-swiggy/2061901/
40. Mitter, Sohini (2020), "Agritech startup DeHaat raises $12M to reach more farmers in India,” TechCrunch, April 7. Available at: https://techcrunch.com/2020/04/06/agritech-startup-dehaat-raises-12m-to-reach-more-farmers-in-india/
41. Sheth A, Krishnan S, Samyukktha T (2020) Perspectives on the funding and start-up ecosystem: India Venture Capital Report 2020, Bain and Company, Mumbai
42. Parthasarathy G, Shameem (1998) Suicides of cotton farmers in Andhra Pradesh: an exploratory study. Econ Polit Wkly 33(13):720–726
53. Pray C, Nagarajan L (2014) The transformation of the Indian agricultural input industry: has it increased agricultural R&D? Agric Econ 45(5):145–156
54. Apoorva P (2019) Agritech startup AgroStar raises $27M in series C funding led by Bertelsmann India. Available at: https://yourstory.com/2019/03/agritech-startup-agrostar-funding-series-%E2%80%93j2id3844s
55. Singh S (2017) How inclusive and effective are farm machinery rental services in India? Case studies from Punjab. Indian Journal of Agricultural Economics 72(3):230–250
56. Ravi Mayuri J. (2017), “Using these 5 innovations, Kamal Kisan is helping farmers reduce labour costs”, Yourstory, November 22. Available at: https://yourstory.com/2017/11/kamal-kisan-social-innovations
57. Gogoi Angarika (2019) “Meet the Man whose ‘KisanRaja’ smart irrigation device helps over 34200 farmers”, The Better India, November 19. Available at: https://www.thebetterindia.com/204393/india-water-pumps-innovation-agritech-invention-irrigation-agriculture-farmers-kisanraja/
58. Ayyar Ranjani Aparna Desikan (2016) Drought-hit farmers get help from startups, Times of India, March 10, Available at: https://timesofindia.indiatimes.com/business/india-business/Drought-hit-farmers-get-help-from-startups/articleshow/51342848.cms
59. Anand, A., Saravanan Raj (2019) "Agritech in India: emerging trends in 2019, National Association of Software and Services Companies. Noida, New Delhi
60. Prasad, Riya (2018) Can this startup’s AI-based quality assessment tool help farmers get a fair price?” Techcircle, 30 May, Available at: https://www.techcircle.in/2018/05/30/can-this-startup-s-ai-based-quality-assessment-tool-help-farmers-get-a-fair-price/
61. Patil, Komal (2018), “This agritech startup is betting the farm on its AI-based crop-grading SaaS solution”, Inc42, 11 July, Available at: https://inc42.com/startups/this-agritech-startup-is-betting-the-farm-on-its-ai-based-crop-grading-saas-solution/
62. Balakrishnan Rekha (2020) “These women entrepreneurs aim to transform the fresh food supply chain in India and tap into a market worth $2B”, Yourstory, 22nd June. Available at: https://yourstory.com/herstory/2020/06/women-entrepreneurs-agritech-product-supply-chain
63. Lianos, I, Katalevsky, D. and Ivanov, Alexy (2016), “Understanding the impact of agritech startups in India”, Asia Pacific Tech Monitor, 24(1), 5-16
64. Kashyap Pratam (2020a) “Arya Collateral launches A2ZGodaam, an aggregator business model to locate agri-warehouses”, Krishijagr, August 18. Available at: https://krishijagr.com/agriculture-world/arya-collateral-launches-a2zgodaam-an-aggregator-model-to-locate-agri-warehouses/
65. Harisharan Sindhu (2018) “My Startup Idea: Shameek Chakravarty’s Farmizen helps you rent a farm to grow”, The Times of India, December 9. Available at: https://timesofindia.indiatimes.com/people/my-startup-idea-shameek-chakravartys-farmizen-helps-you-rent-a-farm-to-grow-your-own-food/articleshow/67000466.cms
66. Sangwan, Sujata (2020), “Agritech startup Vegrow raises S2.5M led by Matrix Partners India, Ankur Capital”, Yourstory, July 21, Available at: https://yourstory.com/2020/07/agritech-startup-vegrow-matrix-partners-india-ankur-capital.
67. Kashyap Pratam (2020b) “Dairy tech startup Stellapps announces expansion of digital solutions”, Krishijagr, August 7. Available at: https://krishijagr.com/industry-news/dairy-tech-startup-stellapps-announces-expansion-of-digital-solutions/
68. Dossani R, Kenney M (2002) Creating an environment for venture capital in India. World Dev 30(2):227–253
69. Nathalapati, Chandra S.R., and Kartikeya Singh (2019), “Venture capital for technology and innovative startups in India”, Asia Pacific Tech Monitor published by the Asian and Pacific Centre for Transfer of Technology of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). January-March, 20-27. Available at: http://www.techmonitor.net/tm/images/2/25/19jan_mar_s23.pdf
70. Narayananmooorthy A (2007) Deceleration in agricultural growth: technology fatigue or policy fatigue? Econ Polit Wkly 42(25):2375–2377+2379
71. Hennessy T, Lapple D, Moran B (2016) The digital divide in farming: a problem of access or engagement? Applied Economic Perspectives and Policy 38(3):474–491
72. Singh S (2016) Institutional innovations for smallholder development: a case study of agri-franchising in Bihar. Indian Journal of Agricultural Economics 71(3):264–284
73. van der Boezem T, Schoe G, Pascucci S, Dries L (2015) “Startups: key to open innovation success in the agri-food sector”, Complete Working Paper N21. Wageningen University, The Netherlands
75. Putrevu, Sampath (2020), “Farmer engagement is the hardest obstacle in agritech, says Mark Kahn of Omnivore”, April 16. Available at: https://yourstory.com/2020/04/farmer-engagement-agritech-mark-kahn-omnivore?utm_pageloadtype=scroll

76. Chaudhari Deepti (2012) “Omnivore capital invests in farm-tech firms”, Livemint, October 2. Available at: https://www.livemint.com/Companies/prMEVrojB172U9KZ6VXW9K/Omnivore-Capital-invests-in-farmtech-firms.html

77. Anand N (2020) “ITC Agri rolls out more collaborative e-Choupal 4.0”, The Hindu, June 22. Available at: https://www.thehinds.com/business/itc-agri-rolls-out-more-collaborativee-choupal-40/article31893194.ece

78. Naik, Amit Raja (2019) “ITC to acquire stake in vending machine startup delectable to expand retail distribution Network”, Inc42. Available at: https://inc42.com/buzz/itc-to-acquire-stake-in-vending-machine-startup-delectable-to-expand-retail-distribution-network/

79. Soni, Sandeep (2020), “Mukesh Ambani invites startups to work with Jio; offers market access, tech development, capital, more”, Financial Express, July 15. Available at: https://www.financialexpress.com/industry/sme/mukesh-ambani-invites-startups-to-work-with-jio-offers-market-access-tech-development-capital-more/2024942/

80. Poojary, Thimmaya (2020), “Flipkart launches startup accelerator programme with 16-week mentorship, $25,000 grant”, Yourstory, August 10, Available at: https://yourstory.com/2020/08/flipkart-leap-startup-accelerator-programme-mentorship.

81. Medhi, Trisha (2020), “AgriBazaar, Crofarm, Unnati – these agritech startups are empowering Indian farmers in times of coronavirus”, Yourstory, July 18. Available at: https://yourstory.com/2020/07/agritech-startups-empowering-farmers-coronavirus

82. Narain, D (2020), Lessons that we learnt during lockdown on agri-supply chain: a report. Agro & Food Processing. 27th June. Available at: http://agronfoodprocessing.com/lessons-that-we-learnt-during-lockdown-on-agri-supply-chain-a-report/

83. Swinnen J, Kujipers R (2019) Value chain innovations for technology transfer in developing and emerging economies: conceptual issues, typology, and policy implications. Food Policy 83:298–309

84. UNECE (2010) Intellectual Property and Open Innovation. Knowledge-Based Policy Dispatch, Policy Brief

85. Alexy O, Criscuolo P, Salter A (2009) “Does IP strategy have to cripple open innovation?”, MIT Sloan Management Review. October 01

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