

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 from the advent of the New Millennium. 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 hypothesised to play this role in the Indian food system. The 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. 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, international institutions like the World Bank, 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 internalise 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

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1. Introduction

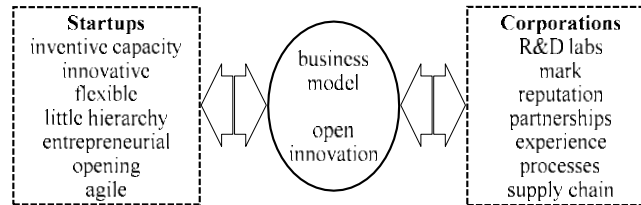
Open innovation has been permeating every field of economic activity all over the world in the last two decades. More consciously and as a planned development process, after the word ‘open innovation’ was coined and formalised as a new paradigm of creating and profiting from technology by Chesbrough (2003) in his celebrated book. 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 (Chesbrough, 2006). 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’ (Chesbrough and Bogers, 2014). This kind of organisation of innovation is only possible in economic activities with high level of sophistication and complex processes. However, the evolving experience in disparate industries showed that this can have traction in relatively conventional industries too (Chesbrough and Crowther, 2006; Medeiros et al., 2016). As the midstream and downstream of food value chains reached two-thirds magnitude in most of the world (Reardon et al., 2019) including India (Reardon et al., 2020), the ramping up of technology with newer innovations has been spurring transitions in the food industry. Research has shown that diverse actors in the long food chains with heterogeneous needs (Sarkar and Costa, 2008) and an assortment of technologies required to produce changing consumer demands (Bigliardi and Galati, 2013) all lead to the open innovation paradigm for faster technology development and diffusion. 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 (Swinnen and Kujipers, 2019; Zilberman, et al., 2019). However, the new paradigm goes beyond joint diffusion and involves disparate actors in both the development and diffusion of innovations.

The knowledge flows can be outside in 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 (Figure 1). Startups specifically need external knowledge sources given the scarcity of internal resources and competencies (Di Pietro et al., 2018). The food system is ideally suited to combine the knowledge specificities of many actors including startups in the open innovation framework (De Bernardi and Azucar, 2020, pp 109-110).

Startups have been proliferating across the countries not only in the developed, but also in the developing countries of Asia, Africa and Latin America (Nanda and Rhodes-Kropf, 2013; de Angelis, 2017). 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 (Subramanya, 2015; Korreck, 2019; Singh, 2020). 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 (Audretsch et al., 1999, Audretsch, 2009; Acs et al., 2004; Ries, 2011). The explosion of

startups has made it possible to leverage 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 on³. These startups are hypothesized to bring open innovation through new business models in association with established companies and other players (Fabricio et al., 2015; Chesbrough, 2020).

Figure 1: Startups and Large Companies Relationship



Source: Fabricio et al., (2015)

This paper 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. 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. 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 Traxcn and also collates with other published as well as news items in business dailies.

The rest of the paper is organised as follows. The next Section examines the nature of innovations of startups in regard to their functioning at various nodes of the value chain. The third Section brings out the discussion on open innovation knowledge flows. The last Section concludes with policy suggestions.

2. 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 (Komarek et al., 2020) and these startups endeavor 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, 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 inbound and outbound as well as bi-directional knowledge flows as shown by Bogers et al., (2018). 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 mechanisation, irrigation control, and financial support; helping in quality maintenance, monitoring, traceability, and output predictions (SaaS); post-harvest management and farming as a service (FaaS); and those supporting animal husbandry

³ Detailed expositions of these technologies and their applications in agriculture can be seen from Deichmann et al (2016), Lele and Goswami (2017), Tripoli and Schmidhuber (2018), Jha et al (2019), Anand and Raj (2019) and WB (2019).

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.

2.1. 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 realisation (Chand, 2017; Nuthalapati et al., 2020; Pingali et al., 2019). 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 (Poojary, 2019). 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 modernisation 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 considerable 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 (Nuthalapati et al., 2017), 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 (Poojary, 2019). *Ninjacart* supplies fresh produce to *Flipkart* for its *Flipkart Quick* and deals with 1500 tons a day (Velayanikal, 2020). *Zomato* acquired Bangalore-based *WOTU* in 2018 and renamed as 'Hyperpure' for starting direct procurement from farmers through operations in B2B foodtech space (Kashyap, 2019, 2020), while *Swiggy* entered hyperlocal grocery delivery recently and also procuring from farmers directly (Garg, 2020). Leveraging e-mandi model, *Agribazaar* works with 200,000 farmers and connects them with procurement agencies and food processing companies like *Britannia*, *AgroPure*, and others at no cost, though it collects transaction fees from buyers (Mitter, 2020). *DeHaat*, based on the franchise model connects farmers with traders, institutional financiers, and buyers like *Reliance Fresh*, *Zomato*, *Udaan*, etc on one platform in 20 regional hubs in eastern India and serves 210,000 farmers (Singh, 2020a). 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 (Sheth et al., 2020).

Table 1: Startups connecting farmers with output markets

Startup Name	Overview	Founded year	City	Funding	Funding Mn. USD	Company stage	Revenue Mn. USD
Bigbasket (Unicorn)	Online marketplace of grocery products	2011	Bangalore	Yes	1020.000	Series F	366.077
Zomato (Unicorn)	Online platform enabling food ordering and delivery	2008	Gurgaon	Yes	975.000	Series J	169.140
Swiggy (Unicorn)	Online platform for food ordering and delivery	2014	Bangalore	Yes	1620.000	Series I	159.332
Udaan (Unicorn)	Online B2B marketplace for multi-category products	2016	Bangalore	Yes	900.000	Series D	7.760
Grofers (Unicorn)	Online retail store offering groceries	2013	Gurgaon	Yes	548.000	Series F	11.121
Ninjacart (Soonicorn)	App-based B2B platform offering vegetables and fruits	2015	Bangalore	Yes	163.000	Series C	17.110
WayCool (Soonicorn)	E-distributor of farm products	2015	Chennai	Yes	65.737	Series C	22.693
ZopNow (Soonicorn)	Online grocery platform with a three-hour delivery promise (Acquired by More and Amazon)	2011	Bangalore	Yes	12.045	Series A	2.943
Agrevolution (DeHaat)	Provider of end-to-end farming services to the farming communities	2012	Patna	Yes	16.508	Series A	5.417
Bijak	Online B2B marketplace to trade agriculture commodities	2019	Gurgaon	Yes	14.592	Series A	
Jumbotail	Online B2B platform for packaged food, fruits and vegetables	2015	Bangalore	Yes	25.361	Series B	29.233
ShopKirana	Mobile-based B2B marketplace for groceries	2015	Indore	Yes	12.472	Series B	3.011
Otipy	App-based platform offering fruits and vegetables	2019	Delhi	Yes	2.500	Seed	0.000
Kisan Network	B2B marketplace for farmers, bulk buyers	2015	Delhi	Yes	3.493	Seed	0.867
Crofarm	Digital supply chain of fruits and vegetables from farm to business	2016	Gurgaon	Yes	5.867	Seed	1.476
Aibono	Services for farm data collection & analytics and mobile application for farm management	2013	Bangalore	Yes	6.489	Seed	0.244
Clover Ventures	Provider of supply chain solution for fruits and vegetables	2017	Bangalore	Yes	6.931	Series A	0.148
Teabox	Online retailer of tea	2012	Bangalore	Yes	19.000	Series B	2.689
Satvacart	Online platform offering multi-category grocery products	2014	Gurgaon	Yes	2.324	Seed	0.184
Tokri	Online platform to buy fresh produce and groceries	2014	Pune	Yes	2.500	Seed	0.056
Milkbasket	Subscription based daily need items delivery (Milk and F&V)	2015	Gurgaon	Yes	40.575	Series B	10.349
FarmPal	Online platform delivering farm produce to businesses	2017	Pune	Yes	0.136	Seed	0.179
MeraKisan	Online marketplace that connects consumers with local farmers	2014	Pune	Yes	1.000	Seed	0.819
VnF	Online platform to purchase fruits and vegetables	2018	Mumbai	Yes	2.000	Seed	0.423
Inl Farms	Provider of farming services to horticulture industries	2009	Mumbai	Yes	14.635	Series A	14.404
FarmTaaza	Manages supply chain of fruits and vegetables from farm to business (Acquired by Way Cool)	2015	Bangalore	Yes	10.693	Series A	
Daily Ninja	Hyper-local subscription based delivery service (Acquired by Big Basket)	2015	Bangalore	Yes	10.744	Acquired	0.414
Smerkato	Online B2B platform offering multi-category grocery products	2016	Bangalore	Yes	na	Funded	
GeeCom	Online E-commerce platform offering agricultural products and supplies	2018	Indore	No	na	Unfunded	
Farmley	Online platform linking farmers with customers (Earlier called Technify Biz)	2016	Delhi	Yes	na	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	
Brownsoil	Online B2B platform offering farm produce	2018	Bangalore	No	na	Unfunded	5.531

Source: Compiled from Traxen database as of February 2020

2.2.Startups Facilitating Input Supply: Several studies showed that availability and quality of inputs to the farmers is a serious problem impinging productivity and profitability of farmers, where fly-by-night operators make quick money by selling spurious seeds, fertilisers, and pesticides (Parthasarathi and Shameem,1998). The transformation of input industries and delivery systems is critical in this regard (Pray and Nagarajan, 2014). Several startups have been offering solutions to optimise 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 mobilised 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 (Apoorva, 2019). Similar services are provided by *BigHaat*, *Khetinext*, *Gramophone*, and several others. Many of them combine input provision with agri-advisory and other services.

Table 2: Startups enabling online procuring of quality inputs

Company Name	Overview	Founde d year	City	Fundi ng	Total funding MnUSD	Company stage	Annual revenue Mn USD
Agrostar (Soonicorn)	Online platform offering agri-inputs, content, and advice	2008	Pune	Yes	47.183	Series C	11.618
Khetinext	Mobile app that enables procurement of farm inputs and provides information	2017	Hyderaba d	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 providers 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 Wholesale	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	Gurgaon	Yes	na	Seed	na
FarmGuru	Online platform for group buying of farm inputs	2015	Pune	No	na	Unfunded	na
Behtar Zindagi	Online marketplace for agricultural supplies	2016	Delhi	No	na	Unfunded	na
Unnati	Unnati	2016	Noida	Yes	0.452	Seed	10.129

Source: Compiled from Traxcn database as of February 2020

2.3.Startups for Mechanisation, 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 (Singh, 2017). *Sickle innovations*, *Distinct Horizon*, *Tractor Junction*, *Khetibadi*, and *J Farm service* are some of the other startups in mechanisation services. *Kamal Kisan* develops farm equipment for small

farm owners to reduce labour dependence and has rental services in Karnataka, Jharkhand, and Andhra Pradesh (Ravi, 2017).

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 34200 farmers in India (Gogoi, 2019), 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 high-value crops (Ayyar and Desikan, 2016). There are others like *Intech Harness* that provides solutions for water pump controller and *Sense It Out*, *Kritssnam*, *Agrirain*, *Manna Irrigation*.

Table 3: Startups helping in efficient mechanisation, irrigation, and financial services

Company Name	Overview	Founded year	City	Funding	Total funding Mn.USD	Company stage	Annual revenue Mn.USD
Mechanisation							
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
JParm Services	Online marketplace platform for equipment rental	2017	Chennai	No	na	Unfunded	na
Trringo	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
Kritssnam Technologies	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 & 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 technology	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
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 Traxcn database as of February 2020

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*, *Kissh*, *SatSure*, *Farmguide*, *Niruthi*, and so on. *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*.

Table 4: Startups for quality monitoring and maintenance and predictions of crop health and output

Company Name	Overview	Found ed year	City	Fund ing	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 technology for traceability	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 grading	2016	Mohali	Yes	4.337	Seed	0.097
RAAV Techlabs	Provider of AI-powered food quality analysers	2018	Delhi	Yes	na	Funded	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 agriculture	2017	Bangalore	No	na	Unfunded	na
BKC Aggregator	Precision agriculture solutions provider	2018	Delhi	No	na	Unfunded	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	0.760
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 Uzhavan	Online agriculture information dissemination platform for farmers	2018	Coimbatore	No	na	Unfunded	na
Nebulaa's Matt	Crop quality assessment system	2016	Jaipur	Yes	0.295	Seed	0.141
TartanSense	Analyzing 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
Bloom	Online mobile-based platform for agriculture risk prediction and mitigation	2009	Delhi	No	na	Unfunded	na
Skymet Weather	Crop insurance and weather forecasting data services	2003	Noida	Yes	11.768	Series C	5.827

Source: Compiled from Traxcn database as of February 2020

2.4. 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, digitisation, 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 (Anand and Raj, 2019). The Government of India has also roped in *CropIn* to streamline crop cutting experiments⁴ 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* (Prasad, 2018). *Agricxlab* harnessed deep learning technology to grade agri-commodity and certify in 30 seconds and acts as a bridge between cold storages and procurement companies (Patil, 2018). 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 (Balakrishnan, 2020). Soil and groundwater sensing and analytics products is 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 minutes 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.

Table 5: Startups in post-harvest management and in farming as a service (FaaS)

Company Name	Overview	Founded year	City	Funding	Total funding Mn. USD	Company stage	Annual revenue Mn. USD
Post-harvest management							
Ecozen Solutions	Manufactures and supplies solar-powered irrigation pump controllers	2009	Pune	Yes	10.591	Series A	9.800
SaptaKrishi (Sabjikothi)	Provider of a micro-climate storage solution for farmers	2018	Kanpur	Yes	na	Funded	na
New Leaf Dynamic Technologies	Off-grid refrigeration	2012	Delhi	Yes	na	Funded	na
AgriGator	Provider of agricultural logistics platform connecting grain shippers and carriers	2019	Bhopal	Yes	na	Funded	na
Star Agriwarehousing & Collateral Management	Agricultural warehousing and post-harvest supply chain solutions	2006	Mumbai	Yes	72.000	Series C	42.600
Arya Collateral Warehousing Services	Warehousing and collateral management services for agri commodities	1982	Noida	Yes	9.333	Series A	11.956
Farming- as-a-service (FaaS)							
Farmizen	Develops and operates digital application for community supported farming	2017	Bangalore	Yes	0.297	Seed	0.047
Triton Foodworks	Integrated business for soil-less cultivation of fruits & vegetables and supply of produce	2014	Delhi	Yes	na	Seed	na
Agro2o	Manufacturer and supplier of indoor hydroponics system	2017	Delhi	Yes	na	Seed	na
Kheyti	Greenhouse and end-to-end farm enabling services	2015	Hyderabad	Yes	na	Seed	0.105
Khetify	Rooftop farming and gardening kits	2016	Delhi	No	na	Unfunded	na
Farmizen	Develops and operates digital application for community supported farming	2017	Bangalore	Yes	0.297	Seed	0.047
Hosa Chiguru	Agri Infrastructure and developer	2006	Bangalore	No	na	Unfunded	na
Vegrow	Provider of tech-enabled farming services to farmers	2020	Hyderabad	Yes	2.500	Seed	na

Source: Compiled from Traxcn database as of February 2020

⁴ 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 have been questioned by many scholars including the National Statistical Commission.

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 (Lianos et al., 2016). 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 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 (NASSCOM, 2019).

2.5. 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 (Reardon et al., 2020), 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 *Sabjikothe*, developed by *Saptakrishi*, for extending shelf-life of vegetables from 7-30 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 fulfilment of warehousing for farmers, FPOs, corporate and other stakeholders. It goes beyond storage by integrating with other services like financial and market linkages (Kashyap, 2020a). 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 (Hariharan, 2018). 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 (Sangwan, 2020). 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.

2.6. 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 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.

Table 6: Startups in animal husbandry

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

Source: Compiled from Traxcn database as of February 2020

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 (Kashyap, 2020b). 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 30000 villages.

3. Open Innovation knowledge flows

The foregoing analysis reveals that open innovation as explained by Chesbrough (2003) 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 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, 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 (Putrevu, 2020). Among its investments are startups working in various segments of the food value chain and include *DeHaat* (Full-stack marketplace), *Stellaps* (Dairy platform), *GramCover* (Rural fintech and farm finance), *Bijak* (B2B agricultural commodity platform). The company has also acquired two startups for digital supply chain solutions for farm business (Chaudhari, 2012).

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 (Anand, 2020). *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 (Naik, 2019). 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 (Soni, 2020). 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 (Poojary, 2020). 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* (Velayanikal, 2020). 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, 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 (Medhi, 2020; Mitter, 2020; Narain, 2020). The ecosystem has been bringing to

⁵ Large companies in tech industry are the forerunners in leveraging startups for innovations (Weiblen and Chesbrough, 2015).

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, 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 (Swinnen and Kujipers, 2019).

4. Summary and Conclusions

Open innovation is a paradigm shift in technology development and benefit sharing in the New Millennium. 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, 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, hoteliers, in the midstream with the processors, wholesalers, and logistic firms, and 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, 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, 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.

The emergence of open innovation in agriculture augurs well to food value chain flows and to harness higher levels of technologies. The factors leading to open innovation, termed erosion factors by Chesbrough and Bogers (2014), 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 (Dossani and Kenney, 2002; Nuthalapati and Singh, 2019). After a long period of stagnation and ‘technology fatigue’ (Narayanmoorthy, 2007), 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 (Medeiros et al., 2016). The government needs to 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.

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, collaboration and licensing agreements between companies, universities and governmental agencies. 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. The limited and available evidence points to the startup innovations accessible more to the larger farmers (Singh, 2016; Hennessy et al., 2016). Also, preliminary studies in the Netherlands show that mediating and moderating factors are important to be kept in mind⁶ (van der Boezem et al., 2015). Enabling these 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 (Korreck, 2019; Singh, 2020). The entry of open innovation in food value chain actor bodes well for the food system and its disparate actors and it 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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⁶ 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.

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