
Startups with Open Innovation: Accelerating Technological Change and Food Value Chain Flows in India

Chandra S.R. Nuthalapati*, **K. Srinivas****, **Neha Pandey*** and **Rajeev Sharma***

ABSTRACT

Entrepreneurial new firms can bring in radical innovations better with a risk-taking approach. startups have been proliferating in all sectors of the economy including agriculture in developing countries in recent years. This paper harnesses a large database of start-ups in India and examines the nature of innovations of the start-ups employing open innovation framework. 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 and introducing innovations by mobilising 8 billion USD investments. This fast-expanding knowledge flows have brought several innovations that could not be imagined just a few years back. Significantly, open innovation has taken root in Indian agriculture with the rise of startups and this has several positive implications. Open innovation is required at the present stage as Indian agriculture is in transition and moving towards a higher level of technologies with better and faster linkages among various food chain actors. There are concerns that need to be addressed about this innovation, bypassing the smallholders, as companies can only plan for their own innovations and marketing. The government needs to develop a policy framework to create the necessary enabling environment for the development of the startup ecosystem and to internalise and mainstream this open innovation into agricultural development strategies keeping the twin goals of growth and equity.

Keywords: Startups, Technological Change, Food Value Chain, Innovation

JEL.:L26, O36, Q13, Q16

I

INTRODUCTION

The debate on large versus small firms as the drivers of innovation has been veering towards the latter in development discourse in recent period that is nearer to the initial hypothesis of Schumpeter (Baumol, 2004; Dolfsma and van der Velde, 2014). Concomitantly, entrepreneurship has been rising simultaneously in most parts of the world as countries transition from managed economies to entrepreneurial economies triggering a shift in government policies away from constraining the freedom of business to contract through regulation, public ownership and antitrust towards a new set of enabling policies which foster the creation and commercialisation of new knowledge (Acs *et al.*, 2004; Audretsch, 2009). While spillovers in knowledge generated in public and private sectors are hypothesised to lead to entrepreneurial new firms by Acs and Audretsch (Acset *al.*, 1994),

*Professor and Researchers, respectively, Institute of Economic Growth, University of Delhi Enclave, New Delhi-110 007, **National Academy of Agricultural Research Management (NAARM), Hyderabad.

Chesbrough (2003) postulated that innovations in the new millennium are to be jointly achieved. In this background, startups have been proliferating across the countries not only the developed, but also in developing countries in Asia, Africa and Latin America both in hi-tech sectors and traditional sectors like agriculture (Nanda and Rhodes-Kropf, 2013; Fabricio *et al.*, 2015; De Bernardi and Azucar, 2020). Notwithstanding the proliferation of startups and a flurry of innovations in various segments of the value chain, the extant literature does not analyse these developments in developing country context empirically to mainstream these developments in the overall growth process. This paper endeavours to address this research gap.

This paper is organised as follows. The following Section expounds the conceptual framework and data source and methods. The third Section examines the nature of innovations of startups in regard to their functioning at various nodes of the value chain. The fourth Section brings out the discussion on open innovation knowledge flows leading to open innovation. The last Section concludes with policy suggestions.

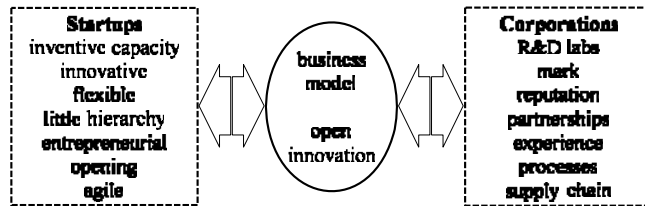
II

CONCEPTUAL FRAMEWORK

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 over a period of the first decade, more details are added to say that open innovation is ‘a distributed innovation process based on purposively managed knowledge flows across organisational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organisation's business model’ (Chesbrough and Bogers, 2014). To start with, this kind of organisation of innovation is only possible in the economic activities as the level of sophistication is high and the processes are complex. 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). The ramping up of technology with newer innovations has been spurring transitions in the food industry, especially as the mid-stream 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). Research has shown that diverse actors in the long chains with heterogeneous needs (Sarkar and Costa, 2008) and an assortment of technologies required to produce the changing consumer demands (Bigliardi and Galati, 2013) all lead to 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 innovation across all the actors in the entire chain when the processing firms bring in new technologies (Zilberman *et al.*, 2019). However, the new paradigm involves disparate actors in both 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, 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 in view of 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 open innovation framework (De Bernardi and Azucar, 2020, p 109-110).



Source: Fabricio *et al.*, (2015).

Figure 1. Startups and Large Companies Relationship.

This paper employs open innovation framework to understand the operations of 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 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.

III

NATURE OF INNOVATIONS IN FOOD VALUE CHAINS WITH STARTUPS AND IMPLICATIONS

There are several types of startups that have come 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 endeavour to address them using new generation IT tools such as internet of things (IoT), big data analytics, blockchain technology and so on. Many of these startups in India operate in tandem with various other related companies in downstream with the supermarkets, retailers, hoteliers, in the mid-stream 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 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 network is examined.

3.1. 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 four of these start-ups are unicorns involved in direct procurement from farmers and selling to other supermarket chains and other downstream actors. *Udaan* is a 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 three unicorns, viz., *BigBasket*, *Swiggy* and *Zomato* engage directly with farming community and procure through viz., like direct sellers of food. By September 2020, large investments are attracted by these startups to the tune of 6.96 billion USD, which is invested in building the long neglected modernisation of the value chains as well as for 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* (535 million USD), *Ninjacart* (164 million), *WayCool* (65 million), *Jumbotail* (25 mn), and *Bijak* (15 mn).

TABLE 1. STARTUPS CONNECTING FARMERS WITH OUTPUT MARKETS

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Bigbasket (Unicorn)	Online marketplace of grocery products	2011	Bangalore	Yes	7.88E+08	Series F	366077300
Zomato (Unicorn)	Online platform enabling food ordering and delivery	2008	Gurgaon	Yes	9.75E+08	Series J	169140273
Swiggy (Unicorn)	Online platform for food ordering and delivery	2014	Bangalore	Yes	1.62E+09	Series I	159331500
Udaan	Online B2B marketplace for multi-category products	2016	Bangalore	Yes	900000000	Series D	77,60,117
Grofers (Soonicorn)	Online retail store offering groceries	2013	Gurgaon	Yes	5.48E+08	Series F	11121000
Ninjacart (Soonicorn)	App-based B2B platform offering vegetables and fruits	2015	Bangalore	Yes	1.63E+08	Series C	17109500
WayCool	E-distributor of farm	2015	Chennai	Yes	65736870	Series C	22692800
ZopNow (Soonicorn)	Online grocery platform with a three-hour delivery promise (Acquired by More and Amazon)	2011	Bangalore	Yes	12045360	Series A	2942600
Agrevolution (DeHaat)	Provider of end-to-end farming services to the farming communities	2012	Patna	Yes	16507907	Series A	5417400
Bijak	Online B2B marketplace to trade agriculture commodities	2019	Gurgaon	Yes	14591780	Series A	na
Jumbo tail	Online B2B platform for packaged food, fruits and vegetables	2015	Bangalore	Yes	25361400	Series B	29233300
Shop Kirana	Mobile-based B2B marketplace for groceries	2015	Indore	Yes	12472215	Series B	3011000
Otipy	App-based platform offering fruits and vegetables	2019	Delhi	Yes	2500000	Seed	
Kisan Network	B2B marketplace for farmers, bulk buyers	2015	Delhi	Yes	3493115	Seed	866700
Crofarm	Digital supply chain of fruits and vegetables from farm to business	2016	Gurgaon	Yes	5866696	Seed	1476300
Aibono	Services for farm data collection & analytics and mobile application for farm management	2013	Bangalore	Yes	6488656	Seed	244200
Clover Ventures	Provider of supply chain solution for fruits and vegetables	2017	Bangalore	Yes	6930813	Series A	148400
Teabox	Online retailer of tea	2012	Bangalore	Yes	19000000	Series B	2689100
Satvacart	Online platform offering multi-category grocery products	2014	Gurgaon	Yes	2324241	Seed	183700
Tokri	Online platform to buy fresh produce and groceries	2014	Pune	Yes	2500000	Seed	55500

(Contd..)

TABLE 1.(CONCLD.)

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Milkbasket	Subscription based daily need items delivery (Milk and F&V)	2015	Gurgaon	Yes	40575340	Series B	10348500
FarmPal	Online platform delivering farm produce to businesses	2017	Pune	Yes	136390	Seed	179463
MeraKisan	Online marketplace that connects consumers with local farmers	2014	Pune	Yes	1000000	Seed	819100
VnF	Online platform to purchase fruits and vegetables	2018	Mumbai	Yes	2000000	Seed	422900
InI Farms	Provider of farming services to horticulture industries	2009	Mumbai	Yes	14634837	Series A	14404300
FarmTaaza	Manages supply chain of fruits and vegetables from farm to business (Acquired by WayCool)	2015	Bangalore	Yes	10693115	Series A	na
Daily Ninja	Hyper-local subscription based delivery service (Acquired by BigBasket)	2015	Bangalore	Yes	10744109	Acquired	413969
Smerkato	Online B2B platform offering multi-category grocery products	2016	Bangalore	Yes	na	Funded	na
GeeCom	Online E-commerce platform offering agricultural products and supplies	2018	Indore	No	na	Unfunded	na
Farmley	Online platform linking farmers with customers (Earlier called TechnifyBiz)	2016	Delhi	Yes	na	Funded	1683221.35
Kirana Monk	App-based B2B marketplace offering farm produce	2018	Sonapat	No	na	Unfunded	na
Atomaday	App-based video shopping platform offering fruits and vegetables	2017	Bangalore	No	na	Unfunded	na
Green-N Good	Online retailer of organic products	2012	Jaipur	Yes	na	Funded	na
Organo fresh Solutions	B2B wholesaler of fruits and vegetables	2017	Chandigarh	No	na	Unfunded	874200
Farmcon	Online B2B marketplace for agriculture products	2017	Pune	No	na	Unfunded	na
LivLush	B2B platform to procure fresh fruits and Vegetables (Sabziwala and LivLush merged as Kamatan)	2016	Bangalore	Yes	na	Series A	5530600
Brown soil	Online B2B platform offering farm produce	2018	Bangalore	No	na	Unfunded	

Source: Compiled from Traxcn database as of February 2020.

While *BigBasket* has been procuring directly from the farmers since 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 tonnes per day, apart from 5000 tonnes of staples (Poojary, 2019). *Ninjacart* supplies fresh produce to *Flipkart* for its *Flipkart Quick* and deals with 1500 tonnes 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 procured 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 fee from the 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. Further, they provide several related services to which we return towards the end of this Section. 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 has been done by *Ninjacart*, *WayCool*, has been a trend recently and B2B startups seem to get higher funding chances relatively (Sheth *et al.*, 2020).

3.2 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 flyby night operators make quick money by selling spurious seeds, fertilisers and pesticides (Parthasarathy and Shameem, 1998). The transformation of input industries and delivery systems are critical in this regard (Pray and Nagarajan, 2014). Several startups have been offering solutions to optimise the use and enable delivery of assured quality inputs to farmers (Table 2). These online services have been of 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 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 (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Agrostar (Soonicorn)	Online platform offering agri-inputs, content, and advice	2008	Pune	Yes	47182672	Series C	11618100
Khethinext	Mobile app that enables procurement of farm inputs and provides information	2017	Hyderabad	Yes	5386498	Series A	na
Gramophone	App-based platform providing farm input products and information to the farmers	2016	Indore	Yes	8062080	Series A	578400
Marut Drones	Provides drone-based precision agriculture services	2019	Guwahati	Yes	100085	Seed	na
LeanAgri	Technology solutions providers for farmers	2017	Pune	Yes	567108	Seed	93300
BharatAgri	Platform that provides crop management solutions for farmers	2017	Pune	Yes	1291537	Seed	93300
BigHaat	Online marketplace offering farm inputs	2015	Bangalore	Yes	2569628	Seed	103894
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
BehtarZindagi	Online marketplace for agricultural supplies	2016	Delhi	No	na	Unfunded	na
Unnati	Unnati	2016	Noida	Yes	452321	Seed	1,01,28,605

Source: Compiled from Traxcn database as of February 2020.

3.3 Startups for Mechanisation, Irrigation and Financial Services

Farming in the Indian context is becoming difficult for lack of suitable equipment especially for small farmers, enormous drudgery in irrigation fields and waste of water and lack of financial services. Startups have been finding these gaps and operating efficient services across the length and breadth of the country (Table 3). Some of them focus on accurate and timely assessment of soil moisture and developing data-driven controlled irrigation models. *Kisan Raja* is an innovative device allows farmers to remotely control the agricultural motor using their mobile or landline and used by 34200 farmers in India (Gogoi, 2019), apart from being

TABLE 3. STARTUPS HELPING IN EFFICIENT MECHANISATION, IRRIGATION AND FINANCIAL SERVICES

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Mechanisation							
FarMart	Web and mobile-based application for renting farm equipment	2015	Gurgaon	Yes	739765	Seed	35000
EM3 Agri Services	Provider of farming services to the farming communities	2013	Noida	Yes	17022002	Series B	1173648
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
Trringo	Mobile based app offering farming equipment on rent	2016	Mumbai	No	na	Unfunded	240000
Irrigation							
FlyBird Innovations	Manufactures irrigation controllers	2013	Bangalore	Yes	223330	Seed	66400
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 Technologies	IOT-based solutions for water monitoring and management	2015	Kanpur	Yes	70119	Seed	na
Financial services							
Jai Kisan	Online supply chain platform for farmers	2017	Mumbai	Yes	6014060	Seed	97900
SG Agtech Innovations	Online platform for providing digital and financial solutions to farmers	2018	Chennai	No	na	Unfunded	na
SafalFasal	Online marketplace for agricultural products	2019	Mumbai	No	na	Unfunded	na
Jai Kisan	Online supply chain platform for farmers	2017	Mumbai	Yes	6014060	Seed	97,900
Niruthi technology	Location-specific crop monitoring and yield prediction solution provider	2005	Hyderabad	No	na	Unfunded	3,40,900
Gramcover	Insurance marketplace focused on rural areas	2015	Noida	Yes	1181090	Seed	3,17,500
SatSure	Data services for crop health monitoring and assessment	2016	Bangalore	Yes	na	Funded	30,400
PayAgri	Online platform to bring cashless ecosystem in Agriculture	2017	Chennai	Yes	348442	Seed	9,775
Farmguide	Digitizing agri supply chain and services	2014	Gurgaon	Yes	1570818	Seed	1,57,200
AgRisk Tech	Core banking, payments, transaction banking, and financial inclusion solution provider	2009	Mumbai	No	na	Unfunded	na

Source: Compiled from Traxen database as of February 2020.

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*.

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 lower cost and some of them are finding good traction among farmers (Singh, 2017). *Sickle innovations*, *Distinct Horizon*, *TractorJunction*, *Khetibadi* and *J Farm service* are some of the other startups in mechanisation services. *KamIKisan* develops farm equipment for small farm owners to reduce labour dependence and has rental services in Karnataka, Jharkhand and Andhra Pradesh (Ravi, 2017).

As we move from traditional marketing services to the modern marketing channels, lack of support structures to provide handholding through credit is a handicap for the farmers. Some of the start-ups resolve this issue through making credit available in a transparent online procedure at lower rates of interest, along with other services. Apart from *Jai Kisan*, *SGAgtech* and *SafalFasal* shown in Table 3, there are others like *Samunnati*, *FarMart*, *PayAgri*, *Kissht*, *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*.

3.4 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 startup 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 experiments and their accuracy.

SaaS start-ups such as *Intellolabs*, *Agricxlab* and *QZense* and *RaavTechlabs* 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 price for the farming community and had been working with the Government of Rajasthan to grade grains in *mandis* (Prasad, 2018). *Agricxlab* harnessed deep

TABLE 4. STARTUPS FOR QUALITY MONITORING AND MAINTENANCE AND PREDICTIONS OF CROP HEALTH AND OUTPUT

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
CropIn	Provider of saas-based farming solutions to agribusinesses	2010	Bangalore	Yes	15623458	Series B	1622700
Intello Labs	Image recognition based solutions for multiple industries	2016	Bangalore	Yes	8750809	Series A	157400
FarmERP	Software suite for control over farm operations and traceability	2005	Pune	Yes	1438880	Series A	311600
Jivabhumi	Connecting consumers to farmer groups/cooperatives. Uses Block chain technology for traceability	2015	Bangalore	Yes	na	Funded	316400
Agricx	Provider of AI-based stack solutions for grading	2016	Thane	Yes	774776	Seed	40700
qZense Labs	Provider of an IoT device for food quality check for grading	2019	Bangalore	Yes	253386	Seed	na
AgNext	Platform for monitoring and improving agricultural food quality for grading	2016	Mohali	Yes	4336741	Seed	97000
RAAV Techlabs	Provider of AI-powered food quality analysers	2018	Delhi	Yes	na	Funded	9200
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	18783400
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	4000000	Series A	779068
FarmBee	Online platform providing data-driven agricultural solutions	2006	Pune	Yes	9099055	Seed	760200
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	294730	Seed	141400
TartanSense	Analysing health of plants using drones	2015	Bangalore	Yes	2139340	Seed	1800

(Contd).

TABLE 4.CONCLD.

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Yuktix	Technology sensor products for remote monitoring and control of devices	2013	Bangalore	Yes	133229	Seed	76500
Fasal	AI-powered IoT platform for precision agriculture	2018	Bangalore	Yes	1720000	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	11768115	Series C	5827100

Source: Compiled from Traxcn database as of February 2020.

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 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 though 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 health of plants drone imageries.

Precision agriculture using advanced analytics and prediction platforms are supposed to be the game changing technologies and exclusive preserve of top six companies and likely to be bypassed for the developing world (Lianoset al., 2016). However, startups enter this segment of value chain and make them possible through their innovations in a cost-effective manner for the smallholder farmers in developing country context such as in India. Precision agriculture solutions are provided by software platforms of *Amnex*, *AS Agri Systems*, *BKC Aggregator* and *NeerXTechnovation*. Agricultural information sharing has few startups attending and they include *RML Agtech*, *FArmBee*, *MyCrop Technologies*, *Agrojay* and *NammaUzhavan*. 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 that helps 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).

3.5 Startups for Post-Harvest Management and Farming-as-a Service

As the value chains became 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 mid-stream 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 considerable role is storage of agri-produce. In a country where it is estimated that there is storage gap of around 35 per cent, their role can play crucial role in reducing food damage. *A2Z Godaam* of *Arya Collateral* is foremost among them. It is a digital platform for 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 tonnes 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 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 getting good response. *Farmizen*, and *Hoshachiguru* provide min-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* partners with smallholders for profitable cultivation that might also lead to 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.

TABLE 5. STARTUPS HELPING IN POST-HARVEST MANAGEMENT, FARMING AS A SERVICE (FAAS)

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Post-harvest management							
Ecozen Solutions	Manufactures and supplies solar-powered irrigation pump controllers	2009	Pune	Yes	10590520	Series A	9799600
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 and Collateral Management	Agricultural warehousing and post-harvest supply chain solutions	2006	Mumbai	Yes	72000000	Series C	109300000
Arya Collateral Warehousing Services	Warehousing and collateral management services for agri commodities	1982	Noida	Yes	9333310	Series A	11955900
Farming- as-a-service (FaaS)							
Farmizen	Develops and operates digital application for community supported farming	2017	Bangalore	Yes	296585	Seed	47300
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	105300
Khetify	DIY rooftop farming and gardening kits	2016	Delhi	No	na	Unfunded	na
Farmizen	Develops and operates digital application for community supported farming	2017	Bangalore	Yes	296585	Seed	47,300
HosaChiguru Vegrow	Agri Infrastructure and developer Provider of tech-enabled farming services to farmers	2006 2020	Bangalore Hyderabad	No Yes	na 2500000	Unfunded Seed	na na

Source: Compiled from Traxcn database as of February 2020.

3.6 Startups for Farmers in Animal Husbandry

Animal husbandry sector, with one-third of gross value added in 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 farm-to-fork model and supply to the consumers directly. They received funding to the tune of 95 million (Series E funding) and 47

TABLE 6. STARTUPS IN ANIMAL HUSBANDRY

Company Name (1)	Overview (2)	Founded year (3)	City (4)	Funding (5)	Total funding USD (6)	Company stage (7)	Annual revenue USD (8)
Licious (Soonicorn)	Online platform for delivery of meat and seafood	2015	Bangalore	Yes	94500000	Series E	9133000
Fresh to home (Soonicorn)	Manages supply chain of meat and seafood from farm / fishermen to home	2012	Bangalore	Yes	47200000	Series B	929567
ZappFresh	Online fresh meat delivery service	2015	Delhi	Yes	9059375	Series A	4087400
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	751549	Seed	362900
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	1101687	Seed	204300
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	19009146	Series B	6895700
Country Delight	Online retailer of dairy products	2015	Gurgaon	Yes	19636337	Series B	7964500
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	765800
Eruvaka	Provider of IoT based on-farm diagnostic equipment. Animal nutrition and aqua feed	2012	Vijayawada	Yes	6780764	Series B	1360200
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	262000
Aquaconnect	Developer of products for data-driven farming in shrimp ecosystem	2017	Chennai	Yes	1101687	Seed	2,04,300

Source: Compiled from Traxen database as of February 2020.

Million (Series B funding) respectively. Apart from them, large ticket investments are in dairy sector start-ups *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. 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* digitises 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.

IV

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 use. 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 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 food value chain and include *DeHaat* (Full-stack market place), *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 more collaborative mobile platform in the name of *eChoupal 4.0* and other companies like Bayer is harnessing the same (Anand, 2020). ITC has invested in alternative investment funds (AIF) that fund startups and is also investing directly in startups to aid in improving the business (Naik, 2019). Reliance, that 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 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 invest 50 million to strengthen *Ninjacart* (Velayanikal, 2020). Similarly, Amazon acquired the ecommerce 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. This fast expanding knowledge flows has brought several innovations which could not be imagined just 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 the startups (Medhi, 2020; Mitter, 2020; Narain, 2020). The ecosystem has been bringing to the ready access of 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 the fact that innovations in value chain organisation can accelerate technology adoption by the farming community (Swinnen and Kujipers, 2019).

V

SUMMARY AND CONCLUSIONS

Entrepreneurial new firms can bring in radical innovations better with risk-taking approach. Startups have been proliferating in all sectors of the economy including agriculture in developing countries in recent years. Their demand for capital that can support risky innovative ventures catapulted a venture capital industry in the country in the new millennium and enhanced flow of capital. This paper harnesses a large database of startup data in India and examines the nature of innovations in the startups working in agriculture in open innovation framework, analyses startups according to their roles in the value chain, funding and investment and revenue.

There are several types of startups that have come up in the last decade that 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 8 billion USD into food and agriculture sector producing four 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, 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 which could not be imagined just few years back in developing countries. The ecosystem has been bringing to the ready access of 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 missing links covered up.

The accelerated and intensified knowledge flows across disparate actors in the food value chains, leading to emergence and faster diffusion of innovations, are the essence of innovation system (World Bank, 2012). The emergence of open innovation in agriculture augurs well to flows and to harness higher level 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, rise of internet with 800 million internet users, 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 agriculture is in transition and moving towards 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 higher level of technologies and the

innovations will be less radical without knowledge flows (Medeiros *et al.*, 2016). The government needs to develop policy framework to create necessary enabling environment for development of the startup ecosystem that include venture capital industry, and associated policy changes. It is worth mentioning few key measures like early stage support through seed fund, encouragement to angel investors, mass incubators, 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 research focus on the type of business models, collaboration and licensing agreements between companies, universities and governmental agencies. The limited and available evidence points to the startup innovations accessible more to the larger farmers (Singh, 2016; Hennessy *et al.*, 2016). 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 farming community are bypassed by these innovations.

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. Preliminary studies in the Netherlands show that corporate startup collaborations can improve innovation performance and enhance competitive advantage and at the same time mediating and moderating factors are important to be kept in mind (van der Boezem *et al.*, 2015). This is warranted as startups and chain actors interact with others keeping their own 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 (Lele and Goswami, 2017; Korreck, 2019; Singh, 2020). The entry of open innovation in food value chain actor bodes well for the agricultural sector and it calls for wider engagement by economists in research related to the factors leading to this innovation in terms of business mechanisms, socio-economic contexts, technological drivers and both supply and demand side factors.

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