Introduction:

The production, marketing, and consumption patterns in all the economic sectors, including the ostensibly low-tech sector like agriculture, have been drastically altered in recent years by rapidly evolving digital technologies. Through innovations and the application of cutting-edge technologies in the information and communication revolution, such as machine learning, internet of things (IoT), deep learning, big data analytics, blockchain technologies, and others, the explosion of startups in developing nations in Asia, Latin America, and Africa has rendered it possible to digitise food value chains. The six broad categories of digitisation these startups have ventured are identified, namely, (i) providing output market linkages, (ii) facilitating input supply, (iii) enabling mechanisation, irrigation control and financial support, (iv) helping in quality maintenance, monitoring, traceability, and output predictions (SaaS), (v) post-harvest management and farming as a service (FaaS), and (vi) supporting animal husbandry farmers.

In this background, the current paper examines the ongoing digitization of the Indian food system, the nature of innovations in agricultural startups using an open innovation framework, their sectoral and spatial distribution, and the factors that affect their survival, investment, and revenue. The paper also provides examples of how startups at different levels in food value chain are leveraging technology to provide services which enables the actors in the chain to make informed decision ranging from what, when and how to grow to delivery of their produce till the last mile of consumption for better price realisation.

Major Findings:

1. Evidence shows that 50% of the startups are from tier 1 and tier 2 cities, and therefore the stylised fact that most of the startups are located in the three major cities of Delhi National Capital Region (NCR), Bangalore and Mumbai, does not represent ground realities.

2. The education sector has the largest share of startups at 40.7%, followed by healthtech (25.1%) and foodagri (22.1%). The startups are low in artificial intelligence (AI) (0.8% of the total), real estate (0.2%) and fintech (1.1%), although the startups in these sectors have a disproportionately larger share in turnover. The food and agriculture segment attracted a considerable number of startups in recent years, despite lacklustre initiatives until 2016. By September 2020, a large amount of investment to the tune of $6.96 billion was attracted by these startups, and they were invested in the long-neglected modernisation of the value chains as well as for innovations.

3. A large number and proportion of agtech startups focus on innovations for linking the farmers in far-flung areas with the buyers of their produce. The animal husbandry sector, with one-third of agriculture gross value added (GVA) in the country, does attract startup ventures, though not in proportion to its contribution to the country's GVA.

4. On an average, only one in ten startups manage to get funding, which makes it difficult for them to survive and launch their innovations successfully. The analyses of funding deals reveals that 90% of the total amount of funding accrued in Bangalore, Delhi NCR and Mumbai, despite these cities accounting for only 60% of the deals.

5. Startups in food and agriculture sector are relatively worse off with only 11% of them getting funding, while the situation is better in the case of firms in AI (90.6% of them), real estate (88.9%) and fintech (84.7%).

6. Among the firms funded, startups in edutech sector accounts for a lion's share (31.2%), followed by healthtech (25%), food and agriculture (18.7%), and logistic sector (10.6%). Sectors that accounted for a large share of investment include foodtech (30.7%) and logistic startups (24.9%), followed by fintech (13.2%), edtech (12.5%) and healthtech (10.7%). Of all the deals in food and agriculture startups, Bangalore accounted for a major share (53.5%), followed by Delhi NCR (37.0%). There were not many investment deals for the food and agriculture startups in Mumbai.

7. The startups that manage to get some funding account for only 12.9% of the total startups. While funding is crucial for the survival and successful launch and marketing of its innovative product, the stages of funding are also critical. The early stages until it launches the product are critical for the survival of a startup and often this phase is termed as the *valley of death*. Because of difficulties in getting funding as well as uncertainties associated with innovations, only a few micro firms reach advanced stages of development like Stage C, D and so on.

8. Most of the startups that attract funding are funded in seed stage (49.5%) and 12.7% in Series A stage. Funding support is received by only 5% startups in Series B stage and 3% in Series C stage. For 27.1% of those firms receiving funding, the stage at which they received support could not be clearly determined. However, it is possible that these firms might have got funding in the seed and early-stage funding. A few startups in fintech, logistic, foodtech and health have received late-stage funding. Distribution of firms by cities reveals that those firms situated in Bangalore got early-stage funding, followed by Delhi NCR and Mumbai. On the other hand, firms in Mumbai got the

highest number of late-stage funding compared to Bangalore and Delhi.

9. Widespread supply disruptions, due to the most stringent lockdown in the country, came in the way of primary production as well as processing and distribution of food. Social distancing norms and movement restrictions impacted the midstream and downstream of the value chains. Food firms in the downstream have adapted by switching to e-commerce and e-procurement to stay afloat amid the COVID-19 lockdown.

10. The analysis of determinants of survival shows, startups located in Hyderabad and Mumbai, and with female founders, higher gross revenue and venture capital funding tend to strive for a long period. The food and agriculture startups are not short-lived. Positive and significant coefficient values reveal that venture capital funding propels startups to survive longer, probably with their guidance and mentoring. Women successfully start innovative micro firms, and their stewardship enables the startups to survive for longer periods. The coefficient for negative net returns is positive and significant, and this suggests that the startups aim to survive despite their initial losses. It reflects the risk-taking attitude of the startups with an expectation of posting profits in course of time, as they expect to gain more markets for their innovative products and services. Startups that have a large number of employees, founders with advanced educational qualifications and activities in fintech and healthtech may not be able to sustain for long, the analysis shows.

11. The analysis of determinants of revenue and investment shows that income of food and agriculture startups is significantly positive, as also those in the logistic sector. However, they do not attract significantly higher investment, but innovative firms in fintech and AI are gathering more traction. Highest educational degree spurs revenue but is negatively related to investment. Employment is associated with both revenue and investment. Venture capital funding does not influence revenue in the background of its negative association with investment. Female founders do not get significantly higher investment, and they earn significantly lower revenue vis-à-vis those founded by their male counterparts. Both startups' age and funding received lead to higher revenue, but these factors do not influence investment.

Policy Implications

1. The government needs to develop a policy framework to create the necessary enabling environment for the development of the startups ecosystem that include venture capital industry and associated policy changes. While addressing the ecosystem, due considerations should be given to the early-stage support through seed fund, encouraging angel investors, mass incubators, level playing field for nontechnical startups and occasional conduct of regional food system challenges.

2. The nascent stage of development of digital innovation system needs dispassionate research from the equity point of view and for exploring the possibility of scaling up these ventures. Also, required is research focus on the type of business models, collaborations and licensing agreements between companies, universities, and governmental agencies.

3. Social scientists may also examine scale bias, possible risks and redressal mechanisms for digitisation risks that include exclusion, lack of data privacy, cybersecurity breaches and over-concentration of service provider market power. This is even more important because of the welfare loss implications, if the smallholders are bypassed by these digital innovations.

4. Policymakers in Europe have internalised *three* core principles (open science, open innovation and open to the world) for their innovation and research. Preliminary studies in the Netherlands show that corporate-startup collaborations could improve innovation performance and enhance competitive advantage, but at the same time, mediating and moderating factors are important to be kept in mind. This is warranted as startups and chain actors interact with each other keeping their own interests rather than the wider interests, and therefore, this innovation system must be internalised and mainstreamed into the agricultural development planning, while being mindful of the twin objectives of growth and equity. The Mission-oriented Innovation Policy (MIP) under Horizon Europe programme in the European Union is an interesting model in this regard.

5. Available evidence point out that the startups' innovations are more accessible to large farmers. The World Bank (2019) underlines that the digitisation poses several risks like exclusion, lack of data privacy, cybersecurity breaches and over concentration of service providers' market power. As noted by the World Bank, the Maximising Finance for Development (MFD) framework could help to identify public actions that are needed to make the digitalisation process more inclusive.

The full paper can be accessed by clicking here