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# POLICIES TO BOLSTER TRUST IN AGRICULTURAL DIGITALISATION

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# Policies to Bolster Trust in Agricultural Digitalisation: Issues Note

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One important constraint to farmers' adoption of digital technologies, beyond costs, relevance, user-friendliness, human capital requirements, and perceived technology risks, is farmers' lack of trust in digital technologies. A number of issues underlie this lack of trust: 1) problems of data privacy, security, and confidence in data sharing; 2) cases of misaligned incentives of sellers and buyers of digital technologies; 3) difficulty in learning how to unwrap "black box" technologies; and 4) lack of standards for comparing and certifying the operation of digital technologies. Governments have several potential options to help bridge these trust gaps. These include encouraging firms to decouple their sales of problem assessment from sales of solutions; strengthening public sector extension services and farmers' technological learning; facilitating the development of risk-sharing arrangements between technology providers and farmers; and exploring ways to promote the standardisation of evaluation and certification of digital agricultural technologies.

**Key words:** Digital agriculture, mistrust, credence goods, learning, risk-sharing, standardisation

**JEL codes:** Q16, D83, L15

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## Boxes

## Key Messages

- There are many constraints to farmers' adoption of digital technologies. Major barriers include technology expense, relevance and potentially limited uses for some farms; user-friendliness; operator skill requirements; perceived technology risks; and mistrust of algorithms and digitally-enabled tools.
- This issues note focuses on farmers' lack of trust in digital technologies. Four issues explain this lack of trust: 1) problems of data privacy, security, and confidence in data sharing; 2) cases of misaligned incentives of sellers and buyers of digital technologies; 3) difficulty in learning how to unwrap "black box" technologies; and 4) lack of standards for comparing – and certifying – the functionalities of digital technologies.
- Governments have several potential policy responses at their disposal to help to overcome these trust gaps:
  - Encourage firms (e.g. manufacturers, retailers) to unbundle services related to problem assessment from those related to problem solutions.
  - Seek ways to promote farmer on-field experimentation with digital tools, either directly or indirectly.
  - Facilitate innovative risk-sharing arrangements between technology providers and farmers as a way to incentivise the participation of risk-averse operators.
  - Consider methods for standardising the evaluation and certification of the functionality of digital technologies – without promising farmers minimum financial returns on technology investments.
- A multi-pronged approach across these elements is likely to be the optimal path forward for bolstering trust and unlocking the full potential of digital agriculture.

## Executive summary

Agricultural digitalisation holds significant promise as part of the solution to the challenges of long-term sustainability and risk management, labour shortages, and declining productivity growth. That said, several barriers to adoption have dampened the uptake of digital tools: technology costs, user-friendliness and human capital requirements, operational relevance, perceived risks, and mistrust of technologies with heavy reliance on algorithms and automation. Mistrust is a particularly challenging constraint, being both intangible and yet prevalent in many countries.

By better understanding the various sources of mistrust, governments can take policy action to address it, thus helping to realise the full potential of digitalisation for agriculture. Four areas have been identified for such policy action: facilitating data privacy, security and data sharing; aligning the differing goals of sellers and buyers of digital technologies; assisting farmers with learning how to unwrap "black box" technologies; and standardising, evaluating, and certifying the operation of digital technologies.

Firstly, farmers have concerns surrounding data privacy, security and data sharing. Recent surveys of farmers in Australia, Canada, and the United States point to a lack of trust with some dimensions of technology providers, which reduces their comfort level in sharing data with private companies. Some of this trust gap stems from private companies' lack of transparency regarding how farmers' data are used. In some instances, industry-level voluntary codes of conduct and farm data co-operatives are potential solutions; equally, governments can serve as mediator or guarantor of assurances between farmers and technology providers.

Secondly, mistrust of technology providers also arises because of the "credence good problem". This type of problem arises in markets where experts first sell the diagnosis and then sell the treatment of the identified problem. In some situations, this gives rise to conflict-of-interest issues. Farmers can also be sceptical of technology providers that heavily promote bundles comprised of several technologies, especially if the net benefit from each of the component technologies in isolation is not clear. To address this aspect of mistrust, governments can encourage decoupling of the provision of problem assessments from that of problem solutions and strengthen extension services.

Thirdly, digital technologies are based on platforms and algorithms that tend to be poorly understood by non-specialists, including farmers. A further complication is that the uncertain nature of agricultural production can result in "noise" (e.g. poor weather, pest outbreaks) when farmers are attempting to learn about a particular technology, potentially causing systematic misevaluations of its net benefits. For this and other reasons, farmers are experimenting with technologies on their fields; governments could more actively support these activities to enable farmers to learn more about these tools and the relevance for their operations. Such support could also spur further opportunities for greater public-private collaboration and novel risk-sharing arrangements.

Finally, most farmers would like to know whether a tool will increase their operation's profitability; and they make assessments and comparisons of multiple technologies until they find the most suitable tool. However, there is currently a lack of rigorous evaluation and comparison of digital technologies, spurring dissatisfaction that may result in mistrust. One potential solution is the development of standards for assessment and certification of the functionality of digital tools. By defining a set of transparent and common criteria, standards enabling evaluation of technology performance can directly increase farmers' trust in new equipment.

# 1. Digital technologies create new challenges to trust innovation

Most sectors in advanced economies are facing potentially transformational structural change as a result of predictive analytics, artificial intelligence, and automation. As documented in OECD food, Agriculture and Fisheries Paper N°176, many of these same transformational changes are occurring in the agricultural sector. Commercialisation and diffusion of automated technologies in agriculture is seen as a means of helping to address the pressing challenges of long-term sustainability and risk management, waning productivity growth, and transitory or sustained labour shortages.

This note explores whether and how the digital transformation of developed world agriculture and its innovation systems could be facilitated by a greater emphasis on the trust-facilitator role of the government in the digital innovation system, rather than one of direct steward or developer of digital innovations[1]. This note is not an exhaustive analysis of the many social dimensions of trust but rather a discussion of the economic issues from the perspective of the agricultural sector that are likely to apply also to other sectors within the digital economy.

As with many other economic sectors, lack of trust in digital technologies has proven to be a significant barrier to adoption (Glikson and Woolley, 2020[1]; Jakku et al., 2019[2]; Regan, 2021[3]; Wiseman et al., 2019[4])) including due to the different dynamics through which digital innovation is developed and introduced. In some cases, farmers' mistrust or negative perceptions of certain components of digital technologies can be considered to be rational. For example, some farmers' adoption-hindering beliefs relate to identified information and power asymmetries between farmers and manufacturers. Others also reflect the generally noisy process by which farmers learn about new technologies in agricultural settings and the significant uncertainties they face when considering adoption and implementation on their operations, e.g. Conley and Udry (2010[5]). Yet other beliefs could be the result of misinformation or systematic misevaluation of the technologies' net benefits.

[1] It should be reiterated that mistrust is only one dimension of farmers' complex technology adoption decisions. Further, the policy approaches and sector-specific examples presented and discussed in this study are meant to be illustrative rather than comprehensive.

Innovation in agriculture has been traditionally guided by the public sector, including through university research, and a few large equipment and input firms. However, in recent decades and many countries, the private sector has been increasing its participation in R&D and other innovation-related activities. Much of digital innovation applications for agriculture, such as data-intensive automation and monitoring or decision support services, have been advancing under the leadership of the private sector, including non-traditional actors in agriculture – whether large or a range of new, smaller firms that have been entering this space (Graff, 2020[6]; Birner, Daum and Pray, 2021[7]). This is underscored by the fact that the distinction between hardware and software applications has been declining in recent years (see Figure 1 in OECD food, Agriculture and Fisheries Paper N°176). This trend is largely explained by the proliferation of "smart" equipment – technologies relying on complicated software platforms whose development requires unique combinations of computer programming and engineering expertise (McFadden and Schimmelpfennig, 2019[8]).

The differing factors underlying farmers' mistrust in the digitalisation of agriculture suggest four key areas for policy action, which this report explores in more depth:

- Facilitating data privacy, security and data sharing
- Aligning the differing goals of sellers and buyers of digital technologies
- Assisting farmers with learning how to unwrap "black box" technologies
- Standardising, evaluating, and certifying the operations of digital technologies

A key policy question is what type of public policies and programmes can help farmers to manage mistrust in digital technology applications, and the extent to which policies can provide support and incentives for farmers to participate in the development, experimentation and uptake of digital tools.

This issues note explores several ways in which the public sector can facilitate trust and ensure that adoption is not hindered by misaligned incentives, misinformation, or other challenges. It highlights four potential issues at the intersection of trust and agricultural digitalisation, and provides a discussion of potential policy responses to address market externalities; reduce conflicts of interest between digital technology providers and input sellers; facilitate farmer-led learning; and deliver agriculture innovation systems that function well over the longer term.

## 2. Facilitating data privacy, security, and data sharing

The first area for reflection for policymakers relates to the notion that trust must be bolstered in order to resolve challenges of network externalities for digital tools. Many technologies rely on aggregation and recombination of data from a large number of farmers in order to automate the provision and implementation of management recommendations (OECD, 2019[9]). With fewer or potentially biased data, the quality of these management recommendations declines; in other words, the value of the tool (as a function of the underlying network) rises as the number of users increases. Thus, it is paramount that governments evaluate – and potentially bolster – their role in facilitating data privacy, security, and sharing arrangements.

Although many studies have touched upon the importance of trust in data sharing for digital agriculture adoption (OECD food, Agriculture and Fisheries Paper N°176), it has very rarely been quantified in a rigorous manner. Important exceptions come from small surveys of farmers in Australia, Canada, and the United States. In 2017, 32% of a sample of 1 000 Australian farmers indicated they had "no trust at all" in service/technology providers to maintain the privacy of their farm data, whereas only 6% had "total trust". Similarly, 36% of this group of farmers had "no trust at all" in service/technology providers not to share the data with third parties, with 6% having "total trust" (Wiseman et al., 2019[4]).

In a recent survey of Canadian farmers, 49% of 1 732 respondents indicated their comfort level with sharing farm data was related to their trust level (including security and privacy) with the company. In comparison, the next largest predictor of comfort level with data sharing (20% of the sample) pertained to impacts on return-on-investment. Moreover, 82% indicated they had little to no trust or had lost trust over the last two years (Canada Farm Credit, 2018[10]).

This is similar to the sentiment identified in surveys of US farmers. In a 2016 survey of more than 400 US farmers, 77% were concerned about which organisations can access their data (American Farm Bureau Foundation, 2016[11]). A 2020 survey of 610 US farmers indicated the greatest amount of trust in "my lenders and bankers" (71%) with respect to security and use of data, while only 27% of farmers trusted "private companies." Although 87% felt data on their farm's production and management practices should be as tightly secured as their family's health records, only 58% believed collecting and sharing data about production and management practices would help their operation be more financially successful in the future (Trust in Food and The Sustainability Consortium, 2021[12]).

Thus, to realise the full net benefits of digital agriculture, governments must seek to facilitate equitable and secure data sharing between farmers and technology providers – which is more likely to occur when each side of the market trusts the other. Multiple reasons lie behind farmers' mistrust, e.g. (Jouanjean et al., 2020[13]), although two are particularly relevant and lend themselves to government intervention for improvement. First, many – if not most – farmers do not understand how private companies are using data collected from their operations, including whether their data are sold or otherwise shared with third parties (Jakku et al., 2019[2]). To some extent, this is to be expected, since some technology firms collecting the data may not have developed methods for data aggregation, finalised algorithms, or identified other profitable data-based opportunities. Second, data security (i.e. protection from data breaches or leakages) is a substantial cause of concern for many farmers, especially in light of numerous highly publicised instances of large companies being "hacked."

In relation to both dimensions, prior OECD work has laid out legal aspects surrounding certain of these issues, mainly pertaining to the notion of data governance. In particular, contracts and farm data licensing, various personal data and privacy protection regulations, and intellectual property rights are all regulatory frameworks that have bearing on the degree to which farmers' data remain confidential and safeguarded at and beyond the farmgate. However, these mechanisms are still in their infancy, with legal contours that require further clarification. Amidst this backdrop of potential legal frameworks, digital sectors within agriculture have been increasingly pushing for voluntary codes of conduct and farm data co-operatives (Jouanjean et al., 2020[13]).[2]

## What can governments do to address information asymmetries hindering trust?

Many governments can draw upon their experiences of collecting reliable data from large samples of farmers for policymaking purposes to inform their trust-building initiatives. These data collection experiences, among others, include the Farm Accountancy Data Network (FADN), an instrument for collecting annual microdata on farms throughout EU member countries, as well as the Agricultural Resource Management Survey (ARMS), an annual survey of US farms conducted by the US Department of Agriculture (USDA). For decades, farmers in many OECD countries have been providing reliable farm data to national governments, notwithstanding the fact that the data are shared securely with external third parties, mainly university researchers.

In the United States, for example, there are strong reasons that farmers trust USDA when providing field-level information through ARMS, because the microdata: 1) cannot be used for (environmental) regulatory compliance; 2) are anonymised and access is restricted; 3) cannot be released to the general public through legal processes (e.g. Freedom of Information Access requests); and 4) are secure in the sense that any knowing and wilful disclosure is a felony offense, punishable by up to five years of imprisonment and fines up to USD 250 000. (See Box 1 for a case study of USDA's ARMS data collection efforts).

Nonetheless, farmers may view disclosure of farm data to the public sector as being inherently less risky than (or otherwise different from) disclosure to the private sector. In certain scenarios of high distrust between farmers and private technology providers, the public sector may be able to act as mediator or

[2] Readers are referred to this past OECD work for a thorough discussion of the many policy-relevant aspects of data governance, including national and supranational legislation, such as the EU's General Data Protection Regulation (GDPR).

guarantor of assurances in order to help remove impasses related to data sharing. One possible initiative that policy-makers could explore may be the extension of public sector protections and penalties to private farm datasets. Ultimately, however, each national government will need to tailor its trust-related policies to address farmers' specific data concerns, of which little is currently known.

### Box 1. The USDA's Agricultural Resources Management Survey (ARMS): Trust and data-sharing in large government surveys

Many OECD countries implement annual surveys of farmers' production and management practices, business and household income, and demographics of farm operators. Significant variation exists across these surveys regarding mode and coverage level, although many are designed to be representative of national commodity acreages, number of farms, and/or farm size classes. An example of one such survey, which has collected data every year on farmers' use of precision agriculture (PA) equipment since 1997, is USDA's Agricultural Resource Management Survey (ARMS).

ARMS is a complex, multi-phase survey. Phase II of ARMS contains a questionnaire that is answered by producers of a target commodity (e.g. wheat) in the survey year. The Phase II questionnaires elicit information about farmers' field characteristics, seed or livestock types, nutrient and pesticide applications, other pest management practices, field operations (including use of PA equipment), and irrigation. The Phase III questionnaires collect information on the farm business and farm household, including measures of income, expenditures, assets, and debt (USDA-ERS, 2021[14]).

Survey response rates for ARMS Phase II are relatively high, in part because survey enumerators drive to the operation and conduct the interview in person at the "kitchen table." Many of the survey enumerators tend to be seasonal employees hired by the National Association of State Departments of Agriculture, an organisation that represents the heads of the Departments of Agriculture in each state and territory of the United States.

There are various factors that contribute to farmers' trust in sharing sensitive data with the USDA via ARMS. Beyond the four factors already mentioned, some operators are more likely to appreciate the interpersonal approach associated with in-person survey enumeration, as compared to online or mail surveys. More importantly, the survey takers are generally not full-time government employees, and many are retired farmers or farmworkers, spouses of farmers, or employees retired from private agriculture companies (e.g. agrichemical dealers, equipment retailers, custom service providers). In many instances, the survey takers are well known to members of the local agricultural community and can build on (or develop) a productive working relationship with the surveyed farmer based on a shared sense of community or culture. These factors, among others, are closely related to those found to be important for development of trust between farmers and agricultural sales representatives, e.g. (Newman and Briggeman, 2016[15]).

## 3. Addressing cases of misaligned incentives of sellers and buyers of digital technologies

Underlying any government's facilitation of digital agriculture is the assumption that technology firms or service providers will not "mistreat" users. While firms have a clear interest in attempting to ensure the satisfaction of their customers, this latter concern is not a foregone conclusion – at least with respect to certain aspects of the technology or service (Acemoglu, 2021[16]). In a large number of markets, including those relevant to digital agriculture, experts first "diagnose" a condition and then treat the condition they have diagnosed, i.e., the "credence good problem" in economics parlance. Credence goods are so called because they contain one or more attributes that cannot be directly verified even after purchase.

Within agriculture, conflict-of-interest problems are likely to arise for large technology providers that also have close financial ties with manufacturers of important variable inputs (e.g. seeds, fertiliser, pesticides) or for service providers that first provide assessments and then furnish input applications. Importantly, in credence goods markets, efficiency is not fully guaranteed by competition – as prices do not adequately signal the existence or direction of biases – nor by considerations of professional ethics and reputation (Hilger, 2016[17]; Fong, Liu and Meng, 2022[18]).

It is generally not possible to fully resolve the credence good problem by providing verification because such verification is generally impossible or infeasible (i.e. prohibitively costly). However, less intractable conflict-of-interest problems could be handled by promotion of markets that sever the link between diagnosis and treatment. For example, service providers or other firms that assesses a farmer's fields to have nutrient deficiencies would not then sell fertiliser to the farmer or otherwise receive a monetary benefit from these types of tied sales.

Currently, tied sales are relatively prevalent in the agricultural marketplace. In many instances, tied products such as herbicide-tolerant corn, soybean, and cotton seeds and the tied herbicide result in substantial benefits to the farmer. In this sense, broader adoption and diffusion is a result of the innovation's high private value to farmers.

In other instances, the net benefits from linked products are less clear. For example, highly-variable crop yields within a farm – as visualised by a yield monitor – could be indicative of suboptimal fertiliser or irrigation applications, which can be partly remedied through variable rate technologies (VRT). In many instances, the same firms that manufacture and/or retail yield monitors also manufacture or retail VRT equipment and/or fertiliser. It is thus not surprising that some farmers may be sceptical of digital technologies that promise greater benefits through adoption of increasingly more expensive and complex "bundles" of technologies, e.g. (Schimmelpfennig and Ebel, 2016[19]).[3] This could become even more problematic as digital agriculture becomes increasingly integrated, with larger traditional firms acquiring smaller startups (McFadden and Schimmelpfennig, 2019[8]).

## What can governments do to help mediate between farmers and technology providers?

In the era of "prescription agriculture," governments must ensure that farmers have access to *neutral, disinterested* advisory services *that do not have financial stakes in the provision of inputs or customer services*. In certain countries (e.g. the United States), such advisory services exist in the form of extension staff funded by universities, although for-profit crop/livestock consultants also compete in this marketplace. Thus, to enhance trust, governments could encourage a decoupling of problem assessments from problem solutions in actors throughout this space. Beyond this, governments should note that trust between farmers and advisory or sales consultants is bolstered through greater openness in two-way communication, knowledge, dependability, and a genuine desire to help farmers (Newman and Briggeman, 2016[15]). Extension services may thus evolve within the context of agricultural digitalisation (Box 2).[4]

In a similar vein, governments should exercise caution when considering substituting systems of national data collection with data obtained directly from farmers' operation of precision equipment on their fields, e.g. (Milgrom and Roberts, 1986[20]). Apart from the serious caveats that data from farm equipment may not be: 1) accurate (i.e. equipment may not be calibrated correctly); 2) representive (i.e. farmer-customers are likely to have some measure of brand loyalty); 3) accessible (i.e. private firms may not be compelled

[3] In some sense, certain digital technologies can be considered to be "complex" because they involve more linkages among inputs than other technologies (e.g. herbicides and herbicide-tolerant seeds). For example, georeferenced maps are used in tandem with algorithm-based management apps to develop high-resolution management plans, which then typically require specialised technology and high-speed internet to implement on the field.

[4] To the extent that extension and advisory services staff are trained in traditional agricultural schools, there is likely to be an increasing need to re-evaluate higher education curriculum and training programs to ensure acquisition of relevant computer-based and other technical skills of relevance for the digital agricultural economy. This could entail incorporation of (or additional) coursework in data science, in addition to education on the design of technical standards to ensure interoperability and reliability of equipment.

to provide microdata to policymakers or their staff); or 4) comprehensive (i.e. equipment cannot capture farm income, farm and household assets, off-farm labour), there are potential conflict-of-interest problems.

First, firms could collect or report data from farmers' equipment in a way that enhances their likelihood of tied sales to the same farmer or other farmer-customers within similar market segments. Second, firms could selectively provide data or summaries of data to policymakers in a way that best promotes their financial goals – goals that may or may not fully align with policymakers' objectives. The risk of reporting improprieties requires careful management if trust is to be built.

### Box 2. Extension services in the digital era

Traditionally, extension agents have had expertise in the production of crops or livestock in local regions, oftentimes with very specific knowledge of suitable varieties, local weather patterns, soil types and topography, and other production conditions. This expertise is informed by agronomic and economics research, usually performed at nearby universities, and then communicated in an objective fashion to farmer-stakeholders. As such, extension agents are often crucial, trusted actors within regional farming communities that facilitate adoption and use of equipment and other inputs as appropriate for particular farming operations. More recently, the private sector has been increasingly carrying out extension activities along with the provision of services and inputs.

Deepening agricultural digitalisation may bring about large changes to the traditional extension model and deepen ongoing changes in private extension agents, however. Local production conditions and methods are being "learned" by machines with access to large amounts of geo-referenced soil, weather, and production data. Based on these data, in tandem with an analysis of results from thousands of field trials, algorithms have been developed and are being refined to provide recommendations for crop/livestock varieties, planting times, agrochemical and irrigation applications, pest management practices, and harvest operations.

Availability of these services and use of these algorithmic recommendations are not currently widespread, in part because they are not fully developed, nor are they fully trusted. However, should usage rates substantially increase, the role of the extension agent may transition to one requiring much greater expertise in software application development, data science, and digital systems more broadly. Such transitions are to be expected in light of economic theory suggesting automation and greater digitalisation will bring about potentially sweeping changes to the kinds of tasks routinely performed in jobs across many sectors of the economy, e.g. Acemoglu and Restrepo (2019[21]).

## 4. Assisting farmers with learning how to unwrap "black box" technologies

Although mistrust between farmers and digital technology firms is not unexpected in the face of cases of misaligned incentives, another source of mistrust arises from the nature of farmers' means of learning about new digital technologies, which inherently involves some uncertainty. Generally, farmers would like to be assured that automated recommendations from "black box" technologies result in outcomes that are more profitable relative to a reference scenario – usually a scenario in which the farmer makes an assessment and then ultimately decides on the optimal course of action.

Yet due to "noise" in application scenarios (e.g. unfavourable weather conditions, pest infestations), the perceptions of a tool's net benefits may diverge sharply from actual net benefits, e.g. Lybbert and Bell (2010[22]). For example, crop farmers attempting to learn about the profitability of variable rate fertiliser applications could be stymied if heavy, late-season rains cause nutrient applications to run off fields prior to absorption by the crop. In such a case, without taking into account the adverse weather conditions, the farmer could mistakenly assess variable rate fertiliser applications to be ineffective. Farmers face similar challenges when attempting to learn about the net benefits of other technologies (McFadden et al., 2019[23]).

Scepticism thus tends to arise from the farmer's limited or lack of direct experience with the technology on their operations, or even from "word-of-mouth" appraisals from other farmers whose operations may be too dissimilar, such that their appraisals may be of limited relevance to the farmer. As more farmers use the technologies, however, it must be noted that experiences and information exchange between farmers could be positive drivers for their diffusion.

## What can governments do to enhance learning about digital agriculture?

To remedy this, governments could encourage greater on-farm experimentation with new digital technologies (see Box 3 for more information about the on-farm experimentation). By empowering farmers to assess the performance of technologies – over more than one season – on their fields, governments can reduce bias and mistrust. This type of policy, though indirect, has been underway for years in the United States, for example.

The Conservation Stewardship Program (CSP), in existence since 2008, provides annual payments to US participants for improving their environmental performance to address resource concerns. Farmers enter into five-year contracts with USDA, with the opportunity to compete for contract renewal if the initial contract has been met and an agreement has been reached for the farmer to achieve additional conservation goals.

Many precision agriculture practices are explicitly recognised and incorporated into CSP contracts, including controlled traffic farming to reduce compaction, monitoring and recording of soil moisture for use in farmers' decision making, and precision fertiliser and/or pesticide applications to reduce the risks of run-off or leaching into water supplies. Use of these specific practices through CSP has so far been minor, though adoption – as measured by cropland area enrolled – has been gradually increasing since at least 2017 (USDA-NRCS, 2021[24]). Importantly, this (and related USDA programmes like the Environmental Quality Incentives Program) is not a simple subsidy scheme designed to encourage farmers' uptake of digital agriculture tools. Rather, the programme provides cost-sharing financial assistance for farmers' use of these tools because they facilitate the agri-environmental policy goals of interest to national decision makers.

### Box 3. The on-farm experimentation community of the International Society of Precision Agriculture

Experimental use of technologies has been undertaken by farmers on an as-needed, ongoing basis for many decades, if not centuries. One common practice has been to use a single field, or a portion of a small field, to perform a "side-by-side" test of a particular seed variety, agro-chemical application, type of machinery, or other technology – with a neighbouring field or strip serving as a "control" that represents the farmer's management under business as usual. Outcomes are then compared between the two plots, with the difference serving as very small-sample evidence of the effects of the technology.

These types of on-farm experimental trials are generally convenient and easy to implement. More importantly, they allow the farmer to gain direct experience with the technology without bearing the kind of substantial economic risks that would ensue if the farmer were to adopt the technology for the entire operation. One substantial downside, however, is that the trial provides only limited evidence of the technology's effects. Moreover, a comparison of outcomes between the two plots can result in skewed decision-making if preparation and management of the two plots are not carefully controlled to ensure that the only difference in outcomes is due to the technology.

Because of the hands-on experience and "learning by doing" that farmers receive from on-farm experimentation, which can, in turn, drive adoption of technologies on entire operations, there has been renewed interest in promotion of this approach. In recent years, the International Society of Precision Agriculture, a group of university researchers that organises international conferences on precision agriculture, has provided an online forum for the exchange of information about on-farm experimentation. The community focuses on "compiling practical, applied, proven-to-be useful resources" and "connecting practitioners" (International Society of Precision Agriculture (ISPA), 2021[25]).

Communication of best practices related to on-farm experimentation, especially because of its relation toward boosting technology adoption, has an important role to play in the expanded use of digital agriculture. The ISPA community provides a valuable international forum in which practitioners (e.g. extension staff) – in many instances from OECD member countries – regularly network and interact. As such, the diffusion of information between precision agriculture professionals, who are oftentimes focused solely on applications in their home countries and sub-national regions, is accelerated.

Moreover, implementation of an approach that encourages on-farm experimentation would also likely involve new opportunities for public-private collaboration, e.g. Yost et al. (2018[26]). It could also spur the development of new products and service-related initiatives from the private sector (see Box 4 about risk-sharing arrangements in certain digital agriculture applications).

### Box 4. Risk sharing in digital agriculture applications

All product sales, including commercial applications in digital agriculture, involve some measure of inherent risk (e.g. product failure, termination of a seller's follow-up customer service, seller bankruptcy after "locked-in" sales). These risks are typically split – proportionately, in some cases – between buyers and sellers. However, potential buyers who are sensitive to risk considerations, i.e. risk-averse, may be more willing to purchase the product if the seller's return policy includes a money-back guarantee, for example.

Early work by economists has established that, in simple cases, money-back guarantees are risk-reducing mechanisms that cause increases in the demand for a product. Under some conditions, if sellers are less risk-averse than buyers, sellers will find it profitable to bear all risk in the transaction, even though there could be more socially optimal risk-sharing arrangements (Heal, 1977[27]). Additional work has investigated optimal arrangements when there is excessive uncertainty, bundling of the product sale and the guarantee (relative to a guarantee being sold separately from the product), and replacement warranties, e.g. (Mann and Wissink, 1988[28]; Mann and Wissink, 1990[29]).

A main issue for farmers when considering the purchase of a digital tool that provides input recommendations (i.e. "prescriptions"), for example, is whether purchase and use of the tool would result in higher net returns than a scenario in which the tool was not purchased (or rented). To some extent, this concern could be partially addressed by suppliers through bundling of money-back guarantees or other forms of "satisfaction guarantees."

This type of arrangement is somewhat similar to an outcome-based pricing pilot programme in the United States launched by Bayer in 2019. Under this arrangement, Bayer develops an expected yield for its product (e.g. seed variety) on a particular farm based on the company's internal models and the farm's historical data stored in Bayer's digital agriculture platform, FieldView. If the farmer's yield falls below the expected yield, Bayer rebates a portion of the product price back to the farmer. If, however, the farmer's yield exceeds the expected yield, the farmer provides a pre-agreed portion of the additional revenues arising from the positive yield difference to Bayer (Unglesbee, 2019[30]).

## 5. Standardising, evaluating, and certifying the operation of digital technologies

The fourth issue concerns the role of standardisation, an important aid towards building consumer confidence in agricultural technologies. Organisations such as the American Society of Agricultural and Biological Engineers (ASABE) and the International Organization for Standardization (ISO) are heavily involved in developing standards for use in the manufacture of agricultural equipment. Relevant standards from these organisations relate to many dimensions of the machine and component parts, including performance, noise, safety, and environmental quality.

A key difficulty is the lack of standards to compare, evaluate and certify operations of precision equipment. This would allow for easier comparisons of functionality by broad technology categories, while providing for greater transparency in such input markets. Standards can also reduce technological "lock-in" issues for farmers, thus lowering switching costs and promoting greater competition.

In general, standards can be publicly or privately provided, mandatory or voluntary, and serve product differentiation and/or risk management purposes (Henson and Humphrey, 2010[31]). Depending on the market context, standards can help to correct externalities (e.g. public safety, noise, air/water pollution), which, in turn, boosts consumer confidence in the end product. Importantly, increases in demand due to improved consumer confidence can result from increased trust and awareness on the part of domestic consumers, as well as international consumers. The latter dimension suggests large implications for international agricultural trade, especially for products covered by sanitary and phytosanitary measures, e.g. Disdier, Fontagné and Mimouni (2008[32]).

### What can governments do to facilitate standards, evaluations, and certifications?

One simple example of standardisation and trust-building within a food market application is USDA's "certified organic" seals. This type of food product labelling indicates to the consumer that the food's ingredients meet the National Organic Program's organic standard – a comprehensive set of production practices that typically excludes use of synthetic fertilisers and pesticides and genetically-engineered seed varieties, among other criteria. USDA then contracts with third-party organisations to routinely audit the relevant farms to verify that the operation's management practices are consistent with the standard. Overall, this system provides assurances to the consumer that the food's production process is: 1) well defined (as opposed to, for example, unregulated and arbitrary claims of "all natural" in other segments of food markets); and 2) in line with national organic standard. Both dimensions boost demand through greater consumer trust.[5]

As regards digital agriculture and standardisation, most farmers are concerned with the profitable use of digital tools on their operation. The development and application of standards for new autonomous equipment, for example, would not guarantee that its use would result in more profitable outcomes to farmers. However, by defining a set of transparent and common criteria, standards can directly increase farmers' trust in new equipment – especially when used in systems that allow for evaluation of machinery, to ensure they adhere to the standards, prior to sale, e.g. McFadden (2021[33]). See Box 5 for a discussion of how the OECD Tractor Codes – a system of harmonised standards, certification, and mutual recognition agreements – boosts international trade in agricultural tractors.

A closely related notion is industry codes of conduct. These are largely a set of written, non-binding rules developed by an industry describing how participants in the sector are advised to behave. In the context of digital agriculture, voluntary codes of conduct have been developed to encourage transparency and disclosure in agricultural data contracting. Examples of such codes include the EU Code of Conduct on Agricultural Data Sharing by Contractual Agreement, the Charter on the Digitalisation of Swiss Agriculture

[5] Although this example is centred on a particular production practice and trust by consumers, it is relevant within the context of digitalisation since standards and certification schemes can also boost producer trust for technology adoption (Box 5).

and Food Production, France's Charter on the Use of Agricultural Data, and New Zealand's Farm Data Code of Practice, among others (Jouanjean et al., 2020[13]).[6]

By and large, voluntary codes of conduct have not been established for digital agriculture equipment (i.e. tools rather than agricultural data or data platforms) or algorithms for developing high-resolution input recommendations. Nonetheless, such codes could, in principle, be formulated based on best practices learned in the development of codes related to agricultural data contracting. When coupled with certification, such codes could be an effective alternative to legally binding standardisation.

### Box 5. Consumer trust and standardisation: Evidence from the OECD Tractor Codes

The OECD Standard Codes for the Official Testing of Agricultural and Forestry Tractors were established in 1959 to develop and implement standardised methods for countries to assess tractor performance. Since this time, the Codes have been extended to tests of noise and physical safety.

Recognised stations in participating countries perform the tests, which are submitted to OECD and then independently verified by third party contractors. Approved tests are published, mutually recognised by all member countries, and used by tractor manufacturers, machinery and equipment dealers, and buyers. Nearly 11 000 tractors have been tested for noise levels and driver protection; over 3 000 tractors have been tested for performance (OECD, 2020[34]).

The Codes decrease information asymmetries about attributes between governments and firms and increase consumer demand because of third-party verification of performance and safety features. This latter mechanism is not unlike the demand effects from third-party verification and labelling of credence attributes in foods (e.g. organic attributes), for example. The Codes are also expected to 1) reduce export costs because of avoided duplication of test across markets, 2) lower transaction costs associated with tractor trade disputes if they arise, and 3) simplify manufacturers' risk management.

One recent study has demonstrated that the OECD Tractor Codes has large positive effects on international tractor trade. Particularly, the volume of aggregate tractor trade is 33% higher when two trading countries are both Codes members. This finding is robust to several considerations, including the possibility that the Codes do not have instantaneous trade effects because of the need for manufacturers to re-orient or otherwise adjust their supply chains in response to testing requirements. Moreover, this finding varies based on the level of economic development of both trading countries, and to a lesser extent, the broad timing of countries' accession to the Codes (McFadden, 2021[33]).

Experts associated with the Codes have begun to consider how tests can be developed for agricultural robots and autonomous machines. A new code has not yet been written, much less finalised, for such equipment, but there is a clear need given the industry's concerted efforts to autonomise tractors on an abbreviated time scale, e.g. (White, 2021[35]).

[6] See (Jouanjean et al., 2020[13]) for a discussion of standards with more emphasis on software and data, including interoperability standards and development of platforms to facilitate data transfer among market participants.

## 6. Lessons learned

A substantial impediment to farmers' adoption and broader diffusion of digital agriculture tools is the lack of trust in seemingly complex technologies. Four issues explain this luck of trust: 1) problems of data privacy, data security, and trust in data sharing; 2) cases if misaligned incentive between of sellers and buyers of digital technologies; 3) difficulty in learning how to unwrap "black box" technologies; and 4) lack of standards for comparing – and certifying – the operations of digital technologies.

Each of these challenges has potential policy responses:

- First, identify farmers' main concerns with digital agriculture on their operations.
- To reduce distrust in technology providers as a result of tied sales, governments should encourage unbundling of services on problem assessment from problem solutions.
- Governments should not rush to abandon systems of national data collection in favour of data obtained directly from equipment on farmers' fields because such data, at least currently, may be less accurate, representative, accessible, and comprehensive than carefully collected national survey data.
- To hasten farmers' experiential learning with digital technologies, governments should seek ways to promote on-farm experimentation with these tools, either directly or indirectly.
- Where appropriate, public-private collaborations in the digital agriculture space should continue to be established and nurtured.
- Innovative risk-sharing arrangements between technology providers and customers, as a way of incentivising market participation of particularly risk-averse farmers, should be encouraged.
- Standardisation and certification of algorithms underlying highly-detailed agricultural management recommendations – or the tools themselves – should be considered. International standardisation initiatives can additionally enhance trade and competition.
- In situations where standardisation is infeasible or otherwise inappropriate, voluntary codes of conduct, especially when coupled with third-party certification or accreditation, may be a useful alternative.

A multi-pronged approach is likely to be part of the optimal path forward for bolstering trust and unlocking the full potential of digital technologies in agriculture. Governments should prioritise their interventions based on evidence of trust gaps and the potential cost/benefits the measures.

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