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Adoption of Blockchain Technology in the Australian Grains Trade: An Assessment of Potential Economic Effects*

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Recent analysis of Blockchain use has highlighted considerable potential productivity gains arising from lower transaction costs between buyers and sellers of goods. This has been shown by recent examples of Blockchain use in the Australian grains sector. In this paper, we have further developed and quantified this concept of productivity gain by undertaking several illustrative scenarios using a general equilibrium model of the global economy. Our analysis indicates that an assumed modest growth (five per cent) in productivity due to Blockchain use in the grains sector could raise output by eight per cent over the medium term. If this is accompanied by Blockchain use in the Australian finance sector, grains output could reach ten per cent. This reflects the effect of reduction in transaction costs due to the use of Blockchain technology as a "distributed ledger technology" in grain trading. Further, it is anticipated that the wider effects of Blockchain-driven productivity enhancement of the Australian finance sector could contribute to approximately 2.5 per cent increase in GDP in the medium term, relative to what would otherwise be.

Keywords: Australia, Blockchain, general equilibrium modelling, grains trade, productivity.

1. Introduction

An increasing attention is being given to the potential use of Blockchain technology to generate productivity gains in an extensive number of sectors, ranging from finance, energy, agriculture, health, land and property management and development aid, to government services and beyond (Pisa & Juden, 2017; Kim & Laskowski, 2017; Hanson *et al.*, 2017; Staples *et al.*, 2017; International Finance Corporation, 2017a).

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According to Iansiti and Lakhani (2017), Blockchain technology is underpinned by five basic elements: a distributed database; peer-to-peer transactions; transparency; irreversibility of data records; and computational logic (see Box 1).

It has been argued that Blockchain technology has the potential to become a general-purpose technology (GPT; Catalini & Gans, 2016; International Finance Corporation, 2017a). Commonly known historical examples of GPTs include the steam engine, the electric motor, semiconductors and the Internet. In general, these GPTs play the role of enabling technologies in that they facilitate the development of new opportunities and can find application in many sectors and industries. They have the inherent potential to generate significant technical improvements over time which can spawn ground-breaking innovations. With such characteristics, GPTs generate economic activity and, in time, lead to generalised productivity gains.

Given this background of the potential impacts of the use of Blockchain technology, our focus here is on its potential use in the Australian grains industry. We see that there are several reasons for the need for this initial speculation. First, amidst substantially growing investment in approaches to aspects of "digital agriculture" and increasing interest in Blockchain, there have been several recent pilot use case examples of the adoption of Blockchain in the Australian grains industry. For example, in 2016, an Australian wheat grower delivered a consignment of wheat to an exporter in Dubbo, NSW, using Blockchain technology and received payment promptly. This was regarded as a global first between a grower and buyer within the agricultural industry (Australian Financial Review, 2016). Similarly, in 2017, a delivery of oats by an Australian grain grower cooperative (CBH) to a buyer took place using Blockchain technology (AgriDigital & CBH Group, 2017). In both cases, "distributed ledger technology," which underpins Blockchain technology, has been used for the transaction. This meant that no intermediaries were involved, which in turn reduced the transaction costs for the trading parties.

Box: Key elements of a Blockchain system

A *distributed database* in Blockchain technology is similar to a distributed network or a distributed ledger. All the participants (or users) within a Blockchain have access to the entire distributed database, which means that no single participant controls the information or data on a Blockchain. Thus, without need for an intermediary, every participant can verify the records of its transaction partners directly.

Within a Blockchain, *peer-to-peer transactions* take place directly between peers via the nodes (i.e., the peers' or participants' computers on a Blockchain network). Each user/participant both stores and forwards information to all other nodes within a Blockchain, instead of being routed through a central node. This data sharing represents the "distributed nature" of the data or information base within a Blockchain.

It is this distributed nature of the database or the ledger that generates its *transparency*. In practice, every transaction and its associated value are visible to all the users or participants with access to the Blockchain system. Furthermore, in such a system, the submitted records cannot be changed once a transaction is entered in the database and the records are updated. This security arises because every legitimately entered piece of data is intimately linked to every other transaction record that has been previously entered. The term "chain" arises from this process. Overall, the records on the database are permanent, *irreversible*, chronologically ordered and only available to legitimate participants on the network. This is ensured through the use of various computational algorithms and approaches.

The cryptographic and digital nature of the distributed database means Blockchain transactions can be linked to *computational logic*, and therefore, in essence, they can be programmed. Hence, users or participants (who are termed nodes) can set up algorithms and rules that automatically trigger transactions between the chain's nodes (Iansiti & Lakhani, 2017).

Second, there have been several recent examples of the use of Blockchain technology in agriculture. For example, the Commonwealth Bank of Australia, Wells Fargo and Brighann Cotton have recently undertaken the first global trade transaction between two independent banks combining the Blockchain technology, smart contracts and Internet of Things (IoT). The transaction involved a shipment of cotton from Texas, United States to Qingdao, China, using the efficiencies of a distributed ledger – Skuchain's Brackets system – for all parties (see Pearce, 2018; Weston, 2018). Additionally, the Cooperative Research Centre (CRC) for Food Agility, Queensland University of Technology and Beef Ledger Ltd are currently undertaking a project using Blockchain and IoT to create an unbreakable, immutable record, tracking beef from paddock to plate, credentialing the provenance of Australian beef. This information will drive apps for consumers and suppliers, giving them confidence that their meat is 100 per cent Australian (see https://www.foodagility.com/projects/beefledger-export-smart-contracts).

Recently, Zhao *et al.* (2019) have used a systematic literature network analysis to review the state-of-the-art Blockchain technology including its recent advances and main applications in agri-food value chain. Their findings indicate that Blockchain technology together with advanced information and communication technology and Internet of Things has been adopted for the improvement of agri-food value chain management in four main areas: traceability, information security, manufacturing and sustainable water management.

According to Kamilaris *et al.*, (2019), Blockchain technology is already being adopted by many projects, aiming to establish a proven and trusted environment to build a transparent and more sustainable food production and distribution, and integrating key stakeholders into the supply chain. However, there are still many issues that need to be addressed, beyond those at technical level.

A recent review of Blockchain applications in the agri-food sector by Antonucci *et al.*, (2019) indicates the need for greater real-world case studies. According to Sylvester (2019), the key drivers of the use of Blockchain technology in the agriculture domain include self-executing smart contracts together with automated payments. The role of smart contracts especially in agricultural insurance and traceability could be very effective. Agricultural insurance built on Blockchain technology with key weather incidents and related payouts drafted on a smart contract would facilitate immediate payout in the case of a drought or flooding in the field.

Third, there is presently limited quantitative analysis of the economic impacts of Blockchain use. Given the paucity of this evidential background, the purpose of this paper is to undertake an illustrative quantitative analysis of the potential economic impacts of Blockchain technology use, with a particular focus on the Australian grains industry.

The paper is organised as follows. Section 2 provides a broad analytical framework which underpins our approach to analysing the economic effects of Blockchain use. The scenario analysis of the potential economic effects of Blockchain adoption in the Australian grains trade is provided in Section 3. Section 4 provides the results of our scenario analysis. The final section provides some discussion and conclusions.

2. Analytical Framework

Two schools of thought have emerged in the literature in relation to analysing the economic effects of Blockchain. These are (i) the innovation-centred approach and (ii) a governance-centred approach (Davidson *et al.*, 2016), each of which will be summarised here.

2.1. The Innovation-Centred Approach

According to the *innovation-centred approach*, Blockchain is an information and computation technology (ICT) and can be regarded as a software protocol based on cryptography. It can also be regarded as a technology for public databases concerned with digital information, and as such, it can lead to technology-driven efficiency/productivity improvements (Davidson *et al.*, 2016).

This claimed source of the productivity gain can often be traced to an organisational efficiency gain. Blockchain helps lower production costs by changing the organisational form by which value is created, often stripping out layers of activity (e.g., the intermediaries) that are no longer required. In this respect, Catalini and Gans (2016) have identified two key costs that are affected by the distributed ledger technology which underpins Blockchain, namely, the cost of verification and the cost of networking. These are important components of transaction costs which reflect the cost of intermediation which buyers and sellers incur when they cannot efficiently verify all the relevant attributes of a specific transaction by themselves.

A well-functioning market relies on robust identity verification as well as on the ability to verify the goods and services being exchanged. Here, the key issues include the provenance of the data, how transactions were changed or transformed through the supply chain, and an understanding of the credentials of the parties involved, such as their professional licensing and registration status. In general, within an industry the identity and credentials' verification of those involved in transactions relies upon intermediaries such as governments and other entities including banks and financial institutions. However, in general there is always some degree of information leakage and risk of reuse of private information outside of the designated transactions, but it is claimed that Blockchain technology can reduce this risk by allowing for authentication without disclosure of sensitive information (Catalini & Gans, 2016). For example, in ecommerce and online investment activities, various processes of transactions require verification of ownership, checks and balances using various intermediaries such as financial institutions. Blockchain helps to both assure the security of essential knowledge transfer, and to lower the cost of these verifications. It hence improves the efficiency of these transactions (Catalini & Gans, 2016; Suikkanen, 2017) using decentralised solutions without the use of intermediaries. Davidson *et al.* (2016) argue that these decentralised solutions to ledgers can become increasingly cost-efficient compared to centralised solutions, leading to significant efficiency gains.

Davidson *et al.* (2016) also argue that productivity gains resulting from the use of Blockchain can be viewed in the form of shifts in the aggregate production function which translates into multifactor productivity growth. In addition, they point out that a more transformational aspect of Blockchain approaches is that it gives rise to new organisational and institutional forms of economic governance which clearly makes Blockchain a general-purpose technology (GPT).

In this paper, we pursue the productivity impact-related aspect of the likely effects of the use of Blockchain. In particular, we focus on the potential productivity improvements due to the adoption of Blockchain as a vector for information and communication technology (ICT). In particular, we focus on the nature of a Blockchain-enabled efficiency improvement in a sector or industry where it is employed (see Davidson *et al.*, 2016), and this line of investigation is further expanded in Section 3.

2.2. Governance-Centred Approach

The premise of the *governance-centred approach* to the economics of Blockchain is that the transformational aspect of this technology can give rise to new organisational and institutional forms of economic governance (Davidson *et al.*, 2016). In this context, the understandings drawn from transaction cost economics (see Williamson, 1973, 1975,1985) may provide useful insights in relation to this approach (see Davidson *et al.*, 2016). In this respect, according to the transaction cost economics, markets and firms are alternative institutions of economic governance (see Williamson, 1975). In other words, these institutions are the sites that actually organise transactions, and of relevance here is that transaction costs in markets originate from information costs, bargaining costs and enforcement costs of contracts (Suikkanen, 2017).

It has been noted (see Williamson, 1985) that one of the basic insights of transaction cost economics is that the transactions that occur in markets can create room for opportunism. According to Williamson (1985), the existence of organisational form is largely shaped by the need to control opportunism. Whereas markets are often efficient governance institutions for spot contracts where there is immediate payment and delivery, in situations where the economic activity requires asset specificity (coordinated investment through time), frequency (ongoing relation between parties) and uncertainty (un-contractible dealings), alternative governance institutions are needed to deal with the hazard of opportunism (Williamson, 1985).

An important approach, which is available to mitigate opportunism, is to introduce a trusted third party, like a bank or a real estate agent, who can facilitate and manage the trust between the two relevant agents of the transaction (see Williamson, 1985; North, 1990). Accordingly, firms and intermediating centralised entities such as banks have emerged as a mechanism to deal with opportunism (Suikkanen, 2017). Catalini and Gans (2016) argue that Blockchain technology is "more likely to change the scope of intermediation" through reduction of transaction costs and by allowing the formulation of new types of marketplaces.

In this respect, Gifford and Cheng (2016) have analysed the implementation of real-time settlement of banks using distributed ledger technology (Blockchain technology) and have highlighted the potential to considerably lower the cost of financial transactions associated with fund transfers, either bank-to-bank or cross-border transactions. They further argue that innovations built on Blockchain technology will lead to "value movement," providing a way for financial transactions to be carried out as seamlessly as information movement over the Internet. While these innovations are still at early stages, their potential impacts on lowering the cost and time of financial transacting could lead to significantly increased productivity and enhanced economic activity.

As discussed earlier, the transactions on a distributed ledger or database which underpins Blockchain technology are cleared using a "protocol" or set of automated rules, instead of needing a central intermediary to execute and confirm transactions. Such "protocol" can be adapted to financial payment systems using fiat currencies (such as A$ or US$) to settle transactions between parties without necessarily using digital currencies (Gifford & Cheng, 2016).

There are, nevertheless, always operational and technical risks associated with the adoption of new approaches such as Blockchain technology in financial transactions. Gifford and Cheng (2016) point out that one of the principal risks of using Blockchain technology lies in the application of relevant laws and regulations to financial transactions involving the use of this mechanism. Crucial to a distributed financial transfer framework is the question of certainty and clarity as to the participating parties' or entities' rights and liabilities. Addressing these critical issues requires appropriate industry, legal, regulatory and policy frameworks at domestic and international level (Gifford & Cheng, 2016).

A particularly interesting possibility is that lowered transaction costs due to the use of Blockchain technology could help generate the conditions for the creation of new products and services. Gifford and Cheng (2016) point out that innovations which are already in the development stage that foster Blockchain-type technology include applications for the integration of physical and technological systems (often referred to as the *Internet of Things*). These applications would permit functionalities such as enhanced collateral management and greater automation of trade finance, and smart contracts that can streamline various finance-related processes (Gifford & Cheng, 2016). Indeed, in this paper, we particularly focus on the potential reduction in transaction costs, such as the cost of verification and cost of networking, due to the use of a distributed ledger technology which underpins the use of Blockchain (Catalini & Gans, 2016). This is further elaborated in the Section 3.

Blockchain-based smart contracts are contracts that are executed automatically and are supervised by the consensus of the decentralised Blockchain network. Smart contracts facilitate, verify or enforce the negotiation or performance of a contract (Davidson *et al.*, 2016).

Given this background, Davidson *et al.* (2016) argue that Blockchain is in a sense a new type of rule system for economic coordination. According to these analysts, alongside firms, markets, clubs, commons and governments, we now also have Blockchains.

2.3. Productivity Gains due to ICT/Digital Technology

Several studies have estimated the potential contribution of the ICT/digital technologies to the domestic economic growth and improvements to industry productivity. For example, according to the Productivity Commission (2004), increased use of ICT/digital technology can contribute to both increased output and input productivity growth. Increased output growth will come from any effect that increased ICT/digital technology use has on input growth and multifactor productivity (MFP) growth. It has been estimated that the contribution of ICT/digital technology use to the acceleration in Australia's annual MFP growth is around 0.1–0.2 of a percentage point (Parham, Roberts & Sun, 2001; Parham, 2002). Furthermore, growth in ICT use in Australia accounted for about 0.07 of a percentage point of annual market sector MFP growth and about 0.02 of a percentage point of annual finance and insurance sector MFP growth (Productivity Commission, 2004).

According to the econometric analysis undertaken by the Productivity Commission (2004) across major industry groups in Australia, ICT uptake had a statistically significant association with more skilled managers and workforce. Another potentially important complementary input is of an organisational nature that goes beyond the skills and experience of the personnel within a firm. How firms learnt from their experience of success and failure, a form of accumulation of "organisational capital," was also seen as an important influence on investment in ICT over time (Productivity Commission, 2004). Based on a cross-country regression, Bean (2000) has estimated that the increase in ICT investment contributed 0.12 of a percentage point to MFP growth (see Productivity Commission, 2004). In general, the estimates of the percentages added to GDP by Internet-related value for various developed economies range from 1.4 for Turkey to 7.2 for the United States, with Australia at 3.6 per cent (OECD, 2013).

Further, some estimates suggest that the digital economy can contribute $27 billion in productivity benefits to Australian businesses and government entities (Deloitte Access Economics, 2011). Other estimates indicate that through the impact of the digital economy, Australia could return back to its long-term productivity growth rate of 1.7 per cent per year by 2020 (IBIS World, 2012). In this respect, Griffith *et al.,* (2013) point out that the rollout of the national broadband network in Australia together with the adoption of smart digital services has the potential to assist the agricultural sector improve its productivity. They argue that while computing and sensor technologies have been used on Australian farms for the last several decades, adoption has been uneven and the full potential of this change is as yet unrealised.

Keogh and Henry (2016) report that the extent of productivity gains due to the use of digital agriculture systems in order to implement more intensive and data-driven farm management decisions in Australia, can range from ten to fifteen per cent in cropping systems, with about half the gains coming from input efficiencies, and the other half from increases in output.

The relationship between Blockchain technology and productivity growth in the grains sector (which is the focus of this paper) is underpinned by the processes whereby adoption of this innovative digital technology changes the grain trading/marketing systems. This process involves a Blockchain technology-driven lowering of the transaction costs between the grain growers/sellers and buyers which facilitates prompt and speedy payment for grain sales.

It is important to recognise that lower transaction costs in grain trading (driven by the use of Blockchain technology) are likely to lower the overall cost of grain trading services for the growers by affecting their requirement for labour, capital and other inputs per unit of grain output sold.

These factors are likely to contribute favourably towards the financial position of the grain growers, with flow on impacts on their farm business activities. Better farm business performance is likely to favourably influence farm resources allocation and the requirement for scarce land, labour, other inputs and capital resources per unit of grain output.

It is expected that these factors in turn reflect an incentive for growers to increase grain output relative to what would otherwise be. The aggregate of these changes determines changes in productivity and other performance indicators, such as profitability.

Of considerable concern is that it has been pointed out that the rate of digitisation in Australian industries is uneven, and is still therefore some distance away from realising its full potential. Whereas knowledge-intensive industries like financial and professional services have taken a lead in this area, construction and agriculture have only developed low levels of digitisation (McKinsey & Company, 2017).

It has been shown that the Australian finance and insurance sector performs strongly through its focus on its digital supply chain, and is evidencing benefits from its digital spending on workers and assets. Exceptions are for digital transactions and customer service interactions. This latter observation suggests that the finance and insurance sector still have significant work to do in achieving international best practice in levels of digital sales and service (McKinsey & Company, 2017).

3. Analysing the Economic Effects of Blockchain Use

In this paper, we use the Global Trade Analysis Project (GTAP) model (Hertel, 1997) to analyse the economic effects of Blockchain use in the Australian grains sector. The standard GTAP model is a widely used computable general equilibrium (CGE) tool for economy-wide global market analysis, being a multiregional and multi-sectoral general equilibrium model of the global economy. We follow Valenzuela and Anderson's (2011) methodology to construct a projection of the world economy to 2030, and use it as our baseline scenario. The GTAP database version of the model used in this paper comprises a ten-region by seven-sector aggregation of the global trade analysis project database, version 9 (Aguiar *et al.*, 2016). The ten regions include Australia, Rest of Oceania, the United States, Rest of North America, Central and South America, Europe, Asia, Africa, Middle East and Rest of the World. The seven sectors include grains, other crops, rest of the other primary commodities, light manufacturing, heavy manufacturing, financial services and other services.

We quantify the potential economic effects of Blockchain use in the Australian grains sector by using the GTAP model, and undertaking the following illustrative scenarios:

1 Blockchain use (grains) scenario: productivity in the Australian grains sector is assumed to increase by five per cent over ten years (2020–2030) resulting from the adoption of Blockchain technology in trading activities of grain producers. The assumed productivity growth rates are illustrative only. Our premise here is that, given historical trends in productivity improvements in key industry sectors due to ICT/digital technology adoption (Bean, 2000; Parham, Roberts & Sun, 2001; Parham, 2002; Productivity Commission, 2004; OECD, 2013; Keogh & Henry, 2016), it is plausible to assume that greater adoption in the Australian grains sector of emerging digital technologies such as Blockchain technology will result in further enhancement of productivity as assumed in this illustrative scenario;

2 Blockchain use (finance) scenario: productivity in the Australian financial sector is assumed to increase by five per cent over ten years (2020–2030) due to the adoption of Blockchain technology in the financial sector resulting in lower transaction costs facing the grains producers. The assumed productivity growth rates are illustrative only. Our premise here is that, given historical trends in productivity improvements in the finance sector due to ICT/digital technology adoption (based on Productivity Commission, 2004; McKinsey & Company, 2017), it is plausible to assume that greater adoption in the Australian financial sector of emerging digital technologies such as Blockchain technology in digital sales and services (including digital transactions and customer service interactions) will result in further enhancement of productivity as assumed in this illustrative scenario;

3 Combined scenario: this scenario combines scenarios 1 and 2.

Our premise here is that these three illustrative scenarios will provide some insights into the plausible and likely magnitude of productivity effects that approximate or reflect potential productivity enhancements in the Australian grains sector resulting from widespread use of Blockchain technology over the medium term. This perspective is combined here with the expectation that productivity in the Australian finance sector will also expand due to widespread use of Blockchain technology in that sector over the medium term with flow on beneficial impacts on grain trading with the use of enhanced digital transactions and reduced transaction costs.

4. Simulation Results

The simulation results are presented in Table 1. They indicate that an assumed modest growth (i.e., five per cent) in productivity due to the adoption of Blockchain technology in the Australian grains sector could potentially raise the output in the sector by over eight per cent over the medium term relative to what would otherwise be. If this is accompanied by a similar rate of growth in productivity in the Australian finance sector, it could further raise the grains output to a 9.7 per cent increase. This reflects the potential reduction in transaction costs associated with the use of Blockchain technology as a "distributed ledger technology" in grain trading.

These assumed combined productivity enhancements could potentially lead to an estimated rise in GDP of 2.6 per cent with considerable enhancement in economic welfare, relative to what would otherwise be.

The simulation results shown in Table 1 also highlight the high level of economy-wide potential beneficial impacts of Blockchain-driven productivity enhancement of the Australian finance sector (i.e., an estimated US$ 58 billion rise on economic welfare, relative to what would otherwise be). This highlights the broader economy-wide potential ramifications of greater adoption in the Australian financial sector of emerging digital technologies such as Blockchain technology in digital sales and services (including digital transactions and customer service interactions).

5. Discussion and Conclusions

It is estimated that it takes around three to four weeks on average to settle financial payments in the grains sector at present (without the use of Blockchain technology; see https://blog.agridigital.io/blockchain-solutions-for-the-australian-grains-industry-be871e1aef99). The wheat trading case study noted earlier in this paper highlights the potential ability of the use of Blockchain technology in the grains sector to facilitate prompt and speedy payment for output sales. However, it is also important to recognise that investment in digital technologies and related services in the Australian agriculture is relatively low compared to other sectors (Productivity Commission, 2004). Hence, there is significant scope for further expansion in the use of digital technologies (including the use of Blockchain technology) along agricultural supply chains.

As discussed in this paper, the reduction in transaction costs associated with the use of Blockchain technology as a "distributed ledger technology" implies that, for example, in grain trading, farmers receive their returns from selling their grain promptly without a delay. Our economy-wide analysis has tried to reflect the speedy settlement of payments to grain farmers by simulating it as a plausible productivity improvement in the financial transaction services sector which provide such services to the farm sector. Our simulation results illustrate that potential medium-term impacts of the adoption of Blockchain technology in the Australian grains and finance sectors could be in the range of a rise in grains output of close to ten per cent, with an estimated rise in GDP of 2.6 per cent.

There are several caveats to the impacts of this medium-term prognosis for the adoption of Blockchain technology. According to the International Finance Corporation (2017b), adoption of Blockchain technology is likely to be gradual over the next five to ten years. There are various challenges that stand in the way of its widespread adoption. These challenges range from those related to technical and regulatory issues, to those associated with legal and policy issues (Bohme *et al.*, 2015; Gifford & Cheng, 2016; Mazzone, 2017; Pisa & Juden, 2017; International Finance Corporation, 2017b).

One of the key technical challenges relates to moving from the application of Blockchain technology at pilot project level to large-scale applications. The extent of this scalability problem is intimately influenced by the speed of the network, in conjunction with the need for data privacy, operational resiliency and governance issues (see Pisa & Juden, 2017). It must not be overlooked that, according to the International Finance Corporation (2017b), the consensus-based nature of the validation processes in Blockchain means that it needs substantial computational power. This implies that there will be considerable use of electricity (Bohme *et al.*, 2015), and inevitably, the transaction speed will be

Table 1. *Economic effects of Blockchain use in the Australian grains sector (relative to the baseline case)*

Scenario	Change in Australian grains output (%)	Change in economic welfare (US$ m)	Change in GDP (%)
5% productivity gain in grains sector	8.68	432	0.03
5% productivity gain in the finance sector	1.01	58,782	2.53
Combined 5% productivity gain in both grains and the finance sectors	9.68	59,651	2.55

Source: Authors' simulations using the GTAP model and a projected world economy to 2030.

slowed as the demand for data storage expands. This can generate major technical barriers to the scalability of the Blockchain adoption and to achieving required economies of scale.

In their review of literature on the use of Blockchain technology in agri-food value chain management, Zhao *et al.,* (2019) have identified several challenges including storage capacity and scalability, privacy leakage, high cost and regulation problem and lack of skills.

Kamilaris *et al.,* (2019) argue that in order to lower the barriers to Blockchain use, public sector investment is needed in research and innovation, as well as in education and training, in order to produce and demonstrate evidence for the potential benefits of this technology. From a policy perspective, actions that can be taken include encouraging the growth of Blockchain-minded ecosystems in agri-food chains, supporting the technology as part of the general goals of optimising the competitiveness and ensuring the sustainability of the agri-food supply chain, as well as designing a clear regulatory framework for Blockchain implementations. The economic sustainability of existing Blockchain initiatives needs to be assessed, and the outcomes of such assessments are expected to influence the popularity of the Blockchain technology in the near future, applied in the food supply chain domain (Kamilaris *et al.*, 2019).

Sylvester (2019) points out that the key elements to support the adoption of Blockchain technology in agriculture such as high-quality data, enabling policies and regulations, should be first addressed in order to ensure the maximum efficacy for smart contracts. The process of designing, verifying, implementing and enforcing smart contracts in traditional agricultural value chains is still a work in progress, with only a few pilot implementations to show proof-of-concept.

As this technology is more widely adopted, the issue of "interoperability" will be critical for Blockchain flexibility, where connectivity between different Blockchains must be ensured. While the technology required for the demands of interoperability is still in its pilot phase, there are initiatives underway in the financial services sector to address this issue by using, for example, an "open standards" approach (Gifford & Cheng, 2016).

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