TECHNOLOGICAL DEVELOPMENTS FOR INCREASED MARKET ACCESS AND PARTICIPATION IN FRESH FRUIT VALUE CHAINS

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Abstract

Strong performance of the South African fruit industry coupled with strong growth in global demand makes it a central focus for high-value agriculture-led growth. South Africa's export-oriented fruit industry is worth US$3 billion and its share of total agricultural exports value has grown from 43% in 2012 to 52% in 2018. However, ensuring sustainable growth of the fruit sector requires adopting and adapting to advances in technology and shifting to high-value fruits. Drawing from interviews with industry stakeholders, this paper assesses the implications of technological changes on market access and participation of small and medium sized farmers. Using a global value chain framework, we emphasise how power and governance structures in the value chain affect the opportunities for innovation and adoption of new technologies. Institutional power of industry associations, market power of lead firms, constitutive power of growing consumer demands and civil society organisations are driving key investments at various levels of the value chain with implications in terms of who can innovate, adopt new technology and gainfully participate in the value chain.

Key words: agriculture, fresh fruit, technology, upgrading, participation, market access, governance, power

JEL Codes: O13, O14, O31, O33, Q16, Q17

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1. Introduction

Strong performance of the South African fruit industry coupled with strong growth in global demand makes it a central focus of high-value agriculture-led growth. The fruit industry presents large potential to grow exports, to increase the participation of small and emerging black farmers and to create employment. This growth is dependent on adapting major advances in technology to underpin sustainable growth of the sector in what can be termed the 'industrialisation of freshness' (Cramer and Sender, 2015). The industrialisation of freshness hinges on fruit producers' ability to increase the product shelf life through research and technology development throughout the value chain. The goal to produce good quality fruit, a highly perishable product, for export markets is driving key technological changes from inputs, production, packing and storage to marketing and distribution. Constant technology upgrading across these processes is critical for market access and developing timeous, flexible and speedy supply chains.

The major technological developments in the fruit industry both globally and in South Africa have been in the areas of biotechnology, irrigation and precision farming methods, sorting, packaging and cold storage; and electronic certification and integrated digital platforms. These changes in technology have been incremental rather than disruptive. Nonetheless, these technological developments are transforming the structure of fruit production with scope for greater productivity through improved yields, speed, shelf life and quality, as well as transparency and traceability along the value chain.

Despite South Africa being an established global player in a number of fruit categories, it has lagged behind other developing countries such as those in South America for particular high-value fruits such as berries and avocados. South Africa has failed to maximise the substantial opportunities for export growth and increased participation given increasing global demand for these fruits.

South Africa's export-oriented fruit industry is worth US$3 billion and its share of total agricultural exports value has grown from 43% in 2012 to 52% in 2018. Over the same period, the value of exports grew at a compounded rate of 7% while volumes of fruit exports grew at a compounded rate of 3% per annum. South Africa is lagging behind key competitors like Mexico and Peru, which grew exports at 8% and 15% (CAGR) per annum respectively over the same period (in volume terms). In addition, South Africa has not capitalised on the opportunities presented by high value and labour-intensive fruits, like berries and avocados, with fast growing demand in global markets. While South Africa has successfully tapped into the global demand for citrus and has grown to be the second largest exporter in the world in 2017, it has largely missed out on opportunities in these other fruits. Although berries constitute the fastest growing exports in South Africa's fruit export basket (with a CAGR of 9%) between 2012 and 2017, this is from a very low base. Exports of avocados from South Africa have in fact declined over the five-year period, despite global import demand increasing by 87% from 1.1 million tonnes in 2012 to 2.1 million tonnes in 2017 (ITC TradeMap). Both berries and avocado production are labour-intensive, employing 2.96 and 2.6 workers per hectare respectively, which is much higher than employment in field crops that take up most of the agricultural land in South Africa.

Realising the full growth potential of the fresh fruit sector requires adopting and adapting to the advances in technology as a critical strategy to significantly improve South Africa's access and performance in global markets. Traditionally, the application of technologies is identified with key manufacturing activities and not necessarily agriculture. Hence it is critical that government and private sector understand the impact of technological changes on production systems, employment and access to world markets. While market access in itself is not a technological issue, it is enabled by technological advancement and needs to be made a major priority.

Drawing from existing research[1] and from interviews with key stakeholders in South Africa's fresh fruit sector, this paper assesses the implications of key technological changes in the fruit industry on market access and participation of small and medium-sized farmers. This involves identifying the nature of major technological developments in the fruit value chain and the key driving factors. To understand the key drivers of technological changes, we emphasise how power and governance structures in the value chain affect the opportunities for capturing value, creating long term value, and innovation. This provides important insights on which players in the value chain are able to develop and adopt new technologies and how these players can use technology to control certain aspects of the value chain. This has key implications in terms of the growers' and producers' ability to access markets and participate in the value chain.

To understand these dynamics in the fruit value chain, we use a global value chain framework taking into account political economy dynamics. The study also draws key lessons from the experience of the citrus industry on how to grow other industries such as berries and avocados. The citrus industry represents a success story in South Africa's fruit sector particularly with regards to cutting-edge research and technology development, as well as market access.

The study will address the following key research questions:

i. *What have been the most important technological changes in the fruit sector in the past 5-10 years and what are likely to be the main technological disruptors in the future?*
ii. *How do governance and power structures in fruit value chains affect the process of technological learning and upgrading?*
iii. *What are the implications of technological changes for market access and participation?*
iv. *What lessons can we draw from international experiences and what policy responses are required by government and public institutions to drive more positive outcomes?*

This paper is structured as follows. Section 2 sets out a conceptual framework to understand how issues of power and governance can affect technological adoption and upgrading in global value chains. Section 3 provides an overview of the South African fruit industry's performance and identifies areas of high growth potential. Section 4 analyses the different types of power behind drivers of innovation and adoption of technology and the extent to which

[1] Chisoro-Dube, S., das Nair, R., Nkhonjera, M., and Tempia, N. (2018). Structural Transformation in Agriculture and Agro-processing Value Chains. (2018). University of Johannesburg, CCRED Working Paper 2018/8. See also Chisoro-Dube, S., Paremoer, T., Jahari, C., and Kilama, B. (2018). Growth and development of the fruit value chain in Tanzania and South Africa. CCRED Working Paper 2018/5.

these have shaped outcomes in the industry. Section 5 assesses the implications of key technologies on market access and participation of small and medium-sized farmers and producers and suggests policy responses to drive more positive outcomes. Section 6 concludes.

2. Global value chains: a framework to understand governance, power and technological upgrading

The fresh fruit industry is an export-oriented industry with key consumer markets in developed countries and production concentrated in developing countries. Control over production, standards and pricing is increasingly shaped by powerful players in developed markets. These governance and power relationships have implications for technological learning and adoption of technologies for upgrading of local growers and producers, value capture and opportunity for development of production technologies for the sector.

The global value chain (GVC) framework is useful to identify opportunities and challenges for technological upgrading and development of capabilities in global industries. It provides a methodology for understanding power and governance across the full range of economic activities within an industry. It does so by tracing the patterns of value creation and exploring the linkages amongst geographically dispersed economic activities and actors (Gereffi and Fernandez-Stark, 2011).

The traditional GVC literature employs two core concepts to assess global industries, (1) governance and (2) industrial upgrading. Governance refers to authority and power relationships that determine the allocation and flow of resources within a value chain (Gereffi, 1994; Dallas, Ponte and Sturgeon, 2017; Gereffi and Lee, 2012; Gereffi and Lee, 2014; Gereffi and Fernandez-Stark, 2011). While governance is about understanding the value chain in a 'top-down' manner, upgrading takes a 'bottom-up' approach, exploring how firms or countries can maintain or improve their positions within global value chains.

The extent to which specific types of governance contribute to reinforcing or hampering the process of technological upgrading in firms is important to understand. The opportunities for building production and innovation capabilities in domestic firms are structured by the governance patterns that are dominant within international production chains (Lema, et al., 2018). While integrating into GVCs can create new opportunities for learning, innovation and technological upgrading; specific patterns of governance can also become a hindrance for the building up of innovation capabilities (Lema, et al., 2018). The ability of local producers within the GVC to engage in different forms of upgrading can be constrained by the ways in which local firms are inserted into the GVC and the power asymmetries between them, lead firms and other actors. GVC structures and chain leaders' strategies set the pace and direction of knowledge flows and upgrading either in favour or against the interest of local producers (Morrison, et al., 2008).

Given the multiple dimensions of power, different forms of governance may produce similar outcomes in terms of knowledge generation and technological upgrading, yet similar governance structures may also differently affect the transfer of technology depending on the specificity of technology, the sector and the type of knowledge (Morrison et al. 2008).

However, the emphasis on vertical linkages along the value chain is a major weakness of the GVC approach. This approach misses the important role of horizontal linkages among different firms at each node of the value chain, which possibly cut across multiple sectoral value chains (Andreoni, 2018). Similarly, Gereffi and Lee (2016) also argue that there is need for more integrated frameworks that show how GVCs and clusters are connected through a variety of globalisation processes. Successful upgrading requires that firms develop horizontal linkages in the domestic economy while integrating into global production and trade. As such typologies of GVC and cluster governance need to be expanded to take into account both vertical and horizontal relationships and the complex interactions - tensions, conflicts, displacement, complementarity and synergy – between public, social, and private forms of governance. Hence, there is need to take into account the vertical and horizontal types of governance and their interaction in order to fully understand the functioning of a global industry and its consequences to upgrading.

The role played by powerful 'lead' firms in coordinating production activities and shaping the distribution of profits and risk within an industry is central to understanding governance structures (Gereffi and Lee, 2012). Lead firms in GVCs control production through setting and enforcing product and process parameters including standards and protocols that must be met by other players operating in the value chain. This includes controlling decisions about what to produce, how to produce and how much to produce (Humphrey and Schimtz, 2002; Gereffi, and Fernandez-Stark, 2011). However, this also creates competition among suppliers – endogenous asymmetries.

Iterations and developments of the GVC literature have identified five basic types of value chain governance structures through which coordination of activities in the value chain may occur. These are market, hierarchy, modular, relational and captive relationships (Gereffi, Humphrey and Sturgeon, 2005). The degree of power asymmetry within these different relationships is based on three factors - the complexity of the information involved in the transactions, the ability to codify the information, and the capabilities of the suppliers along the supply chain (Gereffi, et al., 2005; Lema et al., 2018). The different types of governance can affect technological upgrading in different ways, as discussed later.

Although the concept of governance is widely captured in GVC literature, the concept of power is not explicitly defined, and it is often applied as a unitary static concept in dyadic relations between buyers (lead firms) and suppliers (Dallas, Ponte and Sturgeon, 2018; Kadarusman and Nadvi, 2012). The exertion of power is however not always limited to a 'lead' or powerful firm exercising their authority on other actors in the value chain. There are often other multiple dimensions of power exercised in GVCs, beyond the simple bargaining power between buyers and suppliers captured in most of the GVC literature (Dallas, et al., 2018).[2]

Clarifying the concept of power has become increasingly important following the growth of new forms of GVC frameworks with multiple stakeholders and mechanisms that have an impact on the development of the value chains, such as NGOs, labour unions, standards and conventions (Davis, Kaplinsky and Morris, 2018; Dallas, et al., 2018). Power can be shaped by various factors and actors including standards and certifications on quality and

[2] Bargaining power typically captures the power asymetries between lead firms in advanced countries and suppliers in developing countries

sustainability, multi-stakeholder initiatives, corporate social responsibility and social movements. Control over the qualification of specific products can be a key source of power for lead firms, but counter-actions by other actors along the value chain can also challenge the status quo (Dallas et al., 2018). Power can also be diffuse, and it is not always a negative thing if it leads to more socially optimal outcomes (Gibbon and Ponte 2005; Morrison, et al., 2008).

Building on existing frameworks, Dallas et al., (2018) try to capture the emerging approaches to power and governance in GVCs by considering the role of government, business associations, social and consumer movements. They categorise the different types and usages of power exercised in GVCs into four groups - bargaining, demonstrative, institutional and constitutive power. These forms of power are an interaction of two principal dimensions – 1) transmission mechanisms, which can be direct or diffuse, and 2) arena of actors, which can be dyadic or collective (Figure 1).

Figure 1: Typology of power in Global Value Chains

	Transmission Mechanisms	
	Direct	**Diffuse**
Arena of Actors		
Dyadic	*Bargaining Power* • Operates in firm to firm relations • Can exhibit different degrees of asymmetry in hierarchy, captive, relational, modular, and market linkages • Also operates when powerful firms interact individually with government agencies to carve out exceptions to rules, etc.	*Demonstrative Power* • Operates through informal 'transmission' mechanisms along value chains between buyers and suppliers, or aspiring value chain actors. • Can be shaped by quality conventions implicitly accepted by parties to a dyadic transaction • Can drive isomorphism among or between lead firms and suppliers, or among non-firm actors
Collective	*Institutional Power* • Operates through government regulation, multi-stakeholder initiatives and/or other institutionalized forms • Can leverage and be leveraged through industrial standards and codified 'best practices' • Can be "agenda-setting" by removing issues from the bargaining table, as well as *de facto* and *de jure* standards to support platforms and their ecosystems	*Constitutive Power* • Operates through broadly accepted norms, expectations and best practices, e.g., isomorphism at the industry or societal levels. • New norms and disciplines generated by unorganized social and consumer groups, education, media, etc. • Decentralized collaboration through loosely or un-affiliated actors, sometimes engendering new norms and practices (e.g. non-proprietary, collaborative open source software).

Source: Dallas, Ponte and Sturgeon, 2018

Power can be transmitted through direct and diffuse mechanisms. Within the direct forms of transmission, the actor or collective wielding power and those who are objects of it are relatively easy to identify by all parties. The exertion of direct power is most often intentional and the goals of powerful actors are well known. These actors 'possess' power either by wielding material or ideational resources, or by leveraging their structural or network position within a GVC. Transmission mechanisms can also be diffuse, based on less direct and more demonstrative processes. Such mechanisms follow broader societal trends or are based on taken-for-granted or emergent 'best practices' (e.g. corporate conduct and organisation) or dominant quality conventions (Gibbon and Ponte 2005).

The arena of actors specifies how power is exercised in both dyadic and collective relationships. Most GVC literature focuses largely on direct power in dyadic relations between individual buyers (lead firms) and suppliers. Collective power on the other hand is a function of the collective behaviours of multiple players acting simultaneously (intentionally or not). For example, institutional power is a form of direct power that is exercised by collectives that are more formally organised, such as through business associations, multi-stakeholder initiatives, shared technological platforms, or within the state.

Bargaining and demonstrative power capture the dyadic power relationships between firms and suppliers. For example, bargaining power operates in firm to firm relations and generally captures the power asymmetries between lead firms in advanced economies and suppliers in developing countries. On the other hand, demonstrative power operates through informal transmission mechanisms along value chains between buyers and suppliers, or aspiring suppliers. Within the demonstrative power relations, quality conventions and requirements that are implicitly accepted by parties in a dyadic relationship can also shape the behaviour and choices of many other suppliers in the industry beyond the dyadic transaction. For example, upgrading by a single supplier in the value chain may induce other suppliers in the value chain to adapt or otherwise be excluded from participating in the value chain. Downstream firms may also transmit new requirements in the value chain through imposing new standards or requirements on upstream suppliers (Dallas et al., 2018).

Institutional and constitutive power on the other hand is embedded or exercised by a collective of actors. Institutional power refers to direct power exercised by collectives with some level of formal organisation. This type of power operates through business associations, multi-stakeholder initiatives, shared technological platforms or government departments. Such institutional arrangements can also leverage and be leveraged through industrial standards and codified best practices. Constitutive power is exercised by a collective of actors that do not have clear or formal common membership. It is less explicitly codified and operates through broadly accepted norms, expectations, and best practices. This includes new norms and disciplines generated by unorganised social and consumer groups (Dallas et al., 2018).

Application of the GVC framework to the fresh fruit industry

Most of the existing literature focuses on the role of standards and compliance in fresh fruit value chains and their impact on smallholder farmers (Lee, Gereffi, and Beauvais (2010), Tallontire, Opondo, Nelson and Martin (2011), Fernandez-Stark, Bamber and Gereffi (2011); Katete Kazeluka (2014); Chisoro-Dube et al. (2018)). Lee, Gereffi and Beauvais (2010) use a global value chain approach to explain the relationship between value chain structure and agrifood safety and quality standards and to discuss the challenges and possibilities private food standards entail for the upgrading of smallholder farmers. Similarly, Katete Kazeluka

(2014) used the global value chain framework to understand the linkages between buyers and small-scale horticulture growers. The paper focused on how rising quality, timely delivery and other post-harvest handling requirements by supermarkets and consumers impact small-scale horticulture producers in Zambia who are locked in low-value chains and experiencing erosion to their profit margins.

Slightly different from the above papers, Tallontire et al., (2011) focus on the governance implications in terms of how private standards affect national level institutions – public, private and non-governmental. The article applies the value chain and governance framework to analyse how Private Standards Initiatives in the global south (ChileGAP, KenyaGAP, Horticulture Ethical Business Initiative in Kenya) affect national level institutions (public, private and non-governmental) drawing from the Kenyan horticulture industry. The paper explores the legislative, executive and judicial aspects of governance in these southern PSIs highlighting how different stakeholders shape debates and act with agency.

Fernandez-Stark, Bamber and Gereffi (2011) focused on the process of entry and upgrading of five developing countries (Chile, Jordan, Kenya, Honduras and Morocco) into the global fruit and vegetables value chain. The paper highlights how upgrading could be linear or non-linear, depending on whether a country or firm must gain expertise in one segment of the value chain before moving to the next stage. The paper provides examples of upgrading paths in the horticulture and offshore services sectors. Upgrading could also mean moving to the pre- and post-production stages, in particular by increasing the services content of the production package sold to lead firms. Therefore, a country needs to assess its capacities upstream and downstream as well as its current position in the value chain, and facilitate the upgrading process through capacity building and workforce development.

This paper will focus on how issues of governance and power in the fresh fruit value chain impact on the process of technological upgrading among local growers and producers in South Africa. This analysis will contribute to further understanding how power and governance structures in the value chain affect the opportunities for capturing value, creating long term value, and innovation.

Technological upgrading and power in fruit GVCs, with a focus on South Africa

These issues of governance and different forms of power are relevant in the context of fruit value chains. Overseas supermarkets govern activities in the fruit value chain by setting and enforcing the product and process parameters that must be met by producers in the fruit value chain. They exert significant control over the entire value chain and dictate how the fruit is produced, harvested, transported, processed and stored, imposing strict private standards in addition to national sanitary and phytosanitary standards (SPS) (Fernandez-Stark, et al., 2011). The ability of growers and producers to comply with international food safety and quality standards is thus a prerequisite to access global markets. Furthermore, lead retailers' emphasis on cost competitiveness, quality, consistency and product differentiation puts farmers and producers on a steep learning curve, forcing them to learn quickly and rapidly expand capabilities (Humphrey and Schimtz, 2002).

Other important drivers in fruit value chains include growing demand from consumers in developed countries for certain requirements. Consumers are increasingly demanding more organically-grown, pesticide-free fruits, with more stringent requirements for ethical labour

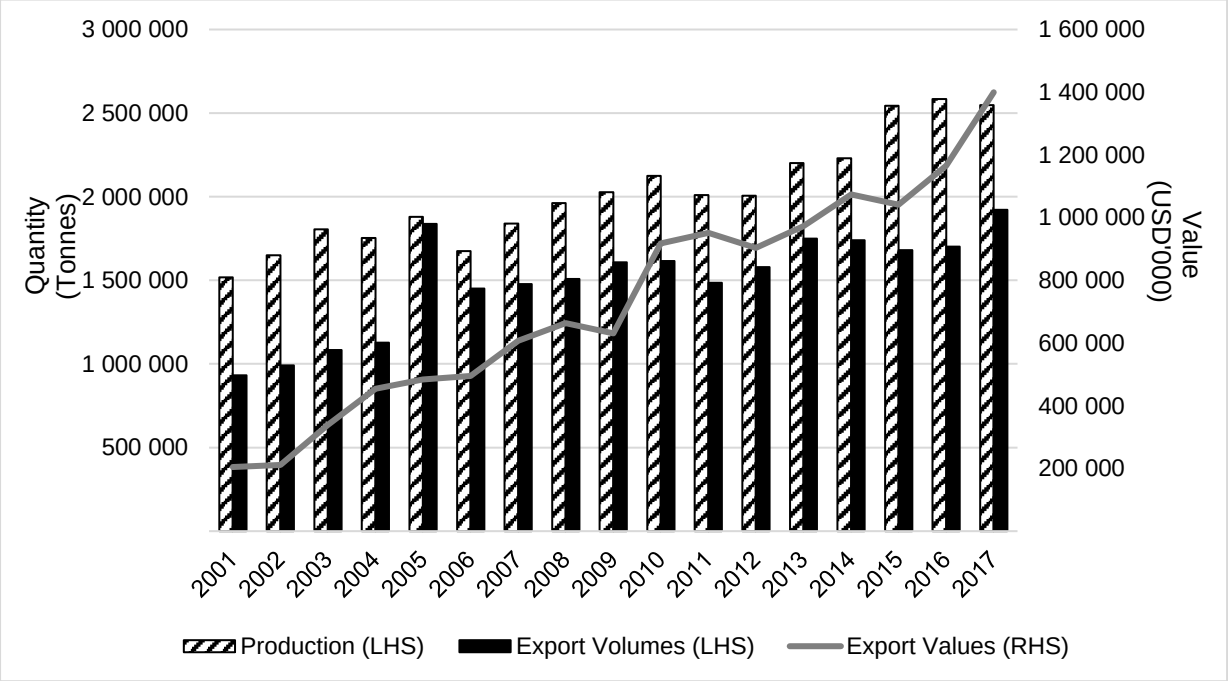
standards and responsible environmental practices. These are examples of conventions shaped by social movements and corporate social responsibilities.

There is also a very strong institutional power aspect demonstrated through the role of industry associations in South Africa's fruit sector. Industry bodies such as Fruit South Africa and the Citrus Growers Association of Southern Africa play key roles in shaping industry outcomes. The locus of power that has enabled the citrus industry to grow stems from the industry association that is at the forefront of technological developments and accessing new markets.

3. Performance of the South African fruit industry: citrus, berries and avocados

South Africa's fruit industry is a globally competitive industry particularly in the citrus segment. In 2017, South Africa was the second largest exporter of citrus fruit in the global market. The country's export share in the top six exporting countries more than doubled from 6.6% to 15.7% between 2001 and 2017. As such, citrus represents a success story in South Africa's fruit sector providing key lessons on how to grow other fruit value chains such as berries and avocados.

Figure 2: South Africa's production and exports of citrus



Source: ITC Trade map and DAFF (2018)

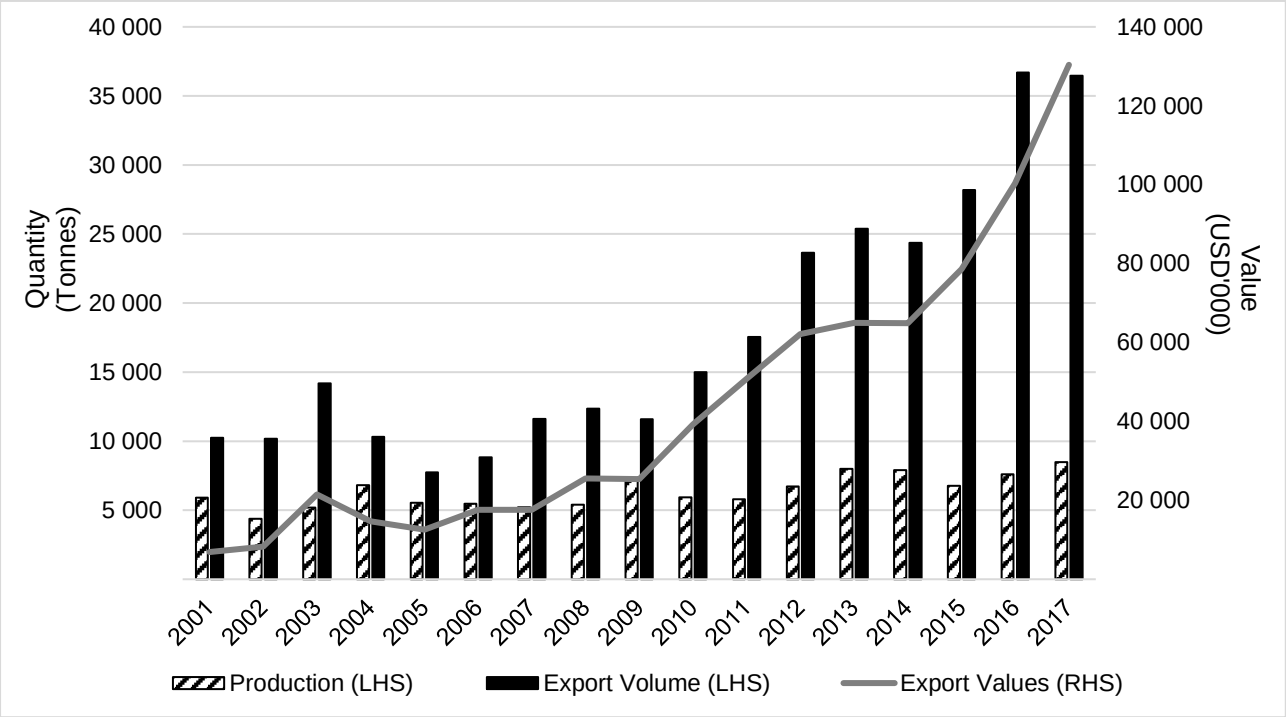
Berries and avocados represent fast growing and high value products, with large export potential in global markets (Figure 2).[3] However, South Africa has largely missed out on the opportunities from global demand growth for these fruits.

South Africa's berries industry is relatively small compared to the citrus industry in terms of production and exports. However, berries constitute the fastest growing exports in South Africa's fruit export basket with a CAGR of 21% in volume terms whilst export values grew by

[3] The unit value is relatively high for both fruit, more especially berries.

27% between 2009 and 2017. Berries are export-oriented because their high price does not appeal to the local South African market.[4] They are also highly profitable as consumers globally are moving to healthier lifestyles and blueberries in particular are regarded as a super food. There is an opportunity for South Africa to export more berries, but the industry is still young and has limited market access.

Figure 3: South Africa's production and exports of berries[5]

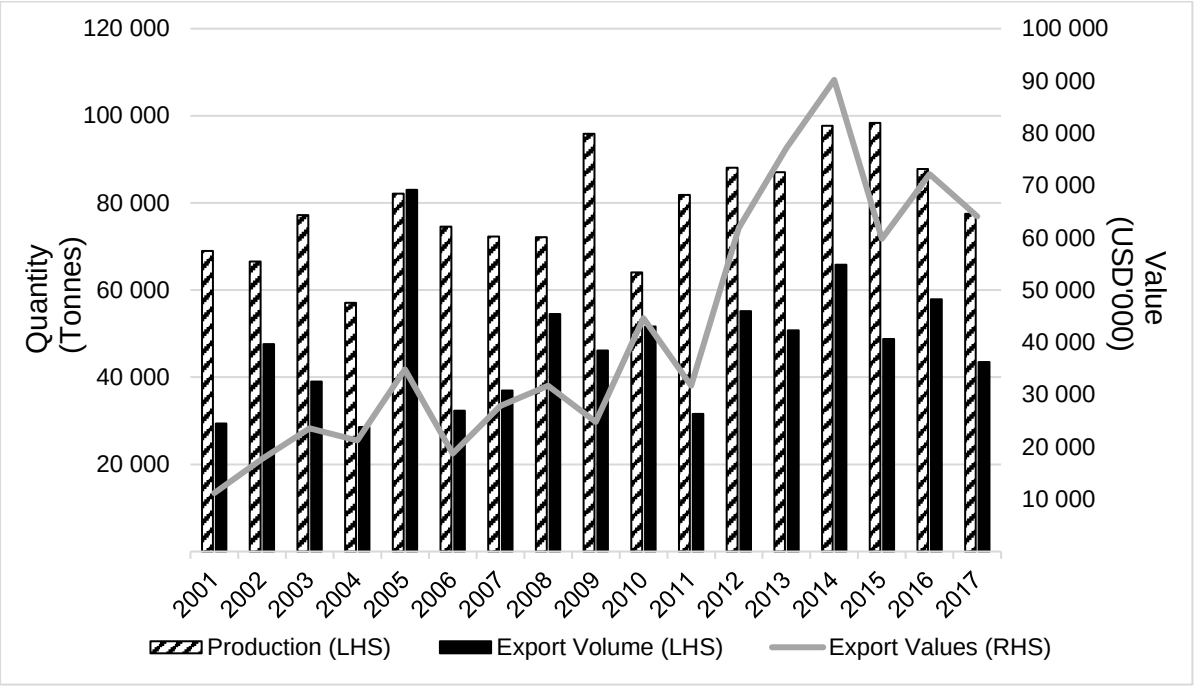


Source: ITC Trade Map[6] and DAFF (2018)[7]

On the other hand, production and exports of avocados fluctuates over the whole period owing to the cyclical nature of production (Figure 4). Overall, production of avocados has not consistently grown over the period starting 2001 to 2017 although there are peaks in production observed in particular periods. However, the value of exports has grown steeply between 2011 and 2014 owing to higher international prices as demand for avocados as a healthy food continues to grow.

[4] Interview with the South African Berry Producers Association (SABPA), 19 October 2018.
[5] Production data only includes strawberries, raspberries, blackberries, gooseberries, youngberries, boysenberries and loganberries. It excludes blueberries which comprise 90% of all berry orchards in South Africa https://www.saberries.co.za/wp-content/uploads/2018/10/Berry-Industry-Overview-2018.pdf
[6] Berry trade data used includes Strawberries HST081010, raspberries and blackberries HST081020, currents and gooseberries HST081030, cranberries and blueberries HST081040.
[7] Production data only includes strawberries, raspberries, blackberries, gooseberries, youngberries, boysenberries and loganberries. It excludes blueberries which comprise 90% of all berry orchards in South Africa.

Figure 4: South Africa's production and exports of avocados



Source: ITC Trade Map and DAFF (2018).

3.1 Employment, key institutions and participation of smallholder farmers

Figure 5: Contribution to employment

Fruit	Employment	Location
Citrus	125,000 total[a] (24,764 permanent and 52,674 seasonal)[b]	Limpopo (44%), Eastern Cape (27%), Western Cape (17.5%), Mpumalanga (8%), Kwa-Zulu Natal (2.5%)
Berries	5,050[c]	Western Cape (60%), Limpopo (15%), North West (10%)
Avocados	12,500 total (7000 pack-house; 5500 growing level)[d]	Limpopo (60%), Mpumalanga (29%), Kwa-Zulu Natal (9%)

Source: ITC Trade Map, CGA (2017), SABPA (2018), SAAGA (2018), Interview with SAAGA (2018). Employment: [a]2017 (CGA, 2018). [b]2016 (Genis, 2018). [c]2018 (Interview with SABPA, 11 October 2018). [d]2018 (Interview with SAAGA, July 2018)

3.1.1 Citrus

The citrus industry directly employs approximately 125,000 workers, comprised of 24,764 permanent and 52,674 seasonal workers.[8] This accounts for 14.4% of total agriculture employment. Employment in the citrus mostly benefits the provinces that have relatively higher levels of unemployment in South Africa [9] In 2017, 44% of citrus production was in Limpopo, 27% in the Eastern Cape and 17.5% in the Western Cape.

[8] Citrus Growers' Association of Southern Africa (CGA). 2017. Annual Report 2017.
[9] Statistics South Africa, 2017. http://www.statssa.gov.za/?p=11092

The Citrus Growers Association of Southern Africa (CGA) is the industry body performing various functions in the sector including training and skills development, and research and development. The CGA was established in November 1997 and it is comprised of 1200 commercial farmers as of 2018. The industry association's main objective is to maximise the long-term profitability of the members who are growers of export citrus.

The CGA through the Citrus Growers' Development Company (CGDC) supports broad-based participation of small and medium-sized black farmers. The CGDC has about 123 productive small and medium-sized black farmers and of these, 68 farmers are exporting contributing approximately 2% to South Africa's total citrus exports. The smallholder farmers account for 10% of the total of 1200 commercial farmers in the whole citrus industry.[10]

3.1.2 Berries

Berries are labour intensive employing 2.96 people per hectare[11]. This translates to 5 050 people employed on a total of 1 706 hectares of land currently planted to berries. Berries can be planted anywhere granted a farmer has the necessary capital to invest in equipment including pots, substrate and water. Currently, 60% of berries in South Africa are produced in the Western Cape, 15% in Limpopo and 10% in North West.[12]

Unlike the long established and mature Citrus Growers Association, the South African Berry Producers' Association (SABPA) has only been operational since 2011 and currently has 68 members on 79 farms.[13] Members range from producers with 5ha of plantings to those with 100ha. The industry association is still at the infant stages of building technical capabilities and an information base to negotiate market access.

Participation of small black and medium-sized farmers is still limited in the berries industry. There are three main companies - BerryWorld, United Exports and Haygrove that dominate most of the activities in the industry. Although berries can be planted almost anywhere in the country and on a relatively small piece of land, they are capital and technology intensive, which partially explains the low levels of participation in the industry.[14] The high levels of technical knowledge required at the production level and the need to access export markets in order to ensure a return on investment limits the ability of smallholder farmers to participate in the industry. The average farm set up cost to plant berries is ZAR 1.5 million per ha, with the cheapest investment being ZAR 750 000 per ha. The large farmers spend up to ZAR 3 million per ha.[15] Therefore, although anyone can grow berries in South Africa, the investment costs involved and restrictions in access to varietals limit the participation of small and black farmers. This is in stark contrast to the citrus industry where set up costs are considerably lower at approximately ZAR 450 000 per five hectares.[16]

[10] The citrus industry has 178 black farmers in total, but only 123 farmers are actively growing and producing citrus on a yearly basis. Presentation by CGA Growers Development Company, 29 August 2018. Presentation by the CGA Growers Development Company, 29 August 2018.
[11] South African Berry Producers Association (SABPA). 2018. Berry Industry Overview August 2018.
[12] South African Berry Producers Association (SABPA). 2018. Berry Industry Overview August 2018.
[13] Interview with the South African Berry Producers Association (SABPA), 19 October 2018.
[14] Interview with the South African Berry Producers Association (SABPA), 19 October 2018.
[15] Interview with the South African Berry Producers Association (SABPA), 19 October 2018.
[16] Industry inputs at a Public Platform held at the Centre for Competition, Regulation and Economic Development (CCRED), 29 August 2018.

3.1.3 Avocados

The avocado industry employs 12 500 workers in total with 5 500 employed at the growing level and 7 000 at the pack house level.[17] The industry employs 1 permanent worker per 2.6 hectares of land cultivated.[18] Production of avocados in South Africa is spread across Limpopo, Mpumalanga and Kwa-Zulu Natal. Avocados in particular would allow for employment creation in provinces that have relatively higher levels of unemployment (above the country average of 37.3%, expanded definition). For example, 60% of South Africa's avocados are grown in Limpopo (41% unemployment, expanded definition), 29% in Mpumalanga (43% unemployment, expanded definition) and 9% in Kwa-Zulu Natal (42% unemployment, expanded definition).

The South African Avocado Growers' Association (SAAGA) established in 1967 represents all South African avocado growers. It aims to improve the profitability and sustain the viability of growing avocados in South Africa. The association carries out a number of functions including conducting research and providing information on production, packing and post-harvest handling and marketing of avocados.

In terms of participation, the avocado industry has 50-70 smallholder black farmers.[19] These farmers typically share communal land and supply the local market. The avocado industry unlike the berries and citrus industries, has a vibrant local market. Farmers can get relatively high prices from national fresh produce markets or through supermarket supply chains such as Woolworths Food Holdings and Pick n Pay Ltd.[20] Supermarkets particularly pay higher prices in the earlier months of March to May of the avocado season.

Exports by smallholder farmers are limited due to a number of challenges. Small avocado farmers cannot meet phytosanitary standards required in export markets. Furthermore, the administrative aspects of exporting are onerous for the small farmers. Accreditation requires audits which cost about R5 000 to R10 000 per year, and the administrative aspect of exporting requires employment of administrative personnel and consultation from time to time.[21] Cumulatively, these costs make it difficult for many small farmers to enter export markets. Also, small farmers trying to export experience cash flow and working capital constraints. Farmers must wait 6-8 weeks after exporting in order to receive payment from the importing country.[22] Lastly, the practice of communal farming further restricts the ability of smallholder farmers to access loans as they are not able to use the land as collateral.

3.2 International comparisons of performance: citrus, berries and avocados

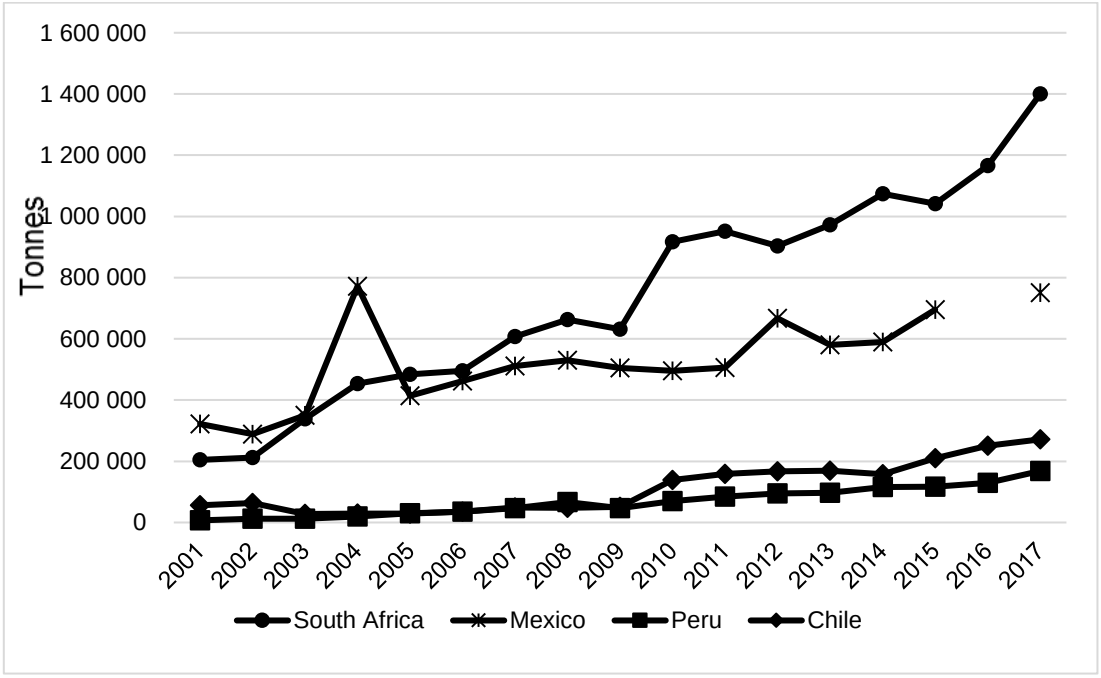
Although South Africa is among the leading exporters of citrus, its growth in high value fruit such as berries and avocados lags behind other fruit exporting developing countries such as Chile, Mexico and Peru. South Africa's exports of berries grew by 17% (CAGR) in volume terms between 2012 and 2017 while Peru's exports of berries grew by over 100% in volume

[17] Interview with the South African Avocado Growers Association (SAAGA), July 2018.
[18] Southern African Avocado Growers Association. 2018. Industry Statistics on the Southern African Avocado Industry. Available Online: https://www.avocado.co.za/overview-south-african-avocado-industry/
[19] Interview with the South African Avocado Growers Association (SAAGA), July 2018.
[20] Interview with the South African Avocado Growers Association (SAAGA), July 2018.
[21] Interview with the South African Avocado Growers Association (SAAGA), July 2018.
[22] Interview with the South African Avocado Growers Association (SAAGA), July 2018.

terms over the same period (Figure 6). Unlike berries, South Africa's exports of avocados between 2012 and 2017 have been declining at an average of 5% per annum in volume terms while competitors Mexico, Chile and Peru have grown at an average of 13%, 14% and 24% per annum respectively, in volume terms.

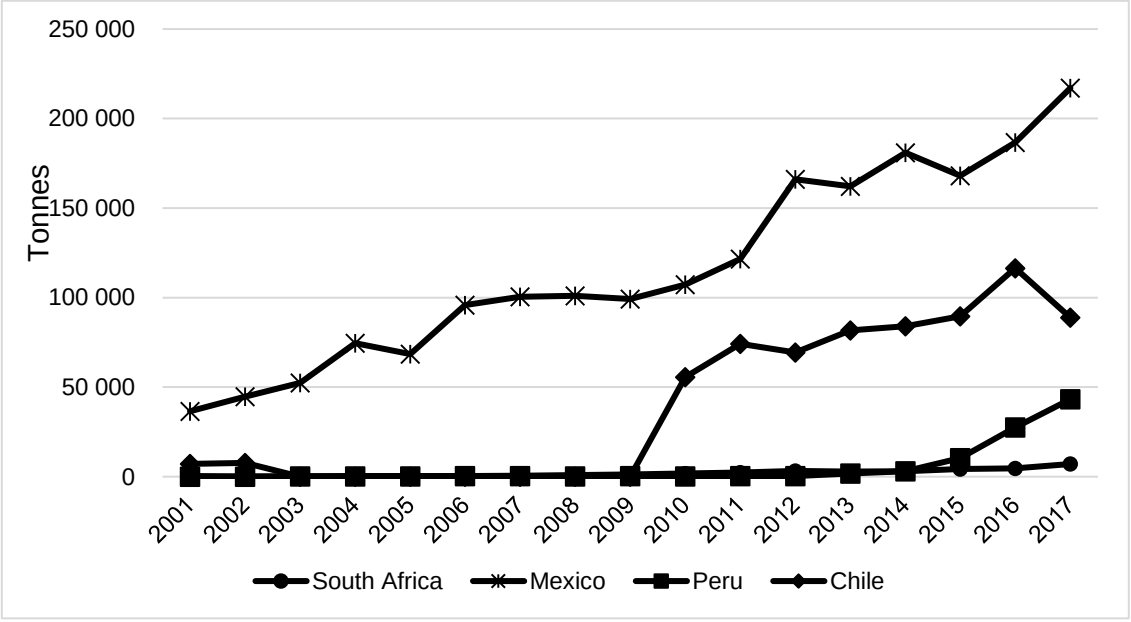
Figure 6: Citrus, berry and avocado export quantities for South Africa, Peru, Chile and Mexico

a. Citrus export quantities for each selected country



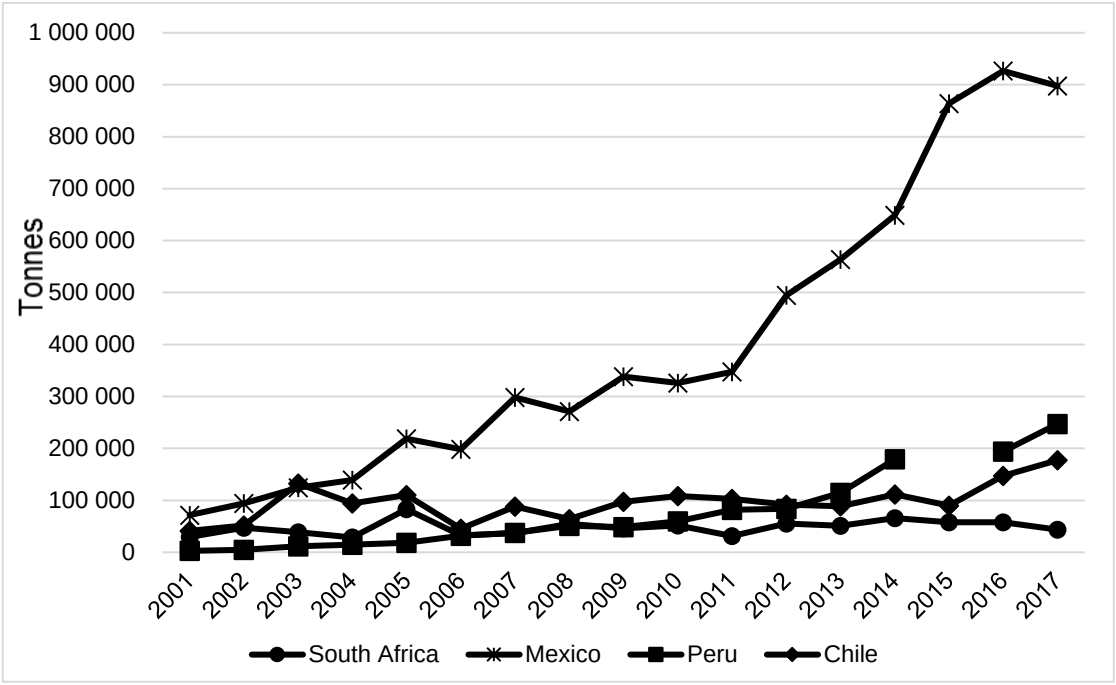
Source: ITC Trade Map

b. Berry export quantities for each selected country



Source: ITC Trade Map

c. Avocado export quantities for each selected country



Source: ITC Trade Map

The trends shown above partly indicate South Africa's limited diversification of its export basket relative to its competitors. South Africa's export basket comprises large volumes of lower value fruit such as citrus and apples, whilst its competitors have relatively more diversified export baskets, which consist of higher value fruit such as avocados and berries. In 2017, South Africa's export basket consisted of 56% citrus and 24% apples. In the same year, Chile had a more diversified export basket which comprised of 31% apples, 27% grapes, 10% citrus and 6% avocados (Figure 7). Similarly, Mexico's export basket comprised of 22% avocados, 23% melons, 19% citrus and 13% bananas while Peru's export basked comprised of 22% avocados, 24% grapes, 18% bananas and 15% grapes.

Figure 7: Comparison of unit values per kg of fruit exports in 2017

Country	Composition of exports	Citrus Unit Value ($/kg)	Berries Unit Value ($/kg)	Avocado Unit Value ($/kg)
South Africa	Citrus (56%) apples (24%), grapes (11%) apricots (3%), avocados (2%), berries (0.21%)	2.54	8.12	0.85
Mexico	Melons (23%), avocados (21%), citrus (19%), bananas (13%), berries (5%), grapes (5%)	6.04	2.82	1.58
Peru	Grapes (24%), avocados (22%), bananas (18%), citrus (15%), guavas (14%), berries (4%)	11.81	8.53	1.31
Chile	Apples (31%), grapes (27%), citrus (10%), berries (3%), apricots (9%) avocados (6%), kiwis (6%)	31.30	6.73	1.87

Source: ITC Trade Map

It follows that, although South Africa exports larger volumes of fruit than competitors such as Chile (Figure 5), the value of Chile's fruit exports is much higher than the value of South Africa's fruit exports. Similarly, although Peru has much lower volumes of fruit exports than South Africa, it is fast approaching the equivalent of South Africa's export values.

With the exception of berries, South Africa's export unit values for citrus and avocados are significantly less than its competitors (Figure 6). For example, South Africa's citrus unit values are two times less that its nearest competitor Mexico and up to twelve times less than Chile. Such differences in prices might be attributed to differences in the quality of fruit, which is affected by a number of variables including climate patterns, access to new varietals and water availability.

Lastly, the success of citrus to a certain extend shows how the industry has been relatively successful in diversifying its export markets relative to berries and avocados. In 2017, citrus exports were directed to the Netherlands (18.5%), United Kingdom (10%), United Arab Emirates (8%) and recently China (7.7%). The industry signed a Memorandum of Understanding with China in 2016,[23] marking large increases in exports of citrus to China in 2017 (Figure 2).

During the same year, South Africa exported 42% of its berries to the United Kingdom, 26% to the Netherlands and 5% to Germany. The berries industry is yet to tap into fast growing markets of East Asia such as China and South Korea.[24] Chile, on the other hand exported 44.8% of its berries to the United States, 11% to the Netherlands and 9% to China in 2017.

Similar to the berries industry, a significant proportion of South Africa's avocado exports in 2017 were directed to the Netherlands (67%) and the UK (20%) and the industry is yet to tap into the fast growing market of China. Unlike South Africa, the Peruvian avocado industry has successfully diversified its markets exporting widely to countries in Europe, America and Asia. In 2017, 37% of Peru's exports of avocados were to the Netherlands, 29% to the United States of America and 2% to China. In the same year, although Mexico exported the bulk of its avocados (77%) to the United States of America and 8.5% to Canada, it has maintained access into the Japanese market exporting 5% of its avocados. Mexico has been exporting between 4 – 6% of its avocados to Japan since the early 2000s.

If South Africa is to follow a similar growth trajectory as its competitors, it needs to aggressively grow and diversify its export markets. If not, this may mean that even if South Africa increases production of high value fruit, market access will still cause South Africa to lag behind.

4. Key technological changes and governance of fruit value chains

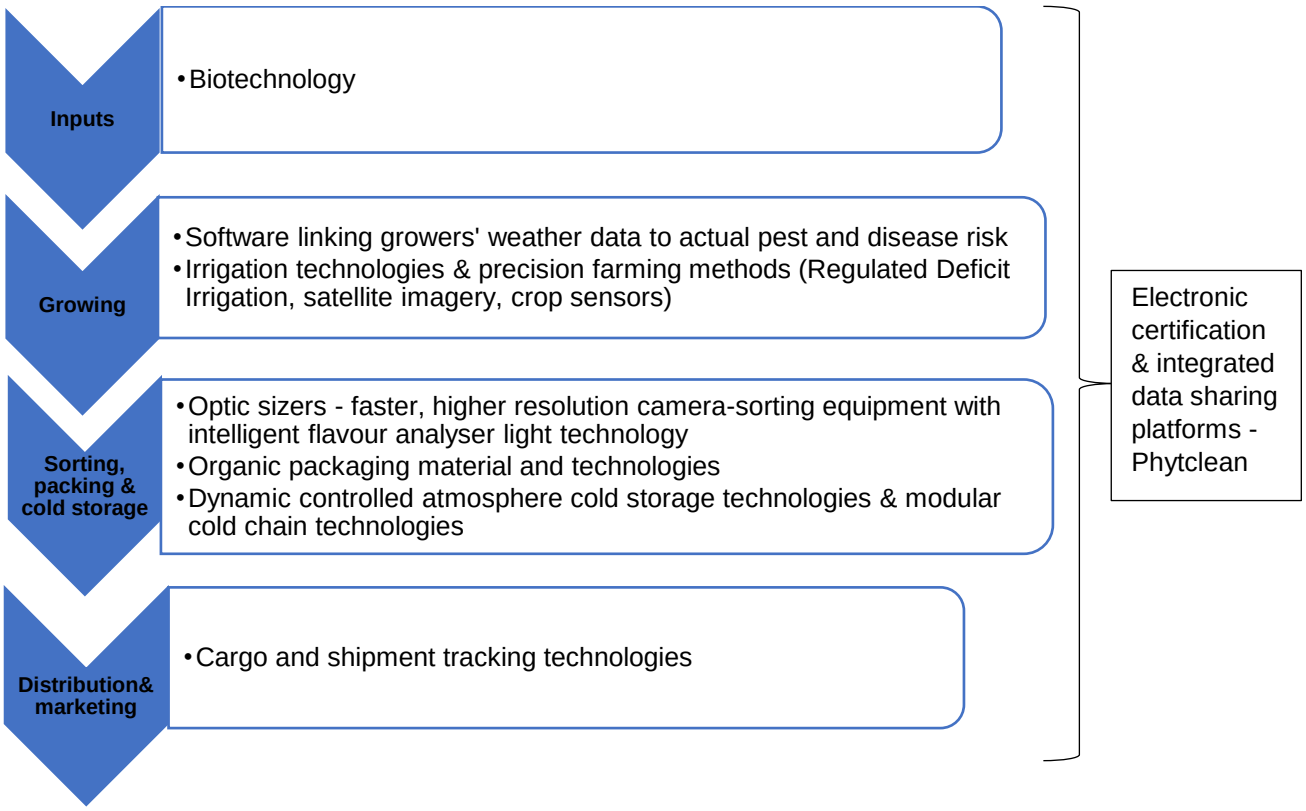
Success of the South African citrus industry shown in Section 3 has been largely bolstered by research, innovation and technological developments. This has also been the case for other large volume fruit exports from South Africa, such as apples and pears, as well as stone fruit.

Technological developments in the fruit industry have been driven largely by the need to increase the quality and shelf life of fruit, comply with SPS and respond to the impacts of climate change.[25] Growing customer demands and complex SPS in different markets are

[23] Fruit South Africa website. Fruit South Africa makes inroads in China. Available Online: https://www.fruitsa.co.za/breaking-news-fruit-south-africa-makes-inroads-in-chi/
[24] Interview with the South African Berry Producers Association (SABPA), 19 October 2018.
[25] Interview with Fresh Produce Exporters, 16 October 2018.

increasingly requiring greater levels of quality and compliance at each level of the value chain. Furthermore, the effects of climate change on fruit production impose a huge constraint on the ability of producers to meet these requirements. In response, firms are adopting technological solutions to continuously meet escalating requirements. The key changes in technology are happening in the areas of biotechnology, irrigation and precision farming methods; sorting, packaging and cold storage; and electronic certification and integrated data sharing digital platforms.

Figure 8: Fruit value chain and key technologies



Source: Author's own representation

It is important to note that while these different technologies may directly address a particular challenge at one level of the value chain, often they address other challenges at different levels of the value chain. The point is that learning is a structural process; solution at one level of the chain makes changes in other parts necessary. Structural process of learning refers to the continuous process of structural adjustment and transformation of production triggered and oriented by existing and evolving production structures (Andreoni, 2013). For example, while biotechnology is a key solution to addressing climate change issues, it is also addressing fruit quality issues through developing genetically improved varieties necessary to comply with phytosanitary standards.

To understand the key drivers of innovation and adoption of technology in the value chain, we analyse the different types of power and governance structures exercised by actors in the value chain and the extent to which they shape these outcomes.

Production technologies

4.1.1 Biotechnology

At the upstream level of the value chain, the impacts of climate change, weather variability, diseases and pathogens are driving investments in advanced breeding technologies to grow varieties that are adaptable to local climate conditions with improved resistance to diseases and pests (insects, weeds and pathogens). Advances in biotechnology ensure that new varieties can be bred according to specific characteristics such as taste, visual appearance, shelf life, seasonality, yield, climatic conditions, soil types and labour requirements.[26]

The process of developing new varieties requires the technical skills to investigate what kind of varieties are available worldwide including extensive marketing of the new variety in international markets to avoid extinction. For example, the citrus industry through the CGA in South Africa has been successful in developing new local varieties of soft citrus such as mandarins and clementines, for which global demand is growing. These include branded mandarin variety called ClemenGold, successfully launched into the world markets, and the Tango mandarin variety. The ClemenGold mandarin is being rolled out to other branded citrus products such as the LemonGold, HoneyGold and NavelGold. Tango's Plant Breeders Rights were granted in South Africa in March 2016, confirming that it is now registered as an individual variety in its own right.[27]

The apple industry like the citrus industry has also been successful in developing new varieties locally such as Bigbucks and Flash Gala. Because the new apple varieties can be coloured in a specific way that is more attractive to consumers in international markets, this has been critical in ensuring that South Africa remains globally competitive and maintains markets. For example, Tru-Cape - one of the largest marketing and distribution companies in the apples and deciduous industry with 20-25% market share, sends its technical experts to Europe to investigate varieties that are available in these markets and whether they can be grown in South Africa. At the same time, the technical experts also market new local varieties to the international markets to avoid extinction of these varieties.[28]

The process of developing a new variety can take up to 10-16 years.[29] Because of the long-term nature of investments required in developing new varieties, only a few leading firms in the industry have the resources to invest in biotechnologies. The extended timelines also expose the new varieties to diseases and pathogens resulting in high levels of mortality rates before the process is complete. To secure their investments, the resultant intellectual property (IP) rights from developing new varieties are copyrighted and licensed. At least half of fruit

[26] The Unlimited Group, Hans Christiaan Muylaert-Gelein, Digital Industrial Policy Dialogue for the fruit sector, 22 October 2018.
[27] http://c1e39d912d21c91dce811d6da9929ae8.cdn.ilink247.com/ClientFiles/cga/CitrusGowersAssociation/Company/Documents/Eurofruit%20-%20Gold%20standard%20for%20Mandarins%20-%20JulyAug%202017.pdf .
[28] Interview with Tru-Cape, 19 November 2018.
[29] The Unlimited Group, Hans Muylaert-Gelein, Dialogue on key technologies in the fruit industry, CCRED, 22 August 2018.

grown in South Africa is under IP licenses and arrangements, where the growers lease the trees and do not own the land.[30]

These developments have an important impact on the structure and governance of the value chain. Development of new varieties, which are tightly managed by intellectual property rights are starting to become the organising principle of the fruit value chain. Owners of protected varieties through intellectual property rights are able to exercise significant power in dictating the terms and conditions of production, volumes, marketing and exports, to farmers. What this means is that owners of protected varieties can control the entire fruit value chain of a specific variety from production to marketing. This leaves growers with limited flexibility and decision-making power despite paying royalties and commission for services provided. In addition, IP holders have the power to determine who has access to the variety because a farmer's access to a specific variety depends on whether they are considered to be in a conducive agricultural climate and land; and whether they can produce the right quality and yield of fruit demanded in export markets. Such value chains exhibit characteristics of captive or even hierarchical forms of governance, where owners of the IP dictate the conditions of participation (Gereffi, Humphrey and Sturgeon, 2005; Gereffi and Fernandez-Stark, 2011). This is evident in the berries and avocado industries as discussed below. The power in the ownership of IPs in these value chains has a clear impact in shaping outcomes.

The berries industry currently imports its main range of varieties from the USA (developed at the universities of Florida and Georgia) and Australia (from Costco Wholesale).[31] These are the Oz blue, Florida and the MBO cultivar range. These imported range of varieties are owned by the three leading producers in the industry namely BerryWorld, United Exports and Haygrove. These producers have the breeding licenses to produce new plant/seedlings from the parent plant. They have contracts with the Universities and Costco to disseminate the tree seedlings.[32] As such, any new farmer planning to produce blueberries would have to buy plants from the incumbents who own the licenses to the plant genetics. New farmers are also required to sell their produce through the incumbent in exchange for payment of royalties and commission for the marketing services. This means that IP holders possess considerable market power and are able to extract rents at each level of the value chain from growing to marketing of the product in export markets.

Development of quality varieties or genetic material constitutes one of the most critical technologies in the berries industry. As such, the local industry has made it a priority to access cutting edge varieties that are attractive in the international market by importing from leading competitors.[33] New varieties have higher yields and are sweeter than old varieties. They fetch higher prices on the export market and perform better on the markets.[34] The older varieties due to their shorter shelf life are transported via air while the new stronger varieties are transported via shipping containers as they can handle longer sea freight transit times.[35] However, more recently, there has been development of new cultivars in the industry in South

[30] The Unlimited Group, Hans Muylaert-Gelein, Dialogue on key technologies in the fruit industry, CCRED, 22 August 2018.
[31] Interview with South Africa Berries Producers' Association (SABPA), 19 October 2018.
[32] Interview with South Africa Berries Producers' Association (SABPA), 19 October 2018.
[33] Interview with South Africa Berries Producers' Association (SABPA), 19 October 2018.
[34] Interview with South Africa Berries Producers' Association (SABPA), 19 October 2018.
[35] Interview with South Africa Berries Producers' Association (SABPA), 19 October 2018.

Africa, which has brought more choice to farmers and reduced reliance on the major players' genetics and services. This can positively impact participation.

The South African avocado industry like the berries industry does not have many varieties compared to the apples, pears and citrus industries. The main varieties include GEM, Maluma and Hass. The GEM variety is owned by one of the main growers in the industry, Westfalia. Maluma's plant breeders' rights are owned by the South African company AH Ernst & Seuns (Pty) Ltd trading as Allesbeste. Although the largest variety for export, Hass, is an open variety, local farmers in South Africa need to wait for long periods, up to 7 years typically, to access a tree due to limited capacity at the nurseries.[36] The quickest way an avocado farmer can access a tree is if they have their own nursery. It still takes a waiting period of 18 months to 2 years to grow a tree. Most farmers are subject to even longer waiting times because they do not have their own nurseries given the difficulties associated with operating a nursery business.[37] Like in the berries industry, there are only three main growers in the avocado industry- Westfalia, Afrupro and ZZ2.

The GEM variety is grown and marketed through Westfalia and farmers pay royalties to buy the trees from Westfalia. Because protected varieties can only be marketed and sold through the IP holders, access to these varieties by farmers depends on whether they are located in the right locations in terms of rainfall, temperature and soil, can produce the expected yields and adhere to the quality demanded in export markets.[38] The owner of the GEM variety (Westfalia) is therefore able to control production volume in order to maintain high prices. Similar to the berries value chain, the owner of the varieties essentially governs the structure and development of the value chain.

Although the South African fruit industry has some access to locally bred varieties (through the Agricultural Research Council) and open (typically older) varieties, the industry still relies largely on imported varieties.[39] Before 1994, South Africa had limited access to internationally developed genetics and developed its own breeding programmes. However, local breeding programmes have largely been abandoned as more imported strains entered the market. This illustrates the hollowing out of industry capabilities due to under-investment in local breeding programmes. For example, the stone fruit industry has imported more than 4,000 stone fruit varieties since 1994 through private institutions. In 2017, of the 700 hectares of land planted to plum trees, 870,000 trees were 'open' varieties that are freely accessible without conditions, while 915,000 trees were 'protected' varieties with producer limitations and marketing conditions.[40]

However, under-investment in South Africa's quarantine facilities has meant that even the process of importing new varieties into South Africa takes a long period - approximately two years before they can be used for commercial production. The quarantine process involves laboratory testing to ensure that the imported varieties are free of pests and diseases. While this is a necessary process, the time it takes for imported varieties in quarantine could be greatly reduced to improve local growing of new varieties. This is currently causing major

[36] Interview with Derek Donkin, South Africa Avocados Growers Association (SAAGA), July 2018.
[37] Interview with Derek Donkin, South Africa Avocados Growers Association (SAAGA), July 2018.
[38] Interview with Derek Donkin, South Africa Avocados Growers Association (SAAGA), July 2018.
[39] Interview with Hans Muyaert, Unlimited Group, August 2018.
[40] Interview with Hans Muyaert, Unlimited Group, August 2018.

delays for growers to plant new varieties with key implications for an industry that relies heavily on imported varieties. The private sector is limited in its capacity to deal with these challenges as it is solely a government responsibility.[41]

4.1.2 Pest and disease technologies

While biotechnology contributes to producing more pest and disease resistant varieties, technological advances in software can link fruit growers' weather data to actual pest risk.[42] This technology uses weather technology through solar-powered wireless weather stations to gather real-time data on temperature, humidity, rain, and leaf wetness. The data is used to generate stepped risk levels to warn the farmer of when conditions are most susceptible to pest development.[43] For example, farmers in South Africa are using scouting smartphone applications to speed up and improve pest and disease identification and treatment. Using the application, a scout can take a photograph of the pest or disease on the tree or plant, then upload the image to a database in real time for immediate identification and treatment.[44] However, due to poor internet and cell phone connectivity growers are limited to the extent to which they can use cell phone applications to improve farming and workforce management. Often growers and producers cannot use cloud computing to store their information.

Investments in software linking growers' weather data to actual pest risk should be complemented by investments in research and development in pests and diseases. This is critical for producers to demonstrate to trading partners that their products are free of pests and diseases. The citrus industry, through the dedicated research and development division of the Citrus Growers Association (CGA), has been successful in terms of maintaining standards and developing the technical and science expertise to keep up with changes in the market place. This has enabled the industry to demonstrate to trading partners that their exports do not pose risk to importing countries. A key example relates to the European Union's False Coddling Moth concern with South Africa's exports of citrus. The citrus industry was able to conduct research and provide technical information indicating that there was no risk in their fruit exports. If CGA had not dealt with the False Coddling Moth concern, the EU would likely have blocked South Africa's exports.

While the CGA through its in-house science and research unit has been successful in carrying out cutting-edge research and solutions for pest-control, the fruit industry as a whole lacks sufficient investments to develop these capabilities. Developing such capabilities requires significant resources, which small industry associations such as the berries and avocados may not have access to. For instance, the CGA spent approximately R60 to R70 million on research and development from its total annual levies of R90 million in the 2017/18 financial year.[45] The South African Berries Association (SABPA) although still in its infant stages, is also investing in research on insects and fungi that affect blueberries including viruses and

[41] Interview with Hans Muyaert, Unlimited Group, August 2018.
[42] https://www.growingproduce.com/fruits/new-technologies-for-fruit-growers/.
[43] https://www.growingproduce.com/fruits/new-technologies-for-fruit-growers/.
[44] http://3b5dca501ee1e6d8cd7b905f4e1bf723.cdn.ilink247.com/ClientFiles/cga/CitrusGowersAssociation/Company/Documents/Farmers%20Weekly%2014%20October%20-%20Katlego%20Citrus%2C%20Marble%20Hall.pdf; and Charl Marais, Westfalia, Dialogue on key technologies in the fruit industry, CCRED, 22 August 2018.
[45] Interview with the CGA, Dialogue on key technologies in the fruit industry CCRED, 22 August 2018.

bacteria. This research information is then used by the Department of Trade and Industry in trade negotiations for market access.[46]

Currently, a handful of large players in the berries and avocado industries have access to resources to set up subsidiary businesses dedicated to research and development. For example, Westfalia, the largest player in the avocado industry, owns a subsidiary business dedicated to research and development called Westfalia Technological Services. However, these investments benefit the large companies and unlike the CGA there is no industry-wide in-house research teams and skills to assist timeously with the technical side of pests and diseases involved in accessing markets.

4.1.3 Precision farming and irrigation technologies

Increased weather variability and water scarcity are driving key developments at the growing level through the application of irrigation technologies and precision farming methods. Regulated Deficit Irrigation (RDI), satellite imagery and high-resolution crop sensors are used to inform application of the right amounts of irrigation or fertiliser while optical sensors or drones are used to identify crop health across the field.[47] The recent droughts in South Africa are increasingly forcing growers to adopt irrigation and precision farming technologies to maintain and improve production.

The recurrent droughts have implications for the growth of fruit production which is expected to grow slowly in the next 5-10 years. For example, the apple industry predicted a 5% growth in production between 2013 and 2018. However, given the persistent water constraints the industry is expected to grow at not more than 2.5% in the next 5 years.[48] As such, the industry is being conservative in new plantings to ensure that there is enough water for the current plantings. Given the water challenges, the fruit industry generally is focusing on producing the right quality of fruit rather than growing larger volumes. With the challenges imposed by climate change, the ability to maintain and grow the right quality of fruit in terms of colour, taste and sugar content becomes increasingly important.[49] For example, South African apple growers recently obtained access into the Chinese market in 2017/2018. However, the industry cannot export large volumes to China because the Chinese market demands large-sized fruit, which South Africa cannot produce in large quantities, due to the effects of climate change.[50]

In response to water challenges, the Western Cape Department of Agriculture developed an online application called FruitLook in May 2016 to provide farmers with accurate and reliable information on the water needs of crops.[51] At an industry level, the Citrus Research International (CRI) conducts long-term research on how to improve water use efficacy in citrus orchards. A key part of the research focuses on understanding the basic principles involved in different fruit physiology and irrigation scheduling, which are critical to increase production and fruit quality.[52]

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[46] Interview with the South Africa Berries Producers' Association (SABPA), 19 October 2018,
[47] https://www.fruitlook.co.za/ ; Interview with Fresh Produce Exporters Forum, 16 October 2018.
[48] Interview with Tru-Cape, 19 November 2018.
[49] Interview with Tru-Cape, 19 November 2018.
[50] Interview with Tru-Cape, 19 November 2018.
[51] https://www.fruitlook.co.za/ .
[52] http://www.citrusres.com/ .

At a firm level, avocado growing companies such as Westfalia are adopting the use of low-flow drip irrigation technologies in their farming methods, programmed using a mobile phone. The irrigation information is recorded and can be analysed. These systems also allow crops to be irrigated and fertilised at the same time. However, the avocado industry is not advanced in its use of precision farming methods partly due to the nature of extensive farming techniques practised in avocado growing. The use of precision farming is widely used in fruits such as plums and berries that require smaller pieces of land and produce intensive output.

Similarly, apple growers are investing in research on narrower plantings on farms to ensure higher yields per hectare with minimum water usage per hectare. Research on narrower plantings is currently being done all over the world including in countries such as Holland. In South Africa, the University of Stellenbosch is undertaking this research.[53]

Investments in irrigation technologies although driven by the impacts of climate change also illustrate forms of constitutive power within the industry. All actors in the value chain – developers of new varieties, growers, producers and government share a common understanding of the challenges imposed by climate change and are actively investing in new production technologies. While precision farming is largely about addressing climate constraints, adoption of these production technologies is increasingly becoming important to ensure full traceability in the product value chain. This follows increased market demands for traceability right down to the field in which the product was grown, the type of fertilisers used and farm labour practices.

4.1.4 Automated sorting and grading equipment

The need to reduce defects and increase the quality and speed of fruit sorting to meet growing consumer demands is driving key technological improvements at the sorting level of the value chain. Growing customer demands and quality standards illustrate the constitutive nature of power exercised in fruit value chains. Although customers are not organised into clear or formal common membership, their conventions regarding how to define 'quality' remain critical in fruit value chains. This has been instrumental in terms of driving key investments by leading producers in the industry.

Access to new sorting technologies that are more accurate than hand grading enables producers to achieve consistency in supply of high-quality defect-free fruit to consumers. Consistency in the quality of supply is also critical for compliance with SPS for market access. Although investing in new sorting technologies is not necessarily associated with cost savings, it is value-adding to the sorting process with the result that more fruit is exported at higher prices – an important form of upgrading.[54]

While sorting technology has been in existence for years, there have been major technological developments in fruit sorting technology. The common sorting technology currently used in the local industry includes optic sizers in packhouses to sort fruit according to colour, shape, size and weight.[55] However, changes in technology are moving towards faster, higher resolution camera-sorting equipment combined with iFA (Intelligent Flavour Analyser) light

[53] Interview with Tru-Cape, 19 November 2018.
[54] Interview with Tru-Cape, 19 November 2018 and Fresh Produce Exporters Forum, 16 October 2018.
[55] Interview with Tru-Cape, 19 November 2018.

technology. This technology uses algorithms to grade and sort fruit based on both external and internal characteristics such as colour, blemish standards, internal defects and measuring the fruit's sugar content. Previously, internal defects could only be determined by cutting into the fruit.[56]

After sorting, the fruit is separated into different classes and sizes and then packed into cartons and pallets of the same grade and size for sale to the buyer. While the sorting technology has been widely adopted across South Africa's fruit industry, packing technology and robotics is the future technology of the packhouse. Globally, new technologies and robotics are being developed that can both sort and pack the fruit. The software enables the user to select the number of pieces of fruit to go into a package including the weight of that package. This technology is known as 'Intelligent Package Weight & Counts'. During sorting, the software tries to ensure that the average weight of all fruit in a certain group is as close to or slightly higher than the desired average weight.[57]

South Africa has limited research, technical and engineering skills to develop new sorting technology in-house. As such, most fruit producers including apples and berries import sorting equipment from leading manufacturers in France, Holland, Netherlands and New Zealand. This results in local firms incurring high costs of adopting new technologies.[58] This is particularly important for the growth of niche industries such as berries which are capital and technology intensive. These industries have to rely on imports for capital and technology, adding to the high costs of production. For example, Tru-Cape Fruit Marketing, one of South Africa's largest marketing companies of apples and pears imported a 10-lane sorting equipment from Netherlands-based manufacturer Greefa at a cost of ZAR 80 million – ZAR 100 million in 2018.[59]

4.1.5 Cold storage and packaging technologies

As highlighted, the need to preserve the shelf life and quality of the fruit up until the point it reaches the supermarket shelves has been a driver of key technological developments in cold storage and packaging. Success in the fruit industry is mainly about adopting cold chain and packaging technologies to ensure a longer product shelf life.

The main cold storage technologies include the use of dynamic controlled atmosphere cold rooms in combination with smart press energy efficient technologies for temperature control. This technology has been around for the past six to seven years with majority of local producers using systems, equipment and software which minimise electricity usage in the cold storage facilities. Producers are able to store fruits for up to ten months of the year.[60]

Although South Africa has been a leader in controlled atmosphere cold storage technologies especially in pome fruit, it has lost its lead position to countries such as Germany and Italy

[56] https://www.tru-cape.com/tru-news/new-technologies-keep-tru-cape-and-its-packhouses-in-the-lead/; https://www.tru-cape.com/tru-news/new-grabouw-sorting-line-and-packhouse-uses-the-latest-global-tech-available/ .
[57] https://www.tru-cape.com/tru-news/new-technologies-keep-tru-cape-and-its-packhouses-in-the-lead/; https://www.tru-cape.com/tru-news/new-grabouw-sorting-line-and-packhouse-uses-the-latest-global-tech-available/
[58] Interview with Sundays River Citrus Company, 17 October 2018.
[59] Interview with Tru-Cape, 19 November 2018
[60] Interview with Tru-Cape, 19 November 2018.

since around 2016. This has been largely due to limited government funding and lack of private sector investment interest.[61] In South Africa, the government's priority with regards to fruit (and agriculture more broadly) has been more focused on transformation (participation). The industry's priority on the other hand has been around quality, growth and increased market access. This standoff creates an investment vacuum in certain areas within the industry resulting in a deterioration of existing capabilities. Although producers and growers are privately investing in cold storage technologies, industry-wide technological impacts require that government also plays a key role in sector investments.

Anticipated future changes in cold storage technologies include modular cold chain technologies built from lightweight and expandable smart materials.[62] Globally, companies are developing automated, controlled and remotely monitored refrigeration storage units that can be adapted in both size and specific layout to suit the needs of any farmer. Data services enabled by remote sensing devices and centralised data management systems support farmers with customised configuration and optimization of their facility. It also enables remote supply chain data aggregation that is supplied to clients to support improved performance and undertake predictive maintenance.[63] This has huge implications for access to cold storage facilities for small farmers located in remote areas without access to reliable supply of electricity.

Investments in cold storage technologies should be complemented by packaging technologies. Packaging technologies are used extensively worldwide to preserve the quality and extend the shelf life of the product while also addressing one of the core challenges in the industry around increasing food safety standards.[64] Packaging is increasingly becoming important with the drive towards energy efficient packaging materials and minimal amount of wastage produced. There is a growing insistence on recyclable and biodegradable packaging material or organic and biological packaging products. Greater environmental awareness has also resulted in consumers being more demanding about the way in which produce is packaged thus creating pressure for the industry. Furthermore, different types of fruit have different packaging requirements and different markets also require specialised packaging.[65]

Key innovations in the packaging industry include packing material made from organic components of up to 50% fresh grass fibres. There is a drive to use recyclable, biodegradable materials that allow greater savings in energy and raw materials.[66] The future of packaging in the fresh fruit industry is going towards smart packaging, which gives more information to the consumer and increased efficiency in terms of lengthening the useful life of the product.[67]

Digital platforms and internet of things

4.1.6 Electronic certification and integrated data sharing platforms

Cutting across the entire value chain is the core challenge around compliance with SPS for increased market access. This is driving key technological developments in South Africa's

[61] Interview with the Fresh Produce Exporters' Forum, 16 October 2018.
[62] http://www.inspirafarms.com/ . Interview with Inspirafarms, 29 August 2018
[63] http://www.inspirafarms.com/ . Interview with Inspirafarms, 29 August 2018.
[64] https://www.dlg.org/en/food/topics/dlg-expert-reports/dlg-expert-report-72018/
[65] https://www.farmersweekly.co.za/agri-business/agribusinesses/science-fruit-packaging-sa-leads-way/
[66] http://fruitattraction.com/en/packaging-innovations-in-the-fruit-and-vegetable-sector-en/
[67] http://fruitattraction.com/en/packaging-innovations-in-the-fruit-and-vegetable-sector-en/

fresh fruit industry. The Department of Agriculture, Forestry and Fisheries (DAFF) is the authority for fresh produce with the institutional mandate to deal with core industry challenges regarding phytosanitary standards and plant health issues. However, the department has been slow in adopting and implementing electronic systems of capturing data continuing to rely on paper-based, email and spreadsheet systems. Reliance on paperwork and manual processes of capturing data on registration of orchards, phytosanitary records of growers and shipping information results in considerable time wasted and human errors. For example, the process of exporting fruit and acquiring phytosanitary certification is a paper-based approach where growers have to physically make frequent trips to government offices to sign paperwork.

The delays in digital migration are exacerbated by the department's constraints around capacity in terms of human resources, skills and lack of implementation of policies. Although DAFF is endowed with the institutional power and regulatory tools to address SPS issues, the department has played a very weak role in improving industry outcomes.

This has seen the private sector, through the umbrella industry association, Fruit South Africa (FSA), step in to address these challenges around certification of phytosanitary standards using technological solutions. FSA is an umbrella body of the local fruit industry established in 2000 representing five fruit producer organisations. These are the South African Table Grape Industry (SATI), Citrus Growers Association (CGA), HORTGRO for deciduous fruit growers, Fresh Produce Exporters' Forum (FPEF), and South African Subtropical Growers' Association (Subtrop). Fruit South Africa has a large membership base. For example, the CGA was established in November 1997 and it represents the interests of approximately 1 200 commercial growers in South Africa for citrus export.

In response to challenges of manual intervention and paper-based systems, Fruit South Africa (FSA) brought on board the Department of Agriculture Forestry and Fisheries (DAFF), jointly developing an electronic data sharing platform called Phytclean to capture, store and report data for export phytosanitary certification in 2016.[68] The platform is used to capture information on the registration of orchards and enables instant updates and verification of orchards, phytosanitary records of growers and ultimately issuing of electronic certificates. As such, Phytclean provides electronic alternative evidence to the paper-based system for all the prerequisite steps in the certification process, which can be accessed by all relevant parties in the value chain including importing authorities. With the new digital platform, after a product is cleared and the SPS requirements are met, the product is signed off electronically without the growers having to visit government offices and sign paperwork.

The electronic certification (e-cert) of phytosanitary standards was successfully piloted in the citrus industry in September 2018 from South Africa to the Netherlands and it is set to be implemented in June 2019.[69]

The industry association, and its various sub-bodies has played an instrumental role in shaping outcomes in the fruit industry in this regard. Through the strategic actions of a collective of growers and producers, the industry association successfully lobbied the government to carry out specific functions including in launching Phytclean and e-certification.

[68] https://www.citrusresourcewarehouse.org.za/home/document-home/news-articles/south-african-fruit-journal-safj/sa-fruit-journal-2016/3748-sa-fruit-journal-aug-sept-2016-cga-phytclean-update/file .
[69] https://www.citrusresourcewarehouse.org.za/home/document-home/news-articles/south-african-fruit-journal-safj/sa-fruit-journal-2016/3748-sa-fruit-journal-aug-sept-2016-cga-phytclean-update/file .

Although Fruit South Africa is a voluntary organization, the combined actions of actors that share membership and a clear vision has enabled it to grow into a powerful organisation.

To complement and realise the benefits of the industry initiative towards electronic certification and data sharing systems, individual firms particularly large producers are implementing electronic data interchange (EDI) systems within their supply chains to integrate information in the packhouse and cold chain facilities rather than using paper-based systems. This technology allows for seamless monitoring of supply chain processes as the system syncs the information from the pack house and cold storage facility and then produces comprehensive reports and documentation. Tablet devices installed with apps that use cloud storage are used to conduct audits and inspections at the source (at the farms) necessary to acquire accreditation in export markets.[70]

Blockchain technology, which is a decentralised or open data/information system that is shared between many computers is expected to be a significant development in the fruit industry addressing challenges around lack of transparency and traceability along the value chain (Provenance, 2018; Wyman, 2018). A core challenge in the fresh fruit industry is the inherent lack of transparency and traceability due to limited availability of data combined with lack of interoperability (Wyman, 2018). These challenges result in manual intervention and paperwork, which waste time with increased chances of errors.

Technological solutions such as blockchain enable the producer to collect and upload data on field location, growing conditions, soil and fertiliser use, harvest details, cold chain initiation and transportation history. The retailer provides an app for end customers, which customers are able to scan the Quick Response code via the app and get insights into origin, harvest date, transportation and cold chain. Hence, blockchain enables end-to-end data transparency for fresh products allowing all players in the chain to access historical and real-time data linked to the product such as timing (time of harvest, time in transport), location (its origin and the history of its journey from farm to fork) or data on the farming, labour and environmental practices (Wyman, 2018).

Greater transparency along the value chain is being driven by retailers' and customers' demands for quality and more information regarding various aspects of the product. Customers are increasingly seeking to know more facts about the product they are purchasing. For example, the Sustainability Initiative of South Africa (SIZA) is a technological platform to address ethical consumer concerns around fair and ethical labour practices; and environmental standards. In response to market demands, South African growers and producers started the community initiative, SIZA.[71]

Ethical and environmental requirements are governed and shaped by mechanisms of broad-based collective action or social movements and conventions by consumers and retailers. This illustrates an exercise of constitutive power of customers and industry quality standards (Dallas et al., 2018). Similarly, Davis Kaplinsky and Morris (2018) explain how actors that are external to the chain, especially Civil Society Organizations, are increasingly exercising their power to influence the social and environmental character of GVCs. This has significantly

[70] Interview with Sundays River Citrus Company, 17 October 2018.
[71] Interview with Sundays River Citrus Company, 17 October 2018.

influenced the capacity of firms within the value chain to generate and appropriate rents in the value chain.

Although blockchain technology is expected to address transparency and traceability issues in the value chain, it is important to note that this technology is a relatively nascent technology and as such the benefits are not yet well-established. There are still a number of challenges associated with the use of blockchain technology. As a decentralised data system, it is slower to process large transactions especially if it is a public platform and there are various efficient systems currently available. Another challenge regarding blockchain technology relates to issues of scalability.

However, there are some concrete cases where blockchain technology is being applied across different industries and value chains. For example, a UK based organisation called Provenance adopted the digital platform in 2013 to track the history and journey of physical products from origin up until the point it reaches the consumer. They have piloted this technology in international projects such as the South East Asia fishing industry and with large retailers and brands such as the The Co-op supermarket - UK's largest consumer co-operative.

In the South East Asia fishing industry, Provenance used the mobile blockchain technology and smart tagging to track fish caught by fisherman with verified social sustainability claims for export. The social and environmental conditions for the fishermen at the point of capture were verified through trusted local NGOs whose audit systems validated their compliance to an external standard. These standards include Fair Trade USA, Pole and Line Foundation Association Member, GPS (working with Seatracker data) (Provenance, 2019).

Provenance worked with local fishermen to help them collect data on their catches of fish and track it through to suppliers. The registered fishermen sent SMS messages to register their catch. The assets were then transferred from fishermen to supplier along with the catch in both physical transactions and in the digital register on the blockchain. After the supplier received the catch, they checked the product on blockchain explorer. The final part of the pilot explored how the information from origin and the supply chain could be accessed and trusted by shoppers at the end of the chain through the use of QR codes and NFC stickers linking products to digital assets (Provenance, 2019).

Similarly, The Co-op project used Provenance software to track fresh produce and their product claims from origin to supermarket. The Provenance app showcased the journey of fresh produce and its data through the supply chain. First, Provence gathered and analysed product data at various producer and supplier locations with attached proof of verified sustainability or authenticity claims. They collected data from the farm, through the factory, and linked it with systems data at Co-op depot and retail, building a real-time digital history for the fresh produce. The retailer communicated product information online and on shelf. The shopper through the Provenance app has mobile access to product information and stories and they discover the journey through the product label.

4.1.7 Cargo and shipment tracking technologies

High levels of congestion and delays at South Africa's main ports demands the adoption of blockchain related digital platforms and the internet of things to timeously handle larger volumes of product and deal with seasonal flows. The process of moving fresh produce

through the ports can take seven to eight weeks, drastically reducing the shelf life of the product long before it has reached the export supermarket shelves.[72] Port congestion and delays are particularly acute during peak seasons of major export products such as citrus. Delays at the major port of Durban are estimated to cost the South African citrus industry US$10.5 million per season (or approximately US$400 million of exports) (World Bank, 2011). Port delays at South Africa's main ports are expected to increase given the growth in citrus export volumes. In 2018, the citrus industry exported 130 million cartons of fruit and this is expected to increase to 170 million cartons in 2019.[73]

Although growers and producers in the fruit industry have computer-generated data on the flow of products which could be provided to the ports to plan in advance and avoid product overload, these systems need to be integrated.

Blockchain technology combined with the internet of things could be used to integrate the whole value chain and improve transparency of processes. Furthermore, blockchain could also address South Africa's gap for technologies that can provide timeous visibility of shipping vessels and tracking of freight containers to 'gate-in' at the port of discharge. Time delays and uncertainty in logistics increase transport costs due to the increasing importance of global supply chains, just-in-time inventory management and lean retailing (World Trade Organisation, 2018).

Global logistics companies such as Maersk - a Denmark-based shipping company is leveraging digital technologies to optimise operations and reduce costs. In August 2018 Maersk in cooperation with the US-based IBM launched a blockchain-based global trade digitalisation platform called Tradelens. The digital platform aims to connect the various parties involved in international trade in order to cut down the filing, verification, processing and coordination costs associated with cross-border transportation (World Trade Organisation, 2018).

Furthermore, Maersk in partnership with Ericsson, a Swedish multinational network and telecommunications company developed a real-time remote container management (RCM) system across its fleet of refrigerated containers. Cargo and shipment tracking reduce logistics costs by increasing operational efficiency, enabling real-time adjustments and making logistics more secure (World Trade Organisation, 2018).

In 2015, Maersk rolled out a system of real-time tracking for its entire fleet of around 300 000 refrigerated containers. The fleet is equipped with remote container devices that transmit container performance data on key parameters such as temperature, power supply and location to the company's private data cloud. This system allows Maersk to track and monitor container performance at any point allowing for corrective actions to be taken at any of the various stages of the cold chain. These stages begin from the supplier's proper pre-cooling of the cargo, to the trucker ensuring that the container is plugged in, to accurate performance during the ocean leg, to the correct handling at destination and to final delivery to the end-customer. Such technology also enables Maersk to detect faults and speed up physical inspection processes prior to releasing containers for export through the use of smart sensors. Smart sensors make it possible to know the condition of the container precisely helping to

[72] Digital Industrial Policy Dialogue for the fruit sector, 22 October 2018.
[73] Digital Industrial Policy Dialogue for the fruit sector, 22 October 2018.

determine the type of inspection required prior to release for export (World Trade Organisation, 2018).

Although companies such as Intrasystems and Remote Monitoring Systems (RMS) Online provide this service in South Africa, they do not always have access to up-to-date information. Large citrus growers such Sundays River Citrus Company have thus developed in-house systems to track their freight containers using the IoT. Beyond the firm level, the industry also provides a set of data which shows vessels of fruit containers en-routes and schedules. This data is used by local exporters and packers to make supply decisions regarding for example when to start packing and how much to pack. However, this process is not IoT-based, and is laborious and tedious with multiple challenges. Therefore, digital solutions that can ensure better coordination between freight forwarders, shipping lines and clients not only save and reduce the administration processes but create increased visibility of shipping vessels. Access to information on the estimated time of arrival is also useful as this could help cut company costs.[74]

Currently, blockchain technology is being used in limited cases to process payments in fruit trading, which has drastically reduced the speed with which payments are processed. For example, some producers use a company called Traderly which utilises blockchain to fast-track trade payments by converting the US dollars into cryptocurrency in South Africa. In comparison to the traditional 'SWIFT' payment method, this technology has sped up the payment process from 3-5 days to 15 minutes.[75]

The main challenges to adopting such digital technologies in the fruit industry is that most producers are located in the rural areas with poor internet and cell phone connectivity. This is also a huge constraint for institutions such as the Perishable Produce Export Control Board (PPECB) that conduct audits for export markets and accreditations. These organisations cannot afford downtime in connectivity because inspections need to be conducted timeously.[76] The challenges of poor connectivity are exacerbated by South Africa's lack of broadband infrastructure, which limits the use of digital technologies.

5. Implications for market access and participation

The above section highlighted the main technological developments and the governance structures and power dynamics that have driven these outcomes in different fruit value chains. As an export-oriented industry worth US$3 billion and among the most labour-intensive areas of agriculture, it is critical that government and private sector understand the impact of technological changes on market access and participation of small and medium farmers. It is important to note that while market access in itself is not a technological issue, it is enabled by technological advancement and needs to be made a major priority. On the other hand, effective participation of small and medium sized producers requires that they adopt key technologies in order to create value and capture value within the chain.

The main challenge in accessing markets in the fruit industry (even before meeting consumer demands on quality) is the ability to comply with SPS or plant health assessments in different

[74] Interview with Sundays River Citrus Company, 17 October 2018.
[75] Interview with the Fresh Produce Exporters' Forum South Africa, 16 October 2018.
[76] Interview with Sundays River Citrus Company, 17 October 2018.

markets. The process of compliance with SPS requires that the industry provides technical and science expertise through research and technology development necessary to prove that they are not putting the importing country at risk of pest and diseases.[77] This research information is a critical tool for government to negotiate trade agreements with other countries or market it to potential trading partners. Furthermore, the protocols and requirements for each market are increasingly becoming complex and growing in numbers. As such, the ability to comply is critical, making technological solutions necessary for firms to comply.[78] Compliance issues also create a key barrier for participation of small and medium-sized farmers leading to concentration in fresh fruit exports.

If South Africa is to double its current growth rate and catch up to competitors such as Mexico, Peru and Chile within the next five to ten years, growers and producers need access to new markets in South and East Asia including China, Vietnam, Thailand, South Korea and India. With the European Union market stagnating, the Asian countries represent markets where most of the future growth is likely to come from, yet South Africa has been very poor in opening-up access to these markets. Although Africa is a large market, it lacks the facilities and infrastructure to move fresh produce across borders for increased trade.[79]

SPS issues are a key reason why South Africa has not been able to access large and high growth markets such as China. Although the large firms have substantial existing capabilities in research and technology development, there is a gap in the government's ability to make use of industry research information to negotiate market access. The government has limited in-house expertise to use industry research to market and demonstrate to potential trading partners that local fruits do not pose disease and pest risk to importing countries. Given the long processes involved in getting access to the East Asian markets, there is a risk that South Africa might miss the current growth opportunities in global demand particularly in the berries and avocado industries. These long delays in getting market access are hindering growth and participation. For example, it took 18 years for South Africa's apples to get access into China.[80]

Digital platforms have played a key role in terms of improved compliance with SPS for increased market access. Such technologies enhance the integrity of the issuing of export and phytosanitary certificates[81] and address the challenges around limited and poor quality of data. However, digital technologies pose the risk of further excluding small farmers and producers from participating in export markets given the required investments in electronic systems. Adoption of electronic systems involves significant changes on the part of growers and producers to develop in-house systems of capturing data. This includes stock systems and big data systems including the ability to standardize the stored and shared information across the different systems.[82]

The use of integrated digital technologies at the major ports has huge implications for market access and participation. Digital solutions by reducing the logistics costs of exporting and

[77] Interview with Citrus Growers Association of Southern Africa (CGA).
[78] Interview with Sundays River Citrus Company, 17 October 2018 and Interview with Fresh Produce Exporters Forum, 16 October 2018.
[79] Interviews with Citrus Growers Association of Southern Africa (CGA), South Africa Avocados Growers Association (SAAGA) and Unlimited Group.
[80] Interview with SABPA, 19 October 2018.
[81] Interview with Paul Hardman, Citrus Growers Association (CGA), July 2018.
[82] Interview with Sundays River Citrus Company, on 17 October 2018.

easing the process of exporting for many producers could increase the value of exports and facilitate entry of new players into the export market.

To ensure widespread adoption of digital technologies in agriculture, there is need to invest in spectrum and internet infrastructure in production areas (mainly in the rural areas). Poor access to internet and cell phone connectivity is a major constraint to sharing and accessing information.

The experiences of the Brazilian Corporation for Agricultural Research (EMBRAPA) established in 1973 provide key lessons on the role of public research institutions in fostering technological change, diversification and upgrading in agriculture and farming (Andreoni and Tregenna, 2018). Embrapa is the largest agricultural R&D agency in Latin America operating 47 research centers throughout the country. Embrapa is involved in a wide range of activities related to agricultural research and technology including plant breeding, pest management, food safety, satellite monitoring and sustainable agricultural development. It also conducts crop research activities which are carried out at locations around the country to develop crops and varieties that are suited for local conditions (Matthey et al., 2004:10).[83] Since inception in 1973, Embrapa has generated and recommended more than nine thousand technologies for Brazilian farmers (Andreoni and Tregenna, 2018).

Embrapa's technological efforts were reinforced by government investment in human skills, which established new universities and postgraduate courses in all states of the Cerrado region. The institution employs 9 284 employees and has an annual budget of over US$1 billion (Andreoni and Tregenna, 2018).

Investments in development of human skills were complemented by the government's concerted efforts to improve and renovate public infrastructure. Included among these investments, at the interface between agriculture, biotechnologies and advanced manufacturing, were:

i. The construction of one of the world's first National Agribusiness Nanotechnology Laboratories focused on the development of sensors and biosensors for food quality control, certification and traceability. The Laboratory was also dedicated to the synthesis of new materials, such as polymers and nanostructured materials or thin films and surface-to-manufacture smart packages.
ii. The building of six new walk-in freezers to increase the storage and preservation capacity of the Embrapa Germplasm Bank (from 120 to 240 thousand seeds). (Andreoni and Tregenna, 2018)

Although research and technology development is critical in terms of producing factual and evidence-based information, market access is also a political economy issue. Countries are increasingly using SPS to erect non-tariff barriers to imports. The CGA has been quite successful at lobbying government for market access into markets such as China while small industries such as the berries with limited capacity and resources are not able to negotiate market access into the same markets.

There are key lessons to be drawn from what other countries are doing to increase access to export markets. Chile and China provide important lessons around compliance with standards and marketing for increased market access. The Chilean Fresh Fruit Association was

[83] http://www.oecd.org/agriculture/agricultural-policies/48218869.pdf

instrumental in sourcing export markets for its fresh produce in the United States and in Europe. To ensure compliance with international standards, the government created ChileGAP (accredited by GlobalGAP) to support local growers and producers in meeting safety and quality standards imposed by global buyers and the SPS imposed by regulators in key markets. ChileGAP provided local growers and exporters with the tools to implement GAP requirements at the lowest cost. Chile also established a local council to assist with genetic improvements, transfer of knowledge and food safety. This was coupled with extensive improvements in infrastructure including connections to highways and ports to reduce transport times from farms. The government further assisted with SPS processes and protocols for pack-houses and for the entire cold chain (Chisoro-Dube et al. 2018).

Similar to Chile, China invested in meeting international quality and food safety requirements across the entire value chain. At the farming level, local governments employed technical advisors to help farmers apply pesticides and fertilisers and to carry out inspections of farm inputs to prevent fake pesticides and fertilisers from entering the orchards. The Chinese government also engaged in strong market development by acting as an intermediary and introducing international customers to local firms (Chisoro Dube et al. 2018).

To access markets, producers in Chile and China relied on extensive government support and the development of strong public institutions particularly in facilitating and monitoring compliance with global food safety standards. In both countries, government institutions established accreditation institutions that ensured compliance with global quality standards and invested in infrastructure to integrate farmers into the transport network (Chisoro Dube et al. 2018). The South African government, on the other hand has provided very little support of the types mentioned above to the local fruit sector. There has been little, if any, effective inter-departmental efforts to grow and support the fruit industry and most efforts have been by the private sector.

With regard to tariffs and non-tariff barriers, Peru and Chile also provide important lessons on how government could leverage their existing trade agreements to increase market access. For example, South Africa as a member of the BRICS should leverage preferential trade agreements for fruit products with Russia, China and India.[84] South Africa has failed to use the BRICS membership to secure better trade deals for fresh produce especially with China.

At the growing level, South Africa's dependence on imported varieties and concentration in the ownership of varieties not only raises costs of production through royalties but heightens exclusion of farmers from growing specific varieties and entering export markets. One of the reasons the avocado industry has not grown as fast as global demand is concentration in ownership of varieties which has limited access to trees.[85] Furthermore, the lengthy processes it takes for imported varieties in quarantine causes major delays for growers to plant new varieties. Access to high quality varieties in a timeous manner is critical for accessing markets in an environment where old varieties are constantly being replaced by new varieties with better traits. The nature of the berries industry as a capital and technology intensive industry has implications for participation by small emerging black farmers. As such, if South Africa is

[84] Interview with Justin Chadwick, Citrus Growers Association (CGA), 27 June 2018.
[85] Interview with Hans Muylaert, Unlimited Group, August 2018.

not at the forefront of growing or developing new varieties, it may lose competitiveness in existing markets.

To reduce South Africa's dependence on imported varieties, and growing control over production by a few powerful players that own the IPs and varieties, it is crucial that South Africa invests in local breeding programmes in partnership with universities and research councils. There are existing industry capabilities in biotechnology as evidenced by the development of new varieties across different fruits. However, due to the long-term nature of investments in developing new varieties, the government could play a key complementary role in supporting these investments.

Furthermore, investments in laboratory equipment and skills in quarantine facilities are necessary to promote local breeding of varieties by reducing the high mortality rates of varieties in quarantines, including the lengthy periods taken to clear imported varieties of pests and diseases.[86] This could facilitate the quick adoption of imported varieties for commercial production. Currently, South African authorities do not accept varieties that have been tested and cleaned in internationally certified laboratories from other parts of the world. They insist on repeating the process in South Africa.[87] However, countries such as Spain and Chile have fast-tracked their systems for pathogen testing by shortening the time to market through accepting product tested in internationally certified laboratories. This gives competitors a significant advantage in terms of time and cost over South African producers. Producer organisations in South Africa are trying to get the government to align the testing process with other countries so the process can move faster.[88]

Investments in new and improved varieties have never been more important given the worsening climatic conditions. The growing effects of variable rainfall and increased frequencies of drought conditions imply that farmers should increase plantings of new varieties that are adaptable to local conditions coupled with new irrigation and pest control technologies. This is critical in terms of producing the right size and quality of fruit demanded in export markets given the limited scope for overall growth of the industry in terms of volumes of fruit production.[89] While investments in improved varieties, irrigation technologies and precision farming are addressing the challenges of climate change, such investments are costly for small and emerging farmers who mainly enter at the growing level. There is therefore a key role for government to scale up investments in these areas following the example of the Western Cape provincial government.

Enhanced accuracy in sorting coupled with controlled atmosphere cold storage technologies has improved the overall quality of fruit and expanded access to geographically dispersed and distant markets particularly of sensitive/delicate fruits. For example, products such as berries have a very short shelf life and the slightest reduction in turnover times will increase profits significantly (Wyman, 2018). While, South Africa has made significant progress in adopting sorting and controlled atmosphere cold storage technologies, these investments are costly and concentrated around the large producers in the industry. This means that growing customer demands are further excluding small producers that are unable to invest in the new

[86] Dialogue on key technologies in the fruit industry, CCRED, 22 August 2018.
[87] Dialogue on key technologies in the fruit industry, CCRED, 22 August 2018.
[88] Dialogue on key technologies in the fruit industry, CCRED, 22 August 2018.
[89] Interview with Tru-Cape, 19 November 2018.

equipment. The nature of fruit as a perishable product coupled with growing customer demands has meant that adoption of technology is no longer an option but a necessary step to participate at any level of the value chain. This has important implications for entry and participation of new players into the value chain who have to invest in new equipment and technologies, which are mostly imported from developed countries.

Extending these investments to support broad-based export growth requires increased government and private sector investment, including in terms of research and skills development. This is particularly important for fast growing industries such as berries with a limited product shelf life where advances in technology are building faster and more flexible, precise and transparent fruit supply chains.

While drip irrigation and automated sorting and grading technologies are resulting in shedding of low-skill jobs, these disruptive technologies are creating a new set of skilled jobs. These include persons to operate the new machinery and equipment, conduct maintenance and repairs and research.[90] Such changes in technology require urgent skills development in partnership with the private sector to meet the demand for different and more advanced skills and to ameliorate losses of low skill jobs in some processes. However, the fruit industry continues to play a key role in employment contribution given that major activities such as fruit picking and packing are done by hand.

Finally, the power of the data generated from all these technologies in the fruit value chains should not be underestimated. With enormous volumes of data generated along the value chain through the various technologies discussed above (blockchain, sensors, water and climate monitoring etc.), the ability to process, analyse and use this data is becoming critical. Big data analytics provides an important tool with which to analyse large volumes of cloud-based data. For example, retailers and consumer packaged goods companies are using large volumes of consumer data to better analyse and forecast changing demand patterns (Wyman, 2018). These advances represent the next big stepwise changes which are anticipated in the industry. Who owns this data and how it is used will be instrumental in understanding who has the power in the value chain and how it is governed going forward. At present, there are no regulations in South Africa which govern and protect the use of such data. South Africa needs to adopt appropriate policies that govern the ownership and use of big data that serve to increase participation and improve market access, rather than benefiting only a handful of large players.

6. Conclusions

Sustainable growth in the fruit industry is increasingly dependent on the producer's ability to adopt key technologies in their production processes. These include production technologies, sorting and cold storage equipment, electronic data sharing systems and internet of things. Adoption of these and other technologies has become necessary for producers to keep up with market demands, complex phytosanitary requirements; and climate and environmental constraints.

The process of innovation and adoption of new technologies in the value chain has been largely shaped by governance and power structures within the industry. The main types of

[90] For example, Westfalia has automated sorting and grading and implemented drip-feed irrigation which reduces the employment previously required in the manual tasks.

power shaping outcomes in the fruit value chain are institutional power of industry associations, market power of lead firms, constitutive power of growing consumer demands and civil society organisations. These forces are driving key investments at various levels of the value chain with implications in terms of who can innovate, adopt new technology and gainfully participate in the value chain.

With most of the technologies imported from developed countries, it is mainly leading firms in the industry with access to resources that are able to adopt and develop new technologies. At the upstream level, large producers are investing in developing new and improved varieties. The owners of protected varieties through intellectual property rights exercise their market power to control access to the variety, production and marketing of the product in export markets. At the fruit growing level, the bargaining power of lead supermarkets imposing stringent private standards coupled with constitutive power of consumers and civil society organisations demanding greater levels of quality and influencing the social and environmental aspects of fruit production, put pressure on the ability of small farmers to comply. At the downstream marketing level, although digital solutions are addressing compliance issues with phytosanitary standards for improved market access, there is the risk of further excluding small and medium-sized growers and producers from participating in export markets given the investments required in developing in-house systems of capturing data.

The citrus industry provides key lessons on the importance of industry-wide research and development to grow other fruits such as berries and avocados. Through the in-house dedicated research and development unit, the CGA has been successful in maintaining standards and timeously assisting growers and producers with the technical and science aspect of complying with standards in export markets. Although young industry associations such as the South African Berries Producers' Association (SABPA) are investing in developing research and development capabilities, they still require significant support from the government.

The experiences of Chile and China provide important lessons regarding extensive support extended by local governments to grow their fruit industries. Chile and China facilitated compliance with global food safety standards through lowering the costs of meeting standards and certification; facilitated access to new markets through linking farmers to international buyers; and invested in infrastructure to integrate farmers into the transport network.

In South Africa, there is particularly a key role for government to play in supporting development of skills, testing and research facilities along with broad-based adoption of new technologies for the overall growth of the industry. Taking the industry several leaps forward especially in the context of digital disruptions requires partnerships and alignment of priorities between government and private sector. The following issues are important in shaping policy responses to technological changes in the fruit industry:

- Investments in spectrum and internet infrastructure in fruit growing areas (mainly in the rural areas) to enable faster connectivity and flow of information across the industry.
- Investments in developing integrated systems of linking growers and producers' in-house systems to ports, logistics companies and shipping lines to address congestion at the ports for timeous, flexible and speedy supply chains.
- Investments in laboratory equipment and skills in quarantine facilities to promote local breeding of varieties and timeous processing of imported varieties.

- Re-skilling of existing workforce to meet growing demand for digital skills required to operate machinery and equipment, conduct maintenance and repairs; and conduct research.
- Formulate and adopt a national data regulatory policy to govern and protect the ownership and use of big data generated from the different technology platforms.

7. Annexure: List of interviewees

	Date	Firm/institution
1	July 2018	Citrus Growers' Association of Southern Africa
2	July 2018	Citrus Growers' Association of Southern Africa
3	July 2018	Citrus Growers' Association of Southern Africa
4	July 2018	South African Avocado Growers Association of South Africa (SAAGA)
5	August 2018	Unlimited Group
6	August 2018	Inspirafarms
7	October 2018	Fresh Produce Exporters' Forum South Africa
8	October 2018	South African Berries Producers Association
9	October 2018	Sundays River Citrus Company
10	November 2018	Tru-Cape
11	April 2017	In2Fresh
12	May 2017	Fruit South Africa

In addition to the stakeholder interviews, this paper draws from the Dialogue on Industry 4.0 and the fruit sector held on the 22nd of October 2018 and hosted by key industry participants. The dialogue aimed to understand how advances in technology are disrupting production processes in the fruit sector. Prior to the dialogue, CCRED also hosted a public platform on the 29th of August 2018 with various industry stakeholders. Similar to the dialogue, the public platform aimed to understand how firms can leverage advances in technology to address core challenges in the fruit industry (particularly sanitary and phytosanitary standards) and increase participation of small and emerging farmers.

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