

Article

Investigating South Africa's Fresh Peach and Nectarine Value Proposition: Measuring Progress on Achieving Sustainable Consumption in Exports

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Abstract: The Sustainable Development Goals (SDGs) have shone a spotlight on the importance of adaption to climate change. However, progress in achieving SDG 12 which calls for, “responsible consumption and production” has been stalled by the unavailability of indicators that adequately capture and motivate increased responsible consumption. To fill this gap, this article presents an alternative indicator that makes use of cultivar characteristics and uses South African fresh peach and nectarine exports as a focus area. Principal component analysis is used to extract and summarize the product value propositions identified in composite indices that were constructed by weighting the proportional use of cultivars in exports between 1956 and 2017. The indices acquired from the analysis were found to measure the provisions for sustainable consumption, good-quality fruit and off-peak fruit supply. The study's results show that progress was found in the provisions for sustainable consumption and this was mainly driven by improvements in cultivars' climate change adaptability. However, the last two decades have seen successive lower readings on this index. Improvements in fruit quality index were found to be attained at the expense of farm enterprise productivity. The study concludes that strategies be developed to encourage the use of cultivars that promote responsible consumption as, if left uninfluenced, market forces will spur unsustainable production.

Keywords: SDGs; responsible consumption and production; sustainable indicators; climate change adaptation

1. Introduction

Climate change is regarded by many as a defining challenge of our times [1], and thus, it is not surprising that the 2030 Agenda for Sustainable Development has two Goals (SDG 13 and SDG 12) that are concerned with the mitigation of, and adaption to, this environmental phenomenon. SDG 12, in particular, aims to, “ensure sustainable consumption and production patterns” and acknowledges the link between consumer behaviour and success of the long-term efforts in combating climate change [2]. The amalgamation of sustainable consumption and sustainable production in this SDG has been hailed as an improvement in global development goal setting, as previous development agendas had failed to fully integrate these two aspects [3]. Such a merger of ideologies allows the development of approaches that bring together technical environmental indicators with consumer values. It consequently asserts Dahl's [4] definition of sustainability as being, “an ethical challenge

which requires a new set of values-based indicators that measure and motivate the implementation of ethical principles”.

Past efforts to encourage sustainable consumption have been designed around the concept of positive and negative incentives and using them to direct consumer behaviour. Examples of these have included the introduction of environmental taxes and eco-labels. Consequently, a shift towards sustainable consumption has occurred as a response to environmental legislation and/or a response to heightened consumer demand for products and services that have a relatively lower environmental footprint [5]. While a number of indicators have been subsequently developed to operationalize the SDG 12 [4], the available SDG 12 indicators are not sufficiently sensitive to measure behavioral changes and are thus inadequate to advocate for continued improvements [2]. For example, the current indicators which use data such as “percentage of anthropogenic wastewater that receives treatment”, “municipal solid waste (kg/year/capita)” and “non-recycled municipal solid waste (kg/person/year)” as proxies for responsible consumption do not reflect consumers’ decisions to make more sustainable consumption decisions. As a result, available indicators do not capture the consumers’ contribution to the fight against climate change that has resulted from the incentives given towards this cause. Therefore, the aspects of shared responsibility in driving responsible consumption are not captured. Consequently, changes in the values of such indices are limited in their ability to motivate for increases in sustainable consumption as the underlying data is not directly linked to consumer behaviour but associated with the actions of public administrative authorities.

A plethora of data has been used to measure market trends of eco-labeled products as measures of sustainable consumption. Despite their plurality, these account for a small proportion of the agricultural products that are produced annually. Thus, the environmental implications of the food choices made on the majority of food eaten remains unknown. The method presented in the current study allows for the accounting of such food using widely available cultivar or seed data and shifts away from relying on eco-labs which are often pricey to develop. As cultivar descriptive data has been harmonized by global intellectual property management organizations such as the International Union for the Protection of New Varieties of Plants (UPOV), this measurement can allow for the development of comparable indices across countries and will contribute towards the harmonization of indicators and advance measurement and operationalization of the SDG 12.

The current study makes a methodological contribution to literature by using data from cultivars that have been used to satisfy consumers’ quality demands, and it develops a measure from the interaction between these characteristics and climate change adaptation characteristics to determine an indicator for sustainable consumption. For the purposes of this study, good fruit quality shall refer to fruit with desirable physical characteristics that are perceived by the consumer at the point of purchase. The study considers the principal external quality indicators which motivate consumption and purchase behavior and takes a long-term view (1956–2017) in calculating the provisions for sustainable consumption. In order to provide an unbiased perspective of the sustainability gains and losses, this composite index’s patterns are compared with the patterns of those indices that do not represent an eco-efficiency value proposition.

Filling the identified gap in the literature is opportune for the agriculture sector, as this sector has received the highest prominence among most sectors in achieving sustainable growth, with the emphasis on the adoption of sustainable farming technology. Thus, the study provides an example of how the widely available data can be utilized to provide insights into the concept of sustainable consumption. The research also fills a critical need for new indices for measuring SDG 12, which has been reported as having the largest number of indicators (10 out of 13) that are not measurable (tier III indicators) [6]. The current gaps in index availability provide a biased picture in determining whether countries are on the right path for achieving SDG 12 [7], therefore, the provision for such an indicator enables calculations to be more with better accuracy. This is important as it will make it easier for the South African industry to formulate more effective or actionable strategies that will aid in improving its performance in this area. The results of this study will also serve as a motivator for increased breeding investment and as a guide for directing focus areas in long-term cultivar development.

This article is organized as follows: Section 2 reviews literature and previous studies that have measured SDG 12. The research methodology is introduced in Section 3, and this is followed by Section 4 which outlines the study's analysis process and highlights the key research findings. Section 5 discusses the results in the context of the market developments and provides wider implications of the research findings. Finally, in Section 6, we draw our conclusions.

2. Review of Literature

There has been an increase in studies that benchmark and evaluate progress in the achievement of the 2030 Agenda's SDGs. A significant rise in the development of methods and indices for measuring sustainable development has been noted since their announcement in 2015 [8]. The rising trend has been attributed to their usefulness as communication tools and as variables in analytical procedures. These summary indicators continue to find relevance because they limit the number of statistics to be presented and allow for quick comparisons of country and industry performance [9].

Deficiencies in indicators for SDG 12 have seen limitations in the number of studies evaluating this Goal. These deficiencies prompted the 2018 high-level political forum review to include two indicators for "migrant workers' rights", and "jobs and labour rights" in the list of indicators measuring this SDG that were detailed, and are shown in Table 1 below [6]. It has been noted with concern that 10 out of 13 indicators listed in Table 1 are classified as Tier III indicators as they lack suitable metrics for operationalization [6]. The slow development of indicators for this SDG is slowing global development as research has shown that there is a relationship between successful measurement and the progress in achievement of development goals [10].

Table 1. Indicators of Sustainable Development Goal 12.

Target	Description
12.1	Implement the 10-Year Framework of Programs on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries.
12.2	By 2030, achieve the sustainable management and efficient use of natural resources.
12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.
12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.
12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
12.6	Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle.
12.7	Promote public procurement practices that are sustainable, in accordance with national policies and priorities.
12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.
12.a	Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production.
12.b	Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products.
12.c	Rationalize inefficient fossil fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities.

Source: [11].

Efforts to explore different ways to improve national ratings on SDG achievement have drawn a demand for indices that are constructed from disaggregated data because these have been found to easily translate into action plans [6]. Hence, several studies have been conducted to measure SDG 12 using specific municipal, market and/or industry-level data. For example, Adams and Judd [6] carried out a study that measured SDG 12 using three indicators: "percentage of anthropogenic

wastewater that receives treatment”, “municipal solid waste (kg/year/capita)” and “non-recycled municipal solid waste (kg/person/year)”. These, as well as an index constructed by Le Blanc [3], measured progress on achieving Target 12.4. Gomez-Paredes and Malik [7] proxied progress using the measure of the increase in the hazardous waste generation (Indicator 12.2), while Cambell et al. [12] report that other researchers have constructed a food loss index while measuring Target 12.3. According to Schmidt-Traub et al. [10], most studies have utilized administrative data and trade statistics on waste generation in order to track progress using Indicator 12.5. However, the limitation with the indicators stated above is that they are not sufficiently sensitive to measure changes in behavior which results from an increased response to legislative directives and industry incentives that encourage collective societal efforts geared towards combating the negative effects of climate change [2]. They mainly measure the successes of the administrative and/or public office efforts to increase responsible consumption and do not filter down to measure individual consumer’s behavior. Therefore, they are thus inadequate advocates of continued improvements in consumers’ lifestyles as they do not reflect society’s response resulting from an individual’s behavioral decision. The approach taken by this study fills this gap as it provides a new set of values-based indicators that is reflective on individual purchase behavior.

In addition to benchmarking studies that have increased in popularity in literature, there has been a drive towards analyzing the linkages that exist between SDGs. It has been envisaged that such links among Goals should facilitate the mainstreaming of dimensions that previously suffered from not having strong sectoral anchoring in development institutions [4]. According to Huan, Li and Lian [8], sustainable consumption and production is an example of such an area that has largely benefited from this approach as it had often been addressed as an ‘add-on’ and not taking the centre stage. This study develops an indicator that assists in drawing a focus on this SDG and address this limitation.

Researchers have also found value in calculating SDG 12 by using product characteristics and market indicators. For example, data on the market share of goods with certified sustainability labeling have, in the past, sufficiently measured the progress on Target 12.1 [13]. Such an approach has been taken as it has been acknowledged that achieving sustainability is fundamentally an ethical challenge and necessitates the generation of a new set of values-based indicators [4]. This is viewed as a more reliable approach for tackling the measurement problem, as Szabo [14] recommends that indices use indicators that adequately represent the priorities and values of the underlying system that they measure. While this study takes a similar approach, it extends the literature by measuring implied sustainability, as the environmentally friendly attributes of the product are not made known to consumers.

3. Methodology

3.1. Data

This study used cultivar descriptions that were collected from Plant Breeders Rights registries of South Africa’s Department of Agriculture, Forestry and Fisheries [15]. These constitute a repository of plant intellectual property data conformed to a format stipulated by the International Union for the Protection of New Varieties of Plants. Other data cultivar descriptions were sourced from the U.S. Department of Agriculture—Agricultural Research Service’s Registries for New Fruit and Nut Cultivars (List 35–List 47) [16]. Cultivar descriptions for older (bred between 1936 and 1967) locally-bred varieties were acquired from the ARC-Culdevco cultivar repository [17]. Only cultivars that made a significant contribution to annual fresh exports (greater than 1% of annual deliveries) between 1956 and 2017 were included in the study’s analysis. The list for cultivars and percentage contribution to annual exports was calculated from Key Deciduous Statistics, a journal published annually by the deciduous fruit growers’ association, HORTGRO, for the period after 1993 [18]. The annual reports of the predecessor organization, the Deciduous Fruit Board, were used for the years before 1994 [19]. These were sourced from a monthly journal called *The Deciduous Fruit Grower*.

The cultivar-description data sources mentioned above contained 15 to 67 cultivar characteristic indicators. The sources measured each characteristic using 2-point to 15-point Likert scales. The

characteristics used for this study were selected based on availability of data for the cultivars utilized for South Africa's exports. The eight cultivar characteristics that were selected for this study were: "chilling unit requirement", "growth habit", "harvesting period", "fruit firmness", "fruit shape", "fruit size", "skin color" and "flesh color". The study used two cultivar characteristics, "cultivar chilling unit requirement" and "cultivar growth habit", to indicate climate change adaptation. While it would have been interesting to include indicators for cultivars' varying water utilization, yield, and disease resistance levels, the available data for peaches and nectarines does not provide proxies that measured these characteristics. The remaining five characteristics were selected using the same criteria as stated above and served as indicators of consumer quality demands. Similarly, data covering the scope of this study that indicates information internal characteristics which significantly influence consumer behavior such as fruit sugar content and acidity were also unavailable.

3.2. Indicator Measurement

Similar to SDSN [20], this study computed the indicators using a worst-to-best ranking method to develop a scale that measures the consumption and sustainability value for the cultivar characteristics. Using a 3-point Likert scale, coded 1 to 3, a cultivar's traits were ranked from least to most desirable. A score of 3 implied that the cultivar was rated as having an excellent trait, which enabled the cultivar to be aligned with existing and future market demands or production challenges in South Africa. A score of 2 implied that the cultivar was rated as having a good trait, which enabled the cultivar to be adapted to existing market demands or production challenges in South Africa. A score of 1 implied that the cultivar met the production requirements, albeit unsustainably and was acceptable for export use but the trait did not enable the cultivar to fare competitively with regard to addressing market and production demands of the prevailing age.

The ranking of the cultivar characteristics is shown in Table 2 below. A short description of the trait associated with each rank is also provided. For the two cultivar characteristics that indicate climate change adaptation, a high score or ranking implies a relatively higher ability to reduce the negative impact of climate change on production output and continued farming enterprise feasibility. That is, a cultivar with a low chilling requirement is better adapted to the changing climate as it will ensure consistently high yields (without the aid of production chemicals), regardless of the warmer winters that are induced by climate change. On the other hand, a cultivar with an upright growth habit is better adapted to modern, high-density planting which gives higher returns to production. This trait enables the recouping of money spent on the on-farm climate change adaptation investment. Similar to the former characteristics, the fruit quality characteristics (cultivar harvesting dates, fruit size, flesh color, skin color and flesh firmness) were also assigned ranking criteria that were literature-informed, but ranking additionally included information acquired from industry experts regarding the fruit quality preferences of South Africa's primary export markets (the UK, the Netherlands, the UAE, Saudi Arabia, Hong Kong-China, France, and Germany).

Table 2. Cultivar trait ranking criteria.

	Traits	Ranked 3	Ranked 2	Ranked 1
1	Chilling unit requirement	Low Chilling requirement <400 Infruitec Chilling Units	Medium Chilling requirement 400 - 800 Chilling Units	High Chilling requirement > 800 Infruitec Chilling Units
2	Cultivar growth habit	Upright	Semi-upright/Spreading	Spreading
3	Cultivar harvesting dates	Very Early and Very Early to Early Very Late and Very Late to Early-Late	Early/Late and Medium-Early- Late	Medium
4	Fruit shape	Broad/Medium Oblate and Flat	Circular and Circular-Oblate	Circular and Circular-Oblate
5	Flesh firmness	Clingstone varieties 13–15 lbf	Semi-cling/freestone 10–13 lbf	Freestone varieties 6–10 lbf
6	Flesh color	White/Red	Orange/Deep Yellow	Yellow/Light/Pale yellow

7	Skin color	Full red/>75% Blush	20%–75% Blush/Mixed colour	No/minimal blush
8	Fruit size	Large-Very Large Diameter 68–81mm	Medium Diameter 62–68mm	Small-Very Small Diameter 52–61mm

Source: Authors' conceptualization.

3.3. Analytical Methods

The Principal Component Analysis (PCA) approach was used to reduce the number of indicators to comprehensive product value indices or Principal Components (PCs). PCA is a suitable method for this analysis because it is an unbiased method that ensures that the attribution of each indicator in the composite index is based on the statistical behaviour of the underlying data, and not by preconceived notions of their influence [2]. This approach has been used by other studies, such as [21–23] that investigated the relationships between cultivar characteristics. Previous studies, such as [4,8,20,24], have used this explicit weighting technique in constructing composite indices measuring the progress in SDGs.

PCA is described as a dimension-reduction analytical tool that is used to reduce a large set of variables to a small set that retains most of the information from the large set. It uses a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables [25]. The analysis detects the structure in the relationships between underlying latent variables and performs an orthogonal procedure which transforms them into linear combinations of uncorrelated variables (called Principal Components). As illustrated in Equation 1 below, PCs 1 to m was generated from a set of variables X_1 through to X_n and weights a_{mn} was assigned to the m th principal component (PC_m) and the n th variable.

$$\begin{aligned}
 PC_1 &= a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n \\
 PC_2 &= a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n \\
 PC_m &= a_{m1}X_1 + a_{m2}X_2 + \dots + a_{mn}X_n
 \end{aligned}
 \tag{1}$$

The first PC accounts for much of the variability in the data, and each succeeding component accounts for as much of the remaining variability as possible. The weights for each PC are given by the eigenvectors of the correlation matrix or co-variance matrix. The variance for each PC is given by the eigenvalue of the corresponding eigenvector, and the sum of the eigenvalues equals the number of variables in the initial data set [26]. The proportion of the total variation in the original data set accounted by each principal component is given by dividing the PC's eigenvalue with the number of original variables extracted to generate it. The eigenvalues/weights of indicators within a component are used to interpret the meaning of each component [27]. Hence, in this study, the product value proposition represented in each PC is interpreted as a reflection of the combination of the underlying indicators that contributed to its construction. This implies that a PC represents sustainable consumption when both fruit quality and climate change adaptation indicators contribute to its construction and the PC represents quality when the latter remains uncaptured.

In extracting the indices, the Kaiser criterion of retaining PCs with eigenvalues greater than 1 was applied. Due to restrictions in data variation in the underlying data, a loading score threshold of 0.3 was used and polychoric correlations were used in the determination of the PC as the underlying variables. The acquired factors were rotated using varimax rotation method. Cultivar value scores were computed for each generated PC using regression analysis. These scores were generated in order to assign asset values to each cultivar for each of the derived PCs. The individual asset value scores were weighted on the proportion of a particular cultivar's contribution to the annual export regimen between 1956 and 2017, and aggregated to form the annual aggregated score. Normalization of the generated scores was done by calculating an average score for each value proposition's time series and dividing it into the annual aggregated score. The normalization exercise was done in order to enable comparability between indices. Hence, the resultant score for the composite index is the

degree of deviation of annual performance from the indicator's mean. According to Saisana and Tarantola [28], this aggregation method is the most suitable method for constructing the composite indicators that have a time series nature.

4. Results and Discussion

4.1. Descriptive Statistics

A total of 225 cultivars were used in this study. These made up 78%–100% of South Africa's annual export deliveries for the period between 1956 and 2017. Table 3 also shows the average mean scores for cultivars used during this period divided into three 20-year periods. The study describes cultivar-use over a 20-year turnover period because Savage [29] and Park and Florkowski [30] report that peach and nectarine cultivars are generally phased out and replaced by superior varieties over a two-decade period. Due to the advanced pace of breeding, competition and fast-changing consumer tastes and values, this turn-over period has been argued to have reduced to approximately 15 years.

Table 3 shows the trend for the average scores for the indicators of climate change adaptation have not shown a pattern of increasing values. As depicted in the table, the industry showed that environmental adaptability was at its highest during the 1976–1995 period. The indicator average scores were recorded at 2.39 and 2.17 for “chilling unit requirement” and “growth habit”, respectively. The sector average scores fell to 2.10 and 2.11 respectively, during the 1996–2015 period, showing that the majority of the cultivars were less adapted to the negative effects of climate change.

The indicators for fruit quality, on the other hand, showed a general increase in average scores during the period under study. The biggest improvements noted were in the “fruit size” and “flesh firmness” indicators, which recorded average score increases of 0.56 and 0.55, respectively. The trend for “flesh color” average scores was different from other quality characteristics, as these showed a decreasing pattern. These results can be explained by the industry's efforts to meet the demands of shifting consumer tastes. At the beginning of the time series, the industry was well-positioned to meet the dominant preference for white-fleshed varieties present in its markets. This is shown by the high average score of 2.93. When the preference shifted toward orange or yellow-fleshed varieties [31], the industry succeeded in matching the demand for orange or yellow-fleshed varieties during the 1976–1995 period as shown by the 1.5 average score. The data has shown that the industry has been sluggish in following the consumers' return to a white-flesh variety preference. This is partly because there has been an increase in diversity in South Africa markets that was especially noted after the deregulation of the industry in 1997 [32]. In the 1950s, 97% of the South African industry exports were delivered to the United Kingdom, and in 2017, that country's market share had been halved and product preferences of markets in the Eastern Hemisphere had a higher influence on export product characteristics. In addition, the long turnover period of the cultivar development process, the trade-off nature of the quality characteristics, and the elevated production and market demands all make it difficult to quickly obtain cultivars that outperform and thus replace the existing cultivars.

Table 3. Average quality scores on cultivars used for exports: 1956–2015.

	Number of cultivars	Chilling Requirement	Growth habit	Supply period	Fruit size	Flesh color	Fruit firmness	Fruit shape	Skin color
1956–1975	14	1.64	2.14	1.5	1.86	2.93	1.93	1.93	2.5
1976–1995	38	2.39	2.17	1.75	2.14	1.5	2.11	1.86	2.33
1996–2015	217	2.10	2.11	1.83	2.42	1.66	2.48	1.98	2.5

*Note: Highlighted values show the highest average scores attained for each sub-indicator in the time period under study.

4.2. Empirical Results

Table 4 shows that the study was able to extract three indices that summatively characterized the principal value proposition offered by South African peach and nectarine exports. These indices

captured 47.23% of the variation in the underlying variables. The loadings for the dominant indicators for the product value propositions are emphasized in Table 4 in bold print.

Table 4. The Principal Component extraction.

Component Matrix			
	PC1 Fruit quality	PC2 Sustainable consumption	PC3 Off-peak supply
Skin color	0.707	-0.195	-0.129
Flesh firmness	0.579	0.394	0.488
Growth habit	-0.551	0.106	0.212
Fruit size	0.357	0.114	0.128
Flesh color	0.139	-0.758	-0.082
Chilling unit requirement	0.090	0.676	-0.137
Fruit supply period	-0.144	0.085	0.659
Fruit shape	0.066	-0.288	0.643
Summary indicators			
Eigenvalues	1.361	1.273	1.143
Proportion of variance explained	17.017	15.932	13.655
Cumulative proportion of variance explained	17.017	32.949	47.235

Source: Author's calculations, 2019.

As shown, the first Principal Component (PC1) captured the highest number of cultivar characteristic indicators. This PC accounted for 17.017% of the total variation in the original indicators. The dominant cultivar characteristics for PC1 were "skin colour", "flesh firmness", "growth habit" and "fruit size". These characteristics had factor loadings of 0.707, 0.579, -0.551 and 0.357, respectively. Therefore, this PC represented a fruit quality index as the dominant characteristics which described fruit that is large, firm and red-skinned. The attained results concur with numerous past studies that have shown that perceivable quality attributes are consistently uncompromised features for exported fresh peaches and nectarines. In addition, the results show that there is a huge trade-off between these quality indicators and "growth habit". This finding indicates that the provision of good quality fruit, as described by the PC1's loadings, has been sustained through the sacrificing of farm productivity maximization. This result is concerning as it shows that there have generally been low prospects for the achievement of shared value where an increase in South African farmers' welfare is pursued in tandem with fruit quality improvement.

The cultivar characteristics captured in PC2 measure sustainable consumption, as it has statistically significant and positive factor loadings for "cultivar chilling requirement" and "flesh firmness" characteristics which represent fruit quality and climate change adaptation indicators. The negative and high factor loadings observed for the "flesh color" indicator shows that the sustainable consumption product value proposition is associated with orange or yellow-flesh varieties. This means that the orange or yellow-flesh firm varieties that were used for exports generally tended to be more adapted to the warmer winters. Table 4 shows that PC2 accounted for 15.932% of the total variation in the original indicators.

The results show that PC3 measures a product value proposition that is crafted around the off-peak supply of large and firm fruit. This is evidenced by the three characteristics: "harvest period", "fruit shape" and "flesh firmness" with loadings of 0.659, 0.643 and 0.659, respectively. This factor accounted for 13.655% of the variation in the data and was interpreted as one that measured the provision of off-peak fruit supply as a value proposition.

4.3. Reliability Test

Three robustness tests were performed. These were the Bartlett's, Kaiser-Meyer-Olkin, and determinant's tests. A value of 0.773 was acquired from the PCA's determinant, showing that the analysis managed to capture a significant amount of the variation occurring between the different values in the cultivar characteristics observed. A p-value of 0.001 was acquired for the Bartlett's test.

This result shows that there was a significant level of correlation in the matrix of assets value indicators considered to justify the use of a data reduction procedure using PCA [33]. A p-value of the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.5. According to Antony and Rao [33], a value of no less than 0.5 indicates that patterns of correlations present in data are compact and that factor analysis yields reliable factors.

4.4. Composite Indices

As shown in Figure 1, the sector has made the most progress in providing for sustainable consumption, which recorded a 3.05 score improvement on the composite index scale between 1956 and 2017 (an improvement from -2.78 to 0.28). The second-highest improvement of 2.13 points was calculated on the progress in delivering fruit quality, as there was an improvement from -2.11 to 0.02 . Improvement on delivering fruit outside the market's peak period showed a 1.39 increase, from -0.78 to 0.61 .

The 1967–1988 period had the most fluctuations in index readings, as this period was characterized with significantly higher concentration of supplies towards peak season, and significant improvements in fruit quality and sustainable consumption. Of the three composite indices, the trend for sustainable consumption was the only index to break through the “zero-mark” and started recording positive numbers in 1987/88. The graph for fruit supply subsequently followed in 1999/2000, and lastly, the index for fruit quality in 2010/11. This means that the significant improvement in sustainable consumption can be attributed to improvements in the environmental adaptability of the cultivars used for exports, as the other indices measuring fruit quality indicators showed a pattern different from that of sustainable consumption. Figure 1 also shows that the industry has failed to maintain the increasing progress in sustainable consumption provision, as the corresponding index shows a decreasing trend since the mid-2000s. The index for off-peak fruit supply was the one of the three indices that maintained a positive growth trend after 2000. As shown, the growth path of fruit quality improvement was broken in 2011/12 as the index reverted to a score of zero by the end of the time series.

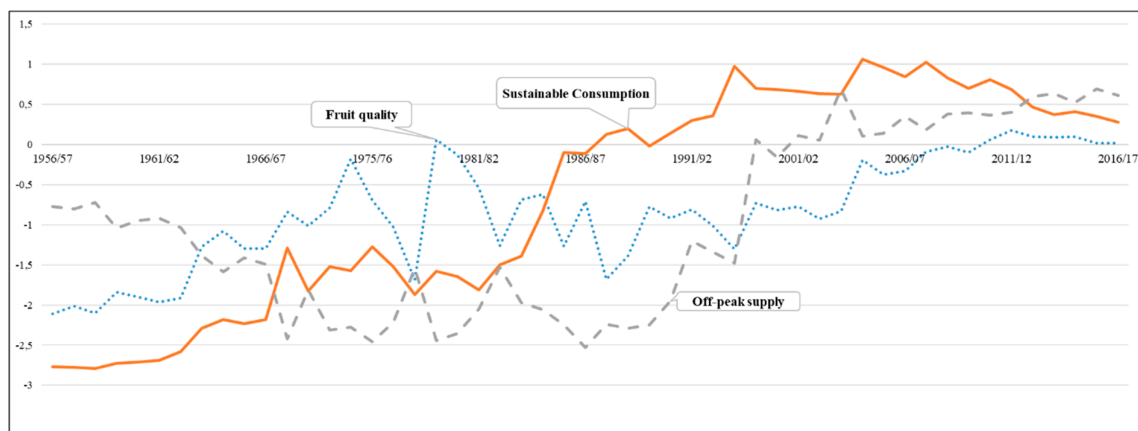


Figure 1. Calculated index for South African peach and nectarine exports: 1956/47–2016/17. Source: Author’s calculations, 2019.

5. Discussion

The derived indices tell of the market strategies that have been used to build and maintain the competitiveness of South Africa’s fresh peach and nectarine exports. The index for fruit supply shows the long-term strategy that the industry has adopted. This strategy involves the use of as many cultivars as possible to supply the market before and after the Southern Hemisphere supply’s peak period. The establishment of off-peak markets has been gainful to the industry as these markets have enabled the sector to attain price premiums of between 50% and 100% [34]. The proportion of cultivars providing this value have significantly increased over time. This is shown on the index by

scores which improved from negative numbers to positive figures. Reports have indicated that climate change has caused the fruit deliveries from other Southern Hemisphere countries to drift into this off-peak niche market and this is slowly eroding premiums of South Africa's fruit. Such shifts have increased competition in this market segment and have further driven improvements in South Africa's cultivar selections to ensure the safeguarding of this niche market.

The use of well-adapted cultivars has been one of the most important drivers of growth in the industry. According to Tsvakirai [34], the provision of cultivars that were adapted to a production environment led to significant growth in the nectarine subsector. As indicated by the PCA results, this market segment is mainly served by orange or yellow-fleshed, cling/semi-cling cultivars, and this finding may point to a new way in which this fruit variety could be marketed, as a significant proportion of the global market's consumers are turning away from this fruit variety type.

The provision of fruit of good quality has always been the prime prerequisite for participation in the exporting industry. This study corroborates this fact with its descriptive analysis findings which showed high indicator average scores at the beginning of the time series. Such a result indicates that cultivar selections have consistently been made with the aim of improving fruit quality throughout the whole period of focus for this study. However, the level of industry quality improvements that can be measured by a composite index is limited by the low probability of natural concurrent occurrence of excellent quality traits in cultivars. The magnitude of progress that can be measured on this index is largely limited by the strong trade-off that exists between quality traits and the high returns to farm productivity. Due to this disparate relationship, the index shows low figures and small positive values. This enduring trend means that the industry has had to sacrifice this dimension of sustainability in order to maintain its market presence and participation. This is a concerning result, as SDG12 advocates for responsible consumption as a strategy that ensures sustainable, long-term growth.

6. Conclusion

This study was carried out in order to provide an alternative way to measure trends in sustainable consumption and production. The constructed composite index used cultivar characteristics that indicated the environmental footprint and fruit quality attributes. In order to provide an unbiased perspective of the sustainability gains and losses, this composite index's patterns are compared with the patterns of those indices that do not represent an eco-efficiency value proposition. These indices measured fruit quality and the delivery of off-peak fruit supply. Of the three indices constructed, the index measuring responsible consumption showed the highest growth in values showing that the industry was making progress in balancing consumer quality demands and sustainable production as compared to progress in providing fruit of good quality or supply of off-peak fruit. This index had its highest values in the 1990s to the early 2000s, but deviated from positive growth in sustainability path in the mid-2000s. The study's results show that progress in the provisions for sustainable consumption was mainly driven by improvements in cultivars' climate change adaptability. The index for fruit quality showed increasing trend; however, improvements in this index had negative implications on productivity of farming enterprises. Growth was more consistent on the index measuring off-peak supply.

Different from previous indicators that were indicative of consumer behaviour, this study has provided an indicator that can link responsible consumption to purchase behaviour. To be more specific, the study has shown that preference for firm-fleshed and orange or yellow or orange-fleshed cultivars is associated with sustainable production, therefore, this provides a starting point on which type of fruit varieties can be promoted in order to advance the goal of improving responsible consumption. For example, marketing campaigns or positive incentives promoting the production or purchase of cultivars identified as meeting responsible consumption criteria can be developed. Further, the indices can also be used to influence the pricing of cultivars. That is, cultivars which are bred to meet both criteria for responsible consumption should attract higher royalties than those that merely provide one. The increase in the production, adoption and consumption of these varieties can amount to an increase in responsible consumption. This is an improvement from past indices which measured improvements in public administrative systems. As shown by the study's findings, such

efforts will increasingly be required going into the future as market forces (demand and supply) are likely to have negative implications for the environment if left unchecked.

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