Developing resilient supply chains in the Southern African Development Community: Lessons from the impact of COVID-19

Background: The coronavirus disease 2019 (COVID-19) pandemic has had a significant impact on international trade and supply chains. Border closures and reduced demand for traded goods provoked demand and supply shocks in supply chains, including those of the Southern African Development Community (SADC). Continued vulnerability of regional supply chains affects the long-term socio-economic development trajectory of the SADC.

Objectives: This article investigates whether supply chains and their various components have exacerbated the pandemic’s trade impact, with specific reference to the SADC. The objective is to inform regional development policy interventions to improve the resilience of the SADC supply chains in future disturbances.

Method: An econometric analysis was conducted to determine the relationship between supply chain efficiency (and the various sub-indicators) and the impact of the pandemic on merchandise trade volumes. The latter constitutes the dependent variable of the analysis and is quantified by measuring the deviation from the pre-shock growth path in the base year (2020) of the pandemic. Data sets from the UNCTADstat database were used. The independent variables are the sub-indices that form part of the Logistics Performance Index (LPI), the data of which are sourced from the World Bank (2022). In addition to the chi-square test of homogeneity and the Shapiro–Wilk test of normality, regression analyses were conducted to determine the significance of the independent variables, in addition to their association and correlation with the dependent variable.

Results: The analysis indicates that supply chain efficiency and components related thereto, including customs clearance, infrastructure, international shipments, logistics competence, tracking and tracing and lead time, are of high significance to and correlate with the impact of the pandemic.

Conclusion: Regional development policy in the SADC should prioritise the targeted improvement of specific physical and non-physical infrastructure to support the development of efficient and resilient supply chains. Interventions should focus on improving border and customs processes and tracking and tracing capabilities of logistics service providers. This will contribute to the achievement of regional development objectives and catalyse the competitiveness of the SADC in the face of increased supply chain regionalisation.

Keywords: supply chains; resilience; regional development policy; SADC; COVID-19; Logistics Performance Index; regional integration; trade.

Introduction
The novel coronavirus disease 2019 (COVID-19) pandemic has had a significant social and economic impact around the world, affecting the daily lives of populations. Production processes, economic output and international trade have not been spared, as governments implemented transmission control measures and social isolation policies. The pandemic has catalysed diverse economic disruptions, precipitated by declining demand for goods and services and affected product and factor markets (Maliszewska, Mattoo & Van Der Mensbrugghe 2020). Rising unemployment and sub-optimal labour use have contributed to decreased investment and capital availability (Maliszewska et al. 2020). A sharp decline in inbound and outbound tourism has had a significant negative impact on related services, including accommodation, recreation and transport (Lin & Falk 2021). On the back of more stringent border inspections, road closures and
reduced operational hours for logistics service providers, transport cost – and thus the cost of international trade – increased (Evans et al. 2014). This affects demand for imports, exports and downstream economic output and disrupts supply chains that connect international, regional and local producers, suppliers and intermediaries (Kerr 2020).

Global supply chains have been disrupted by supply and demand shocks. The former is caused by labour shortages and supply networks and cross-border transport service disturbances, whilst the latter is the result of changes in consumption patterns. In addition, just-in-time inventory, lean manufacturing and offshoring are factors that ‘may have stretched the global supply chain to a breaking point in times of stress’ (Park, Kim & Roth 2020), which has become apparent as the effects of the pandemic have reverberated around the world. The impact of the pandemic on supply chains has seen policymakers preferring to attain more independence or ‘self-sufficiency’ (Kerr 2020:228). The movement towards increased regionalisation or geographical diversification, of supply chains is relevant here (Hoekman, Fiorini & Yildirim 2021). This accelerating trend, driven by the pandemic, shows the allure of a ‘strategy [based on] close-proximity suppliers and importers, serving nearby customers through local sourcing’ (Fiorini, Hoekman & Yildirim 2021:71). This regional approach to supply chain development provides logistical advantages and a degree of trade policy certainty, in addition to being more environmentally friendly. The attraction of such a strategy is strengthened by its potentially limited impact on production cost (Hoekman et al. 2021).

In the Southern African Development Community (SADC), trade constitutes a core principle in achieving the regional socio-economic development objectives (SADC 2012a). Regionally significant supply chains, including agro-processing, mineral beneficiation, pharmaceuticals, leather, textile and clothing, tourism and services, are central to regional development policy as they support the development of downstream value-adding activities (SADC 2020). These are earmarked for further development through a policy of regional integration, which emphasises trade liberalisation and a regional transport system to improve trade facilitation (Pretorius, Drewes & Van Aswegen et al. 2017). Despite policy intervention, it remains challenging to optimise regional supply chains, including ‘limitations in border facilities, excessive red tape and lengthy border procedures and vulnerability to corruption’ (Habiyaremye 2020:15). In addition, the SADC and its member countries are vulnerable to external disturbances affecting regional production systems. This is primarily attributed to the region’s export market dynamics and economic openness (Pretorius et al. 2021), which influence the initial impact and recovery period of the economy subsequent to an external shock. These regional challenges highlight the added potential of the pandemic to disrupt trade and supply chains and significantly impact the regional economy of the SADC and the long-term achievement of its socio-economic development objectives.

In line with this consideration, the pandemic has had a significant impact on the regional economy of the SADC, where economic output decreased by 4.51% from 2019 to 2020 (UNCTADstat 2022) as the effects of decreased demand for goods and services and disruptions to factor markets have diffused amongst its member countries. In the same period, the total merchandise trade volume of the region declined by 15.71%. This trade impact is divergent amongst member countries, ranging from a decrease of 37.61% in Angola, 22.94% in Mauritius and 21.49% in Madagascar, to a limited impact of 1.05% in Comoros and an increase of 3.42% in Zimbabwe (UNCTADstat 2022). In a broader context, the pandemic reduced global trade by 7.47% from 2019 to 2020, lower than the regional impact.

Significant research has been conducted on the global impact of the pandemic on economic growth, trade and supply chains. However, limited focus has been placed on determining potential factors inherent to trade, which may have influenced the extent of the pandemic trade shock and its apparent divergent nature. This gap in the literature extends to the context of the SADC and its member countries. Accordingly, this article investigates supply chains as a factor in the impact of the pandemic on trade volumes, with specific reference to the SADC whilst including the broader, global context. A central objective is to determine whether supply chains and their diverse components may have played a role in mitigating (or exacerbating) the impact of the pandemic on trade. The findings are interpreted in the context of regional development policy in the SADC, with the additional objective of recommending potential interventions to develop the resilience of regional supply chains and support trade during future disturbances. This research contributes to the current body of literature by developing insights into how to mitigate the vulnerability of the SADC supply chains during future disruptions.

The methodology is centred on an econometric analysis using relevant data sets from the UNCTADstat (2022) and World Bank (2022) databases to determine the relationship between the pandemic’s impact on trade and the diverse factors inherent to supply chain efficiency. The following section provides an overview of the applicable literature, followed by a methodology overview, the key findings of the analysis and a discussion relating these findings to the core research objectives.

**Literature**

The literature review focusses on trade and development, supply chain resilience and the impact of COVID-19, as well as the SADC regional development policy.

**Trade and development**

Economic prosperity directly links to the trade abilities of countries, which, in the case of developing economies such as the SADC member countries, are critical in reducing poverty and creating sustainable economic conditions (Behar & Edwards 2011; Takele & Buvik 2019). The extension of trade
opportunities for developing economies is critical in obtaining a competitive market position and stimulating the development of tradeable industries to further economic growth (Visagie & Turok 2021). An increase in regional trade and economic development can only be successful when all stakeholders involved benefit (Visagie & Turok 2021), and the focus is on developing economic activities through trade expansion (Ngепах & Udeagha 2019). The improvement of trade across the SADC is enabled by trade agreements, such as the Protocol on Trade (SADC 1996), which advocates for the reduction of trade barriers across the SADC member states to advance the regional economy. These trade agreements have showcased their relevance and importance in increasing intra-regional trade (Ngепах & Udeagha 2019) and economic growth (Oloyede, Osabuohien & Ejemeyovwi 2021). Therefore, the development, implementation and maintenance of a regional supply chain network across the SADC are critical to regional integration, economic development and regional trade objectives (Konstantinus & Zuidgeest 2019).

Trade, supply chains and COVID-19

Supply chains facilitate the movement and handling of goods and services in raw or final form to the end consumer (Richardson, Quinet & Kitajima 2021). Supply chain activities such as manufacturing, operations, warehousing, packaging and distribution, amongst others, establish trade, as the supply chain is all about competitive prices, delivering at the right time and ensuring quality goods and services are provided to the final consumer. Takele and Buvik (2019) observed that time is a critical factor for the trade industry. Supply chains are extremely sensitive to disruptions, whether man-made (like terror attacks) or natural (like the COVID-19 pandemic). Pandemic lockdown restrictions, including border closures and strict regulations and isolation enforced on anyone entering a country, forced supply chains across the SADC to reduce operational capacity. This resulted in organisations facing operational and human resource challenges in retaining optimal production outputs (Richardson et al. 2021; Sakanga, Mwanaumo & Tvhala 2020).

A prominent example of a demand shock because of the effects of the pandemic is food supply chains, which have had to rapidly adjust as a result consumers ‘panic buying’ (Hobbs 2020:2). Modern supply chains constitute ‘bidirectional interdependencies between organisations’ (Garnett, Doherty & Heron 2020:315), forming a network of nodes where the flow of inputs and outputs, when optimised, is almost frictionless. Supply chain complexity is an inherent vulnerability; the failure of one node or link could disrupt the entire supply chain network. This supply chain complexity is underlined by measures implemented to reduce trade and production costs, including just-in-time inventory management, lean manufacturing approaches and the relocation of production operations abroad.

Lockdown restrictions have had a direct impact on supply chains across the SADC, with various border posts responsible for facilitating trade temporarily closed and organisations decreasing the number of staff to comply with social distancing requirements. The pandemic exposed the limitations in regional supply chains, showing that it lacked agility, flexibility, adaptability and efficiency in times of disruption. Supply chains must be stable to facilitate trade at optimal levels in spite of potential disruptions (Mataba & Ismail 2021). Regional supply chain stability depends on the extent to which regional economies introduce policies that favour foreign and local investments, enhance infrastructure development and maintain regional corridors through which supply chains operate. A standard operating supply chain procedure could make a supply chain more resilient, especially during disruptions (Neboh & Mbhele 2021).

The Southern African Development Community regional development policy

The SADC has made substantial headway in advancing regional cooperation and integration since its formation in 1980. The trading bloc has a population of approximately 350 million people in the 16 member states and has evolved from a coordinating conference to an active regional development community. As such, it forms a key building block of the African Union (AU), especially since the promulgation of the Africa Free Trade Agreement in 2021 (World Bank 2020). On the policy level, the SADCs development agenda is not only formally guided by the UNs Sustainable Development Goals (SDGs) but also influenced by numerous international guides, such as the AUs Agenda 2063 and the Belt and Road Initiative from the Chinese Government (Chen & Li 2021).

Regional policies usually apply and relate to socio-economic development, advanced by different government structures and entities. The objective is to support the convergence of employment and income through investment, leading to the formulation and implementation of regional policy (Dewar, Todes & Watson 1986; Friedmann 1966; Garretsen et al. 2013). Instruments available to relevant governments to realise these goals include spatial targeting and sectoral focus, by means of direct investments or incentives for conforming developments (Drewes 2010). Although numerous post-modern policy approaches have since been developed, initiatives are usually focused on specific locations (or corridors), as well as specific economic sectors or subsectors (e.g. manufacturing and agro-processing). This conforms to the established principle, especially relevant in developing economies, where all the regions’ economic sectors (big-push theory) cannot be incentivised at the same time (Rosenstein-Rodan 1963).

The SADC follows the normative spatial planning guidelines (Laubscher et al. 2016; Puren & Drewes 2021) of the United Nations’ SDGs but then narrows it down to localised integrated development strategies (SADC 2020). The normative development principles of the SADC Treaty are expanded through the newly promulgated Regional Indicative Strategic Development Plan (RISDP). The latter promotes additional development principles, including
regional development and integration. Although not explicitly branded as regional policy, the RISDP’s (2020–2030) aims to classify it to include this, that is, to achieve:

[A]n industrialised regional economy that is based on a competitive and facilitative environment, which includes infrastructure and skills, and sustainably exploits its natural resources by leveraging science, technology, and innovation. (SADC 2020:44)

Of specific focus in this article is the Industrial Development and Market Integration component, which directs its efforts to realising an industrialised regional economy. Thus, industrial developments that focus on the priority sectors of agro-processing, mineral beneficiation and pharmaceuticals will be prioritised, alongside enhancing regional technological capability and capacity through science, technology and innovation (SADC 2020). Related to this, the policy framework focuses on the transformation of the agricultural sector to promote sustainable management of the environment and natural resources whilst ensuring productivity and improved market access for agro-products. The RISDPs focus on the free movement of goods, services and skills attenuates the spatial targeting principle of linking appropriate development nodes via strengthened development corridors. The SADC reinterpreted the aforementioned principles of regional policy to provide a more integrated, globally acceptable approach towards spatial targeting (corridor development).

Resilience in regional supply chains

Regional supply chains must engage at an inter-organisational and governmental level to enhance the management and movement of goods within regional economies (Gölgeci & Kuivalaninen 2020; SADC 2020). There is an increased demand for supply chains to become more resilient as global events such as natural disasters, pandemics, political instability and cyberattacks cause major disruptions. These disruptions force supply chains to improve and strengthen their practices to perform effectively and efficiently throughout such disruptions (Bui et al. 2020). The resilience of supply chains is characterised by their ability to adapt during a disruption. This enables supply chains to restrain or contain the disruption without impacting performance levels. A resilient supply chain is fostered through identifying potential disruptions and developing plans to manage said disruptions in the interest of all stakeholders (Gölgeci & Kuivalaninen 2020). It is important for the SADC to critically reflect on the gaps in the regional supply chains (Gao, Feng & Zhang 2021). This would require the development of an integrated, flexible and diverse supply chain network that is supported by interoperable and interconnected regional trade policies from the respective SADC member countries (Gao et al. 2021; SADC 2020).

Research methods and design

This section provides an overview of the econometric analysis that was conducted to achieve the objectives of this research. Econometric analysis is used to determine the relationship between numerous dependent and independent variables. In the context of the research objectives, the econometric analysis seeks to determine the relationship between (1) the trade impact associated with the pandemic and (2) supply chains, including the different components inherent to their effective functioning. The delineation of the dependent and independent variables, as well as the analysis undertaken to inform the findings, is discussed in this section.

Dependent variable

In line with the research objectives, the dependent variable in the econometric analysis is the quantified impact of the pandemic on trade. To determine this variable, the following steps were followed:

1. Determine the pre-shock growth path, that is, the average growth in trade prior to the pandemic-induced disturbance.
2. Determine the trade growth in the base year of the pandemic, that is, the year the effects of the pandemic commenced.
3. Measure the deviation from the pre-shock growth path in the period subsequent to the initial effects of the pandemic, that is, the difference between trade growth in the base year of the pandemic and the pre-shock growth path.

The outcome is the quantified impact of the pandemic on trade. This method aligns with the delineation of a pre-shock growth path (i.e. equilibrium) and determining the resistance of a system to an external shock – an approach central to resilience analysis (Briguglio et al. 2006; Hill, Wial & Wolman 2008; Pretorius et al. 2021). The trade indicator used to determine relevant trends is merchandise trade (US$, current prices in millions) because of its specific relevance to regional trade facilitation and supply chains. Data sets available on the UNCTADstat (2022) database were utilised for this analysis. The pre-shock growth path is represented by the 5-year average growth in merchandise trade from 2014 to 2019, whilst the impact of the pandemic is measured by the deviation from this average in 2020; the year in which the trade effects of the pandemic commenced.

Independent variables

Whilst the quantified trade impact of the pandemic is utilised as the dependent variable in the econometric analysis, factors inherent to supply chains and their efficient functioning constitute the independent variables. Accordingly, the Logistics Performance Index (LPI) and the various sub-indicators that form part of this index constitute the proxy of supply chain efficiency – and thus they form independent variables in the econometric analysis. This is supported by Ojala and Çelebi (2015:27), who stated that the LPI ‘provides overall metrics of a country’s supply chain efficiency [and] a broad indication of related problem areas’. In addition, in utilising the LPI, Arvis et al. (2012:3) state that ‘logistics performance is strongly associated with the reliability of supply chains and the predictability of service delivery available to producers and exporters’. In determining the relationship between the supply chains (and their various components) and the trade impact of the pandemic, this analysis seeks to highlight potential
vulnerability in the regional supply chains of the SADC and derive lessons from the pandemic in developing their resilience for future disturbances.

The LPI, its various sub-indicators, and the independent variables of the analysis are indicated in Table 1.

Data sets from the World Bank (2022) database were utilised, with specific reference to the aggregate LPI of 166 countries. This includes 14 of the 16 current SADC member countries, with the Seychelles and eSwatini excluded because of data limitations. The data sets provide a large sample of developed and developing countries to adequately determine the relationship between the dependent and independent variables.

**Econometric analysis**

The methodology inherent to the econometric analysis is discussed in the following.

**Step 1: Chi-square test of homogeneity**

This test indicates whether errors in the data, should they exist, are homogenous or homoscedastic. According to Kutner et al. (2005), this includes determining whether the observed values of the sample are different from those delineated in the null hypothesis and whether the said differences may be attributed to the sampling error:

- Expected frequency counts: The following equation is used to calculate the expected values of the respective populations and levels of categorical variable:

$$ E_{a,b} = \frac{(n_a \times n_b)}{n} \quad \text{[Eqn 1]} $$

where:

- $E_{a,b}$ = expected value for population $a$ at level $b$ of the categorical variable
- $n_a$ = total number of observations from population $a$
- $n_b$ = total number of observations at treatment level $b$
- $n$ = total sample size
- Test statistic: Represented by the following equation, a chi-square random variable ($X^2$) is used for the test statistic:

$$ X^2 = \sum \frac{(O_{a,b} - E_{a,b})^2}{E_{a,b}} \quad \text{[Eqn 2]} $$

**Step 2: Shapiro–Wilk test of normality**

This test indicates whether the data are normally distributed. Used in conjunction with the chi-square test for homogeneity, this will inform the use of parametric or non-parametric regression methods (Santana 2015). The following equation is relevant:

$$ W = \left( \frac{\sum_{i=1}^{n} a_i x_i}{\sum_{i=1}^{n} (x_i - \mu)^2} \right)^2 \quad \text{[Eqn 3]} $$

where:

- $x_i$ = sample values in random order
- $a_i$ = mean of the data (size $n$) from a sample that is normally distributed
- If a $p$-value of less than 0.05 is observed, the data are not normally distributed as the null hypothesis is rejected.

**Step 3: Regression analysis**

Based on the outcomes of the chi-square and the Shapiro–Wilk test, either a $t$-test (non-parametric regression) or $F$-test (parametric regression) is conducted. These tests are delineated as follows:

1. Non-parametric regression: $t$-test

   In this analysis, a single sample $t$-test is utilised as one independent variable is applicable. As per Kutner et al. (2005), the following equation is relevant:

$$ t = \frac{\bar{X} - \mu}{s / \sqrt{n}} \quad \text{[Eqn 4]} $$

where:

- $\bar{X}$ = mean from a sample $X_1, X_2, ..., X_n$ (size $n$)
- $s$ = standard error of the mean
- $\sigma$ = standard deviation estimate of the population
- $\mu$ = population mean

Assumptions inherent to the $t$-test include $X$ is normally distributed, with $\mu$ and variance. Data transformation through the Spline function in SAS is undertaken. An additional assumption is that $Z$ and $s$ are independent.

2. Parametric regression: $F$-test

   In the $F$-test, $X_1, X_2, ..., X_n$ and $Y_1, Y_2, ..., Y_m$ are the independent variables that are distributed in an identical manner and taken from two separate populations. The latter are normally
distributed. Whilst there may be a difference in the populations’ expected values, the null hypothesis states that the variances are the same:

In this regard, let $\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i$ and $\bar{Y} = \frac{1}{m} \sum_{i=1}^{m} Y_i$ \[[\text{Eqn 5}]\]

constitute the sample means:

In addition, let $S^2_X = \frac{1}{m-1} \sum_{i=1}^{m} (X_i - \bar{X})^2$ and $S^2_Y = \frac{1}{m-1} \sum_{i=1}^{m} (Y_i - \bar{Y})^2$ \[[\text{Eqn 6}]\]

reflect the variances inherent to the sample. The test statistic in this case is: $F = \frac{S^2_X}{S^2_Y}$ \[[\text{Eqn 8}]\]

If the null hypothesis is true, an $F$-distribution is relevant to this test statistic and the degrees of freedom are delineated as $n - 1$ and $m - 1$. If the null hypothesis is not true, an $F$-distribution scaled to the ratio of the relevant variances is applicable to this test statistic. Rejection of the null hypothesis is applicable should $F$ not be statistically significant. Hence, this test utilises an absolute for $F$ (Kutner et al. 2005). In this case, statistical significance is determined as $\alpha = 0.05$.

**Step 4: Test of correlation and association**

According to Santana (2015), correlation ($\rho$) represents the linear relationship amongst two variables, with a value ranging from 1 to $-1$. In cases where data are not normally distributed, Spearman’s correlation is used to test whether variables are associated. The null hypothesis states that the variables are not associated, whilst the alternative hypothesis is the inverse. When correlation between variables is strong, so is their association. Statistical significance is set at $\alpha = 0.05$.

The outcome of the econometric analysis is thus a comprehensive overview of the relationship between the trade impact of the pandemic and the diverse components of efficient supply chains. The underlying aim is to delineate regional development policy recommendations to support resilient supply chains in the SADC.

**Ethical considerations**

This research article complied with all ethical considerations, in line with the policies, conditions and practices of the IIE Ethics Committee, which reviewed and approved the ethics application. R. 00009 (REC).

**Results**

The results of the equilibrium analysis are delineated in this section. In quantifying the trade impact of the pandemic, Table 2 provides an overview of the trade trends and indicates the pre-shock growth path, the 2020 growth figure (base year of the pandemic) and the consequent trade impact of the pandemic. This is relevant to the sample of 166 countries, as well as the SADC member countries (excluding the Seychelles and eSwatini because of data limitations, as mentioned in section ‘Research methods and design’).

Table 2 indicates that the sample countries experienced a growth in trade in the 5 years prior to the pandemic, amounting to a pre-shock growth path of 1.35%. In the same period, cumulative trade by the SADC member countries declined by 0.05%. However, divergent trade trends are indicated for the said members, ranging from 15.25% growth in the Democratic Republic of the Congo, to 8.16% contraction in Angola in the corresponding period. In 2020, as the effects of the pandemic reverberated around the world, trade declined in the SADC by a regional average of 12.10% – more than the average 11.26% decline seen in the sample countries. Measuring the deviation from the 2014 to 2019 average in 2020, the cumulative trade impact of the pandemic is quantified in the ‘Impact’ column, where a decline in trade growth is indicated as a positive. In the sample countries, trade declined with an average of 12.62%, whilst this figure is 12.05% in the SADC member countries. Angola (29.45%), Madagascar (26.39%) and the Democratic Republic of the Congo (21.65%) saw the steepest declines amongst member countries, whilst Comoros (2.11%), Tanzania (1.13%) and Zimbabwe (growth of 4.50%) experienced a relatively limited impact on trade.

The distribution of the impact of the pandemic on the trade of each country in the sample is illustrated in Figure 1. The vertical axis represents the growth impact, whilst the horizontal axis is the sample countries (in alphabetical order).

As evident from Figure 1, the pandemic had a diverse impact on the sample countries. Examples include Libya, which experienced a trade downturn of 58.52% from the pre-pandemic average, and the Maldives, where trade declined by 42.34%, whilst trade in Burkina Faso (7.78%), Guinea (6.62%) and Liberia (30.55%) increased during this period. In total, the trade of 7.83% of countries increased, whilst 29.51%
of countries experienced a decrease in trade of 10% or more and the trade of 21.69% of countries decreased by more than 20%. Accordingly, the majority of countries suffered a decline in trade of more than 10%.

Whilst numerous factors inherent to the pandemic (and independent thereof) may have influenced the significant decline in trade in the sample countries, the econometric analysis seeks to determine the role of supply chains in this regard. The objective is to determine whether supply chain efficiency and the various related components of supply chains played a statistically significant role in influencing the impact of the pandemic. As the focus of this research is on the SADC, related findings may indicate potential vulnerabilities in its regional supply chains that have exacerbated the impact of the pandemic and inform potential regional development policy interventions to develop more resilient supply chains in the case of future disturbances.

Table 3 quantifies the findings of the econometric analysis, illustrating the significance of and association between the dependent variable (trade impact of the pandemic) and the various independent variables. In addition, their correlation is quantified to expand on the nature of the relationship and inform conclusions and recommendations.

All independent variables are found to be statistically significant and have a strong association with the dependent variable in line with the parameters defined in section ‘Research methods and design’.

The analysis indicates that supply chain efficiency, represented by the LPI, constitutes an important factor \((\alpha = 0.0028)\) in the effect of the pandemic on the trade of sample countries. In addition, the correlation between the trade impact and this variable \((\rho = -0.2499)\) may indicate that as supply chain efficiency increases, the impact of the pandemic on trade decreases. This negative correlation is mirrored by the other independent variables utilised in the analysis. The impact of the pandemic on trade was reduced in countries where the efficiency of customs processes and clearance are proportionally higher \((\rho = -0.2561)\), the quality of transport and trade infrastructure is better \((\rho = -0.2005)\), arrangement of international shipments are more efficient \((\rho = -0.2621)\), logistical services are of a higher quality \((\rho = -0.2908)\), the ability to track and trace is better \((\rho = -0.2409)\) and expected delivery times are met more frequently \((\rho = -0.2319)\). In terms of their importance (based on correlation) in mitigating the impact of the pandemic on trade, the components of supply chains can be ranked from logistics competence to international shipments, customs clearance, tracking and tracing, lead time and infrastructure.

**Discussion**

The discussion is centred on the vulnerability of the SADC supply chains and potential consequences thereof for regional development policy.

**Vulnerability of the Southern African Development Community supply chains**

The findings of the econometric analysis indicate that the pandemic had a significant impact on trade, both in the

**TABLE 3: Relationships between dependent and independent variables.**

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Significance ((\alpha))</th>
<th>Correlation ((\rho))</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics Performance Index</td>
<td>0.0028</td>
<td>-0.2499</td>
<td>0.0012</td>
</tr>
<tr>
<td>Customs clearance</td>
<td>0.0035</td>
<td>-0.2561</td>
<td>0.0009</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>0.0195</td>
<td>-0.2005</td>
<td>0.0096</td>
</tr>
<tr>
<td>International shipments</td>
<td>0.0013</td>
<td>-0.2621</td>
<td>0.0006</td>
</tr>
<tr>
<td>Logistics competence</td>
<td>0.0006</td>
<td>-0.2908</td>
<td>0.0001</td>
</tr>
<tr>
<td>Tracking and tracing</td>
<td>0.0039</td>
<td>-0.2409</td>
<td>0.0018</td>
</tr>
<tr>
<td>Lead time</td>
<td>0.0042</td>
<td>-0.2319</td>
<td>0.0026</td>
</tr>
</tbody>
</table>

Source: Adapted from World Bank, 2022, Aggregated LPI 2012-201, viewed 03 January 2022, from https://lpi.worldbank.org/
sample countries and the SADC. In addition, the analysis indicates that supply chains and their efficiency may directly influence the extent of the pandemic trade impact. This highlights the potential of coordinated intervention in supply chains to increase their efficiency in mitigating the effects of future disturbances on trade. To delineate the nature of potential interventions, the vulnerability of the SADC supply chains should be determined, with specific reference to the different components of supply chains as incorporated in the econometric analysis.

Table 4 compares the sample countries and the SADC in this regard, quantifying the current difference (as of 2018) in supply chain efficiency (the LPI and its various sub-indicators) in the two contexts. This may inform specific supply chain vulnerabilities in the SADC and guide potential intervention. As a result of data availability considerations, the data of prior years are utilised for some countries. The provided quantities are interpreted out of a total rating of 5; the closer the rating is to 5, the better the supply chain efficiency and that of the individual components (Arvis et al. 2014:51).

As indicated in Table 4, supply chain efficiency in the SADC (2.61) is lower than in the sample countries (2.85). In addition, the SADC rates are below the sample countries in all the different components inherent to supply chain efficiency. The largest difference is in the quality of trade and transport infrastructure, which is 2.71 in sample countries and 2.38 in the SADC. This is followed by logistics competence, with a 0.29 difference between the sample countries’ rating of 2.80 and the 2.51 of the SADC. Tracking and tracing are 2.88 in sample countries and 2.63 in the SADC: a difference of 0.25. Both international shipments and lead time differ by 0.22 between the two contexts, whilst customs clearance is 0.18 lower in the SADC compared with the sample countries.

In the context of current differences in supply chain efficiency, Table 5 indicates the growth, that is, improvement, of various supply chain components of the sample countries and the SADC between 2010 and 2018. As a result of data availability considerations, the period of analysis differs for some countries.

Table 5 indicates that the SADC LPI grew with 4.38% compared with 1.39% in the sample countries. This is because of the SADC countries experiencing higher growth in the infrastructure (11.58%), and customs and clearance components (11.42%), whilst lower growth was experienced in the sample countries (5.42% and 5.03%). International shipments grew by 1.49% in the sample countries and 0.58% in the SADC (the lowest growth rate of all the supply chain components). The tracking and tracing (4.93%), as well as logistical competence (4.61%), improved to a greater degree in the SADC than the sample countries (3.99% and 1.77%). Growth trends indicate an overall improvement of supply chain efficiency in the SADC during the delineated period.

In spite of recent improvements, the findings of Table 4 may indicate the enduring vulnerability of the SADC supply chains to disturbances, in comparison to other countries and regions in the global context. An important instrument to guide interventions in support of the development of resilient supply chains in the SADC is regional development policy.

**Consequences for the Southern African Development Community regional development policy**

As discussed in section ‘Literature’, trade facilitation is central to regional development policy in the SADC, with the objective of overseeing increased industrial productivity and economic growth through regional integration. In addition to trade liberalisation through a reduction in tariff barriers, spatial integration through the development of a regional transport network is an important aspect of regional integration and fostering increased trade between member countries. Trade facilitating infrastructure can be categorised into physical and non-physical infrastructure ( Pretorius & Drewes 2020). The former constitutes the physical link that facilitates the movement of traded goods, including road and railway networks. As per the findings of the analysis, the related quality of transport and trade infrastructure is an important aspect of efficient supply chains – one in which the SADC lags behind the sample countries and is the lowest indicator in the region. There are significant challenges relating to the physical infrastructure of the SADC’s transport network (Khumalo & Chibira 2015; Mainza 2019;
Tsakok 2021), including limited capacity (resulting in bottlenecks) and missing links (resulting in sections being gravel), which affect regional trade.

Current policy, including the Regional Infrastructure Development Master Plan (SADC 2012b), seeks to ‘enhance multimodal transport linkages and improve interconnectivity’. However:

[A] major issue across the region is maintenance funding, and many of the proposed projects are the rehabilitation of trunk roads affected by overloading and a lack of adequate regular maintenance. (p. 8)

Usually, these corridors need to be upgraded and developed by the host country and form part of the relevant national budgeting process and regional institutions such as the SADC Secretariat have limited funding available to remedy deficiencies. The absence of a regional development fund to finance trade and transport infrastructure development is a key limitation in this regard and constitutes a potential intervention to enhance the resilience of regional supply chains.

The development of non-physical infrastructure is an additional component of spatial integration in the SADC and is centred on the regulation of movement between member countries along the physical linkages. It comprises two components, namely interoperability and market access (Lakshmanan 2001). Interoperability reflects on the ease of travel for goods between member countries and includes relevant rates and tariffs for infrastructure usage, vehicle regulations, insurance and licensing requirements. On the other hand, market access refers to competition between operators and places downward pressure on the cost of transporting goods. Market access is characterised by so-called access regimes and cabotage, referring to the issuing of travel permits and fleet ownership regulations, as well as limitations to the transport of local goods by foreign fleet owners.

Strengthening interoperability and market access in the SADC is central to improving logistics competence by increasing competition between private sector operators. This enhances the competitiveness and quality of logistics services (Piña & Quindimil 2016; Nair 2020), whilst reducing the cost of trade in the region. In the SADC, some progress has been made in this regard, including moving towards the harmonisation of licensing requirements through the SADC driver’s license (1999) and creating standardised license manuals (2004), as well as efforts to liberalise national transport markets and reduce third-country rules through multi- and bi-lateral agreements (Ncube, Roberts & Vilakazi 2015). However, significant differences between member countries remain in infrastructure standards and usage rates, vehicle and insurance requirements and limitations in market access because of cabotage restrictions. Regional development policy should emphasise increased interoperability and market access to improve logistics competence in the SADC (currently rated 2.51), which is 0.29 lower than the sample countries.

Based on the findings of the analysis, another indicator that needs to be improved to support resilient SADC supply chains is the efficiency of completing the necessary customs and border processes related to a traded good. Recent progress has been driven by the Simplified Trade Regime (STR) Framework and the SADC Electronic Certificate of Origin (E-CoO), which seeks to ease ‘customs procedures and processes’ (SADC 2020:29) by reducing non-tariff trade barriers. The development of One-Stop Border Posts (OSBPs) is also highlighted as instruments to alleviate the challenges associated with the region’s border posts, with several pilot projects delineated. Whilst improving with 11.42% between 2010 and 2018, the region remains behind sample countries in this indicator, with a difference of 0.18. Prominent challenges that delay border and customs clearances are a lack of human resources and capacity, uncoordinated systems amongst member countries, unreliable operating and information technology systems, duplication of inspection activities because of a lack of coordination amongst border agencies, as well as physical infrastructure aspects that limit processing capacity at border posts (Ngarachu et al. 2018). Regional interventions should target the alleviation of these challenges, in line with the Infrastructure and Development in Support of Regional Integration pillar of regional development policy.

The ability to determine the past and current location of a traded good, that is, tracking and tracing, is an important component of supply chains, one in which the SADC is particularly vulnerable in comparison to the sample countries. Effective tracking and tracing mechanisms are important for logistics providers to monitor goods movement (safety measure) (Soliani 2018), reduce communication costs, improve fleet management efficiency and information availability to consumers and determine accurate arrival times (Çemberci, Çivlek & Canbolat 2015). This indicator is enhanced by quality information communication technology (ICT) infrastructure, as well as transparent customs and border processes (Soliani 2018). Tracking and tracing in the SADC have been supported by improvements in the ICT and telecommunications sector, including the development of ‘cross-border transmission links’, ‘geospatial orbit satellite communications network’, improved ‘regional broadband interconnectivity’ and the ‘SADC Roaming project’ (SADC 2020:31). As per the ICT Sector Plan (SADC 2012c:74), these developments enhance ‘the opportunity to provide real time monitoring of networks of trucks, passenger and rail vehicles to help maximise efficiencies and improve security’.

An additional potential intervention to improve this indicator in the SADC is the establishment of an Electronic Cargo Tracking System (ECTS), where traded goods are monitored across the region using Geographical Positioning Systems (GPSs) and electronic seals (Ntuli 2017). This is similar to the Advance Cargo Information System (ACIS) in the Common Market for Eastern and Southern Africa (COMESA), which is an ‘integrated transport logistics tool for tracking transport equipment and cargo’ (Kingombe 2014). These systems improve competitiveness through increased efficiency in customs clearance procedures and ease of doing business.
The need for improved tracking and tracing is highlighted in the SADC Guidelines for Cooperation in Excise Taxes in the SADC Region, which states the need for capacity development of revenue administrators in tracking and tracing methods and technologies to reduce illicit cross-border trade (SADC 2016).

As indicated by the aforementioned interventions, improvements in trade and transport infrastructure, logistics competence, customs and border processes and tracking and tracing, all contribute to the ease of processing international shipments (SADC 2012c) and reduce lead time. The latter is determined by the extent to which the rest of the components support the development and enhancement of the supply chain (Chung, Talluri & Kovács 2018). Supply chain resilience in countries and regions is supported by collaboration between policy-making agents, that is, institutions and private sector stakeholders (Gölgeci & Kuivalainen 2020; SADC 2020). The SADC institutions oversee the development and implementation of regional development policy and related interventions. Whilst experiencing challenges relating to a lack of capacity in this regard (Pretorius et al. 2021), regional institutions should be empowered to facilitate coordination between member countries to ensure unified decisions are made and implemented across the region to effectively facilitate the cross-border movement of traded goods. This is especially important during disruptive events such as the COVID-19 pandemic, which has significantly impacted supply chains (Demertzis et al. 2020). The SADC institutions must utilise, expand and advance regional supply chains across the LPI variables to foster their resilience and ability to contribute to the growth and development of the regional economy (Bausinger et al. 2015). The existing regional policy (SADC 2020) has a broad spatial, economic and social focus, but lacks explicit policy relating to the problem areas identified in this research. Although an integrated and implicit policy approach is necessary and already tabled, the findings of this research identify focus areas and policy initiatives that should form the cornerstone of trade and development policy in the SADC.

**Conclusion**

The COVID-19 pandemic and subsequent government regulations focussed on transmission control and social isolation has had a significant impact on international trade and supply chains. This has also been the case in the SADC, where the associated trade disruption was exacerbated by inefficient supply chains unable to rapidly adapt. This affected regional trade dynamics and the economic output of member countries. There is a need to create more resilient supply chains that are agile, flexible and can adapt to future disruptions. Regional development policy constitutes an important instrument in coordinating interventions towards this end. This research investigates supply chains as a factor in the impact of the pandemic on trade volumes, with specific reference to the SADC whilst also including the broader, global context. The objective is to guide targeted policy interventions to foster resilient regional supply chains in the SADC.

The econometric analysis indicates that the impact of the pandemic on trade in the sample countries and the SADC was significant (albeit heterogeneous) as the majority of countries experienced a marked downturn in trade. This analysis, using the supply chain components inherent to the LPI, determines the relationship between the quantified pandemic impact and the said components. The findings indicate that supply chain efficiency constitutes an important variable in mitigating the trade impact, in addition to the heightened role of the efficiency of customs processes and clearance, the quality of transport and trade infrastructure, the efficient arrangement of international shipments, high-quality logistical services, the ability to track and trace traded goods, and the ability to meet expected delivery times more frequently. The SADC has made progress in developing regional supply chains in the last decade, as supply chain efficiency has increased by 4.38%, and customs clearance and infrastructure have improved by 11.42% and 11.58%, respectively. However, in comparing the supply chain efficiency of the sample countries and the SADC, the indicators of the latter still fall below those of the former. This is a potential indication of the greater vulnerability of the SADC and its member countries to related-trade disturbances because of the comparatively lower efficiency of their supply chains.

Regional development policy is central to facilitating regional trade and supporting the development of efficient and resilient supply chains. Regional investment is required to improve physical trade and supply chain infrastructure. This should be coordinated by capacitated SADC institutions in partnership with the private sector. A remaining challenge in the SADC is the lack of a regional development fund to directly finance physical infrastructure development. Regional interventions in non-physical infrastructure need to be focussed on increased interoperability between SADC member countries and improved market access for logistics service providers to improve logistics competency. Remaining challenges in customs and border processes, including infrastructure limitations, lack of coordination, duplication of activities and lack of capacity, need to be overcome to improve trade facilitation and supply chain function. An ECTS and broader access to ICT services may improve tracking and tracing in the region and enable logistics service providers to monitor traded goods in real time, which has significant benefits.

These interventions will increase the ease of processing international shipments and improve lead times, thus further aiding the development of efficient and resilient supply chains in the region. This constitutes the foundation for the SADC to foster regional integration and trade and achieve its long-term socio-economic development objectives whilst increasing its global competitiveness in the face of increased regionalisation of supply chains.

A potential limitation of this research is that indicators of supply chain efficiency are delineated based on the LPI. The incorporation of other databases may mitigate potential risk through the diversification of data sets whilst also contributing to the identification of additional independent
variables that may add value to the analysis and findings. Areas of future research include a detailed investigation of supply chain resilience in individual SADC member countries to aid nuanced policy development and implementation, as well as analysing the response of individual trading agents, that is, firms to the pandemic, including the adaptation of their supply chains.

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The authors have declared that no competing interest exists.

Authors’ contributions

O.R.P. contributed to the conceptualisation, methodology, formal analysis, investigation, writing of the original draft, visualisation, project administration, validation, data curation and the review and editing of the final draft. J.E.D. and W.H.E. contributed to the conceptualisation, formal analysis, investigation, writing of the original draft and the review and editing of the final draft. G.C.M. contributed to the formal analysis, the software and the data curation.

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Data availability

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