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Article

Enhancing local economic development through biofuel production in Limpopo, South Africa

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Abstract: In wealthy nations, biofuel usage has grown in importance as a means of addressing climate change concerns, ensuring energy security, and promoting agricultural development. Because they understand the potential advantages of biofuel for rural development and job creation, governments have created policies and legislation to encourage the production of biofuel. However, the province of Limpopo hasn't fully taken advantage of the potential to use biofuel production as a vehicle for job development, despite a higher demand for the fuel. There is currently a lack of understanding of the role of biofuel in promoting local development in developing regions. For this reason, this study made use of semi-structured interviews to explore how biofuel production can be used as an instrument for Local Economic Development (LED) in the Limpopo province of South Africa. The research investigated the determinants of empowerment that could impact the commercial feasibility of biofuel production in the province. It also identified the need for human resource development to get workers ready for jobs in Limpopo's biofuel sector. The results showed that, provided certain conditions were met, the production of biofuel in Limpopo may be a useful instrument for creating local jobs. By highlighting the potential for job creation and the importance of human resource development, this research aims to facilitate evidence-based decision-making that can harness biofuel production for sustainable rural development in the region. The value of this study lies in its contribution to the understanding of biofuel's role in LED, offering actionable insights for policymakers and stakeholders in Limpopo.

Keywords: biofuel; Local Economic Development; sustainability; biofuel production; green energy; South Africa

1. Introduction

As countries are transitioning to the use of greener energy sources, biofuel can be used as a more sustainable source of energy generation. Globally, the depletion of natural resources as well as greenhouse gas (GHG) emissions that exacerbate climate change remain a critical problem (Vega et al., 2024). The overreliance on fossil fuels is a main driver for this; thus, biofuel production presents an alternative, more sustainable solution. Additionally, the production of biofuels has the potential to promote rural economies by enhancing agricultural practices and promoting diversification (Paschalidou et al., 2018). This results in capital investments, increased demand for products and services, and the creation of jobs, which can also help minimize rural-urban migration (Paschalidou et al., 2018). Biofuel policies globally have been motivated by issues concerning energy security, the reduction of greenhouse gases, and regional development; however, these policies have resulted in market distortions that impede the attainment of long-term goals linked to biofuels (To et al., 2014). The European Union (EU), which accounts for 31% of global biofuel

production, is the leading producer, followed by the United States of America (USA) at 19% and Brazil at 13% (Mizik and Gyarmati, 2021). In South Africa, over 30% of the population resided in rural areas in 2023 (Macrotrends, 2024). Thus, small-scale farmers may be able to find new avenues for production as a result of the development of biofuels.

While there is some research on biofuel production in specific developing regions, researchers such as de Castro Assumpção et al. (2020) and Vega et al. (2024) write that there is a lack of comprehensive studies investigating biofuel production and its role in local economies within developing regions. The authors further note that more detailed and region-specific research is needed to fully understand and optimize biofuel production in regional areas. In South Africa, the biofuel industry is still in a state of stagnation despite the various frameworks that support its production (Pradhan and Mbohwa, 2014). This is because no manufacturers have committed to building industrial facilities, and mandatory blending cannot start until later (IEA, 2018). As one of the greenest and most sustainable transportation fuels, biofuel has the potential to significantly aid South Africa's transition to a smaller carbon footprint (DoT, 2018). The government's efforts to create policies and strategies to support the production of biofuel are recognized, as are the potential advantages of biofuel for rural development and job creation. But despite these efforts, there has not been much development in the industry. As biofuel is both biodegradable and non-toxic, it is considered the most favorable fuel for promoting sustainability (Brahma et al., 2022). However, some researchers, such as Schuenemann et al. (2016), point towards the possibility that the growth of the sector would heighten food insecurity and that biofuels negatively affect the environment. In light of this, this study aims to investigate biofuel producers' perceptions of how biofuel production in the province of Limpopo can promote employment and Local Economic Development (LED).

2. Literature review

Biofuel is seen as a prominent fuel in advancing sustainability as it is non-toxic and biodegradable (Brahma et al., 2022). The primary goal of producing biofuels is to improve environmental sustainability, while crude oil is currently failing to do so due to its high carbon emissions (Jeswani et al., 2020). Resource allocation must be done efficiently to promote economic sustainability. The economic aspects of producing biofuel include capital expenses, raw material costs, plant capacity, maintenance costs, and process technology (Zetterholm et al., 2020). According to Collotta et al. (2019), social sustainability examines the effects on residents and communities. Are their rights being upheld? The principal source of revenue for many African nations is agriculture (Oluwatayo and Ojo, 2016). The commercialization of biofuel, however, will require a large amount of land, which could seriously jeopardize the livelihoods of those who reside there (Sekoai and Yoro, 2016). In terms of biodiversity, land usage, water, and soil preservation, the land is the focus of environmental sustainability (Correa et al., 2019). However, there could be detrimental effects on the ecology from the manufacture of biofuel. According to Mat Aron et al. (2020), these include overusing water, taking up valuable land that could have been utilized for farming, deforestation, ecological disruption, biodiversity loss, and changes to soil structure

and fertility. Furthermore, just as biofuel production can lead to various benefits in the agricultural sector, the competition for land between producing food and biofuel can affect food security and the utilization of agricultural land (Sivarathnakumar et al., 2021).

International attention has been greatly piqued by the implementation of biofuel policies in Brazil, the EU, and the USA, especially from African governments. The production of biofuel is progressively gaining appeal as a venture for foreign direct investments in the African continent (Widengård, 2011). However, several challenges, including land availability, financial limitations, technical competence gaps, entry barriers, and regulations, have prevented comparable attempts from moving further throughout Africa (Sekoai and Yoro, 2016).

Looking at South Africa, the production of biofuels would provide more inexpensive energy sources, lessen the nation's reliance on fossil fuels, and boost social advantages, including jobs. Many local governments in the country face financial difficulties and restricted income sources, which makes it difficult for them to make investments in infrastructure upgrades or offer inducements to companies looking to locate in their areas (Van der Waldt and Fourie, 2022). Biofuel production has emerged as a potential solution to these challenges, offering a sustainable economic activity that can create employment opportunities and contribute to poverty reduction, particularly in rural areas (Ben-Iwo, 2016). Furthermore, biofuel can promote energy access and security, which are critical for socioeconomic development (Naeem Nawaz and Alvi, 2018).

Although there is no denying that biofuel has the potential to improve the South African economy, it is important to respond to and consider documented complaints. There have been claims that the growth of the industry will worsen the state of food poverty and that biofuels harm the environment (Schuenemann et al., 2016). Furthermore, it's critical to take into account any potential obstacles to South Africa's biofuel manufacturing. For example, in their former homelands, which are primarily controlled by small-scale farmers, South Africa's Biofuels Industrial Strategy emphasizes growing sugarcane, sugar beet, sunflower, canola, and soybeans as feedstock crops for biofuels (DMRE, 2007). It is suggested that the best usage of these permitted crops may not be for South Africa because they are claimed to exacerbate the conflict between food and fuel (Malobane, 2019). This challenge is attributed to water scarcity across most of the country, especially in rural areas, and the South African Department of Water and Sanitation therefore does not endorse or encourage the cultivation of biofuel feedstocks (Mengistu, 2016). In addition, a study by Funke et al. (2009), conducted in South Africa, found that in certain instances, the economic viability of producing biofuels faces obstacles due to a lack of adequate incentives and commitments.

Research relating to the role biofuel production plays in economies is still debatable, with various contrasting findings. For instance, Heijman et al. (2019) found that a bioethanol facility in Hungary has had a positive effect on the rural job market, demonstrating the potential of biofuels to stimulate economic development in rural areas. Additionally, as stated by Nkolo et al. (2018), policies that support biofuels have been shown to have beneficial effects on GDP and household income, with an average rise of 0.25 percentage points in GDP and 0.49 percentage points in household

incomes. The authors further surmise that these benefits are more significant in developed nations and in situations where agricultural productivity increases. Similarly, a study by Lynd et al. (2015) found that the production of biofuel significantly increased GDP and employment on a net socioeconomic basis. A similar study by Ogaboh (2010) established that 60% of the labor force in Nigeria is employed in the agricultural sector; after the biofuel industry is completely established in the nation, this figure is expected to rise to between 70% and 80%. In addition, according to the study of Balogun and Salami (2016), the manufacturing of biofuel gave Nigeria's women and youth numerous employment opportunities.

In contrast, the findings of research by Wang et al. (2020) showed that while bioethanol production is useful for energy conservation and economic growth, it is less useful for creating jobs. Moreover, research by Hoffmann et al. (2015) established that in Western Tanzania, substituting food crops with biofuel crops such as sunflower and groundnut oils could lead to greater hunger among the most vulnerable farmers. This underscores the important trade-off between the production of energy and the availability of land for food. Furthermore, the effects of biofuel production on natural resources and environmental sustainability differ by region, as shown by Zaman et al. (2016). For instance, the aforementioned authors found that in Europe and Central Asia, biofuel production has been linked to lower emissions, while in other areas, it has worsened environmental challenges (Zaman et al., 2016). What's more, the majority of the research takes a quantitative stance; thus, more in-depth knowledge relating to the challenges and opportunities faced by operators within the biofuel industry is lacking. Due to the aforementioned contrasts and complexities, this study intends to add to the expanding body of knowledge regarding the viability of biofuel production as a tool for LED and employment creation in South Africa.

3. Methodology

The study region, the Limpopo province, has a population of around 58 million people and is located in the northern part of South Africa. This study followed a qualitative research methodology. Biofuel manufacturers that consented to take part were interviewed individually through virtual meetings. Semi-structured interviews were held with 12 biofuel producers that are currently based in the Limpopo province. The participants were contacted with the use of a snowballing technique. This method allowed participants to elaborate on their answers. Consequently, it was suitable for this study as it enabled biofuel producers to give comprehensive answers to the research questions asked. In addition, this qualitative approach does not impose limitations on participants' responses. Before the formal interviews, a pilot test with three participants was held to ensure that the questions were clear and easily understood. The questions were open-ended and centered on the current state of biofuel production at present and its potential to increase jobs in Limpopo. The topics covered in the interview are presented in **Table 1**.

Table 1. Concepts covered during the interview process.

Empowerment aspects that determine the commercial viability of biofuel production
Factors that motivated the start of biofuel production
What raw materials are being used?
Training received?
The biggest challenges faced?
Do they receive any form of support, such as funding, tax rebates, or incentives to produce biofuel or any training programs?
Who are the main consumers of the produced biofuel?
Is the community aware that they produce biofuel?
What would make biofuel commercially viable in South Africa?
Human resource development
How many people have been employed since production began?
The nature of employment (full-time, part-time, seasonal)
What skills are employees equipped with to produce biofuel?
What are the determinants for employment growth in the organization?
Is there any formal training given to the employees?
What is expected from the employees?

Ethical clearance for contacting and interviewing participants was obtained from the School of Economics Ethics Committee at the University of Johannesburg.

4. Results and discussion

From the interviews with the 12 biofuel producers in the study region, it came to light that these participants had been engaged in biofuel production for an average of 4.75 years, highlighting that the practice is fairly recent in the region. However, what is noteworthy, given the study location, is that throughout these 4.75 years, a total of 105 full-time and seasonal jobs were generated. This result concurs with studies such as Arndt et al. (2011) and Gasparatos (2012), who surmise that the production of biofuels has the potential to promote LED in rural regions by generating employment opportunities and enhancing the demand for agricultural goods.

In addition, the majority of the participants indicated that the production of biofuel is not their primary source of income, as farmers engage in the production of biofuel as a secondary means of income generation. The empowerment aspects that determine the commercial viability of biofuel production in Limpopo had six themes that emerged from the interviews. These themes are illustrated in **Figure 1**.

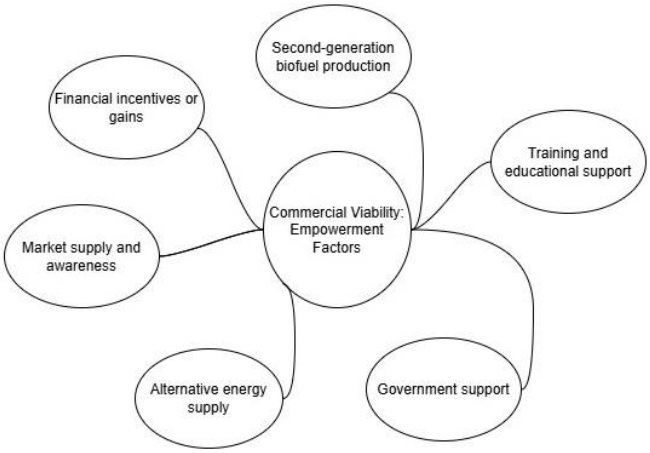

Figure 1. Empowerment factor themes that determine the commercial viability of biofuel production.

From **Figure 1**, the first theme is second-generation biofuel production. All of the participants produced second-generation biofuel using cooking oil as their feedstock. The majority of participants made biofuel by utilizing leftover cooking oil; only one utilized castor oil. Based on the volume of waste cooking oil produced worldwide, Suzihaque et al. (2022) claim that waste cooking oil has significant potential as a source of biodiesel. Waste cooking oil is expected to play an increasingly greater part in the manufacture of biodiesel in the future due to its cheaper cost compared to other raw materials. According to an Albanian study by Topi (2020), the price of spent cooking oil, which was significantly less expensive than unused oil, was a major factor in the decision to use it as feedstock. In addition, studies such as Kumar et al. (2017) and Ingle et al. (2020) explain that using inexpensive raw materials such as animal fats or lignocellulosic sources can aid in lowering costs in producing biofuel. These findings are in line with Antizar-Ladislao and Turrion-Gomez (2008), who write that the establishment of community-based bioenergy systems for second-generation biofuels is viewed as a means to enhance both production and consumption, which could bring advantages to local economies. The authors further highlight that second-generation biofuels could lower net carbon emissions, promote energy efficiency, and reduce reliance on fossil fuels.

The second theme emerging was that of market supply and awareness. There can be a rise in demand for renewable energy sources like biofuel as people become more conscious of its advantages for the environment. Participants provided farmers with their goods, and farmers stated they sold the goods through their network. One participant indicated that they had their first client referred to them by the biofuel business incubator (BBI). The impact of market forces on the sustainability of biofuel and bioproduct production was examined by Gan et al. (2019). They explained how supply and demand affect biofuel production, and use and the resulting socioeconomic and environmental implications. Some participants describe how their exposure in the media helped them attract customers and raise awareness of the manufacture of biofuel in their town and throughout the nation. They were able to purchase one of the biggest petroleum corporations in the nation because of this recognition. A study by Edeseyi et al. (2015) writes that successful marketing techniques, such as green and social marketing, are crucial for promoting biofuels and improving consumer acceptance.

Therefore, to secure the growth of biofuel producers, successful marketing, consumer awareness, business-to-business (B2B) partnerships, media exposure, and customer satisfaction are essential.

The third emerging theme was training and educational support. Most of the participants indicated that they have received some form of training. A high school degree or its equivalent is normally required for farmers and other agricultural workers, while some may have an agricultural college degree, according to Richards (2013). To create high-quality biofuel while minimizing their negative effects on the environment, biofuel producers need to be trained in best practices. Some of the participants mentioned that they initially attempted to produce biofuel exclusively without instruction. However, after seeing their outcomes, they visited the BBI to use its resources and acquire training. Because traveling to the incubator can be difficult, one of the attendees stressed the value of having the ideal location. Capacity-building initiatives and training programs are vital for providing stakeholders with the skills they need, as highlighted by Grieco and Javan (2010). Research by Hidayatno et al. (2019) states that education and training in sustainable supply chain management is key to making sure that biofuel production is both environmentally sustainable and socially responsible. They add that this encompasses grasping the intricacies of sustainable practices and enforcing eco-friendly regulations. The results show that in order to guarantee high-quality output, environmental sustainability, and regulatory compliance, biofuel producers must invest heavily in training.

Government support was the fourth theme emerging from the responses. Participants said that for the production of biofuel to be economically feasible, the government must provide some kind of assistance. The participants believed that one of the things preventing the commercial viability of biofuel production is the absence of government support. Similar calls for more knowledge and participation from governmental organizations, business owners, and other stakeholders were made by Awogbemi et al. (2021) to encourage the use of leftover cooking oil and lessen its detrimental effects on the environment. Government intervention would help with issues like the unregulated price of spent cooking oil and biofuel, which posed another challenge for farmers. Most biofuel producers are concerned with the large free will present in the biofuel market, which creates the gap left by a lack of government policies. The economic feasibility of producing biofuel in the presence of conventional fuels was assessed by Ndokwana and Fore (2018), who found that biofuel production is only feasible in conditions of substantial government support. In addition, studies such as Mvelase et al. (2023) opine that insufficient government support and pricing competition with gasoline and petroleum alternatives impede the financial feasibility of the biofuel sector in developing regions.

The second-to-last theme relating to empowerment aspects is financial incentives or gains. When participants were questioned about what drove them to start generating biofuel, one of the things that came up was financial gain or incentives. The majority of participants did not rely on biofuel production as their primary source of income. As a result, they started making biofuel to supplement their primary income. The need for alternate energy sources gave entrepreneurs creative ideas for profitable ventures in the agriculture sector. This shows that there is potential for the provision of incentives within the region in an effort to promote the biofuel industry. The provision

of incentives within the biofuel industry has proven successful in countries such as America, where Denizel et al. (2020) write that these incentives include reduced costs for producers and lower retail prices, stimulating the production of biofuel. Incentives can play a critical role in empowerment within the biofuel industry, especially in regions such as here where the production of biofuel is still in its infancy. The last theme emerging from the responses was alternative energy supply. Participants responded that their growing awareness of the need for another energy source as a result of the fuel price increase, the crude oil crisis, and the fact that ethanol is biodegradable led them to begin producing biofuel. A study by Jeswani et al. (2020) highlights the pressing need to combat climate change, lessen reliance on fossil fuels, promote sustainable development, and create a more dependable and environmentally friendly energy future, which is what motivates the demand for biofuel production. Because biofuel emits less carbon dioxide than other fuels, it can help slow down global warming. As a result, the participants were informed about the possible applications of biofuel as an environmentally friendly substitute energy source. The need for alternative energy sources, the advantages of biofuel for the environment, and the growing cost of fossil fuels were some of the factors that motivated the participants to start producing biofuel.

The criteria for human resource development that participants emphasized to get ready for jobs in Limpopo's biofuel industry had four themes emerging from the responses. These themes are illustrated in **Figure 2**. The first theme was the type of employment. Most of the participants indicated that they recruited more workers to aid in the production of biofuel. According to Kedron and Bagchi-Sen (2018), biofuel production has drawn interest from farmer-entrepreneurs and investors from related industries following the establishment of policy mandates and subsidies that created a dedicated market for this fuel. All participants agreed that the production of biofuel opens up new business and job prospects, particularly in rural areas. Similar findings were made by Hartley et al. (2016), who found employment growth in the biofuel industry is highly dependent on market demand. Furthermore, Ahmad et al. (2013) surmise that the demand for sustainable energy solutions together with reducing greenhouse emissions are some of the primary drivers of biofuel production. Depending on the needs of the business at the time, several participants employed individuals on a part-time basis. This suggests that employment within the biofuel industry is highly dependent on demand. Skills development and preproduction training are the second theme emerging as a criterion for human resource development. Again, participants agreed that to guarantee the development of clean, high-quality biofuel, workers and producers of biofuel must have training. Workers require specialized skills in the biofuel production process, which are generally not included in conventional academic curricula. Jagadale et al. (2024) stress that workers are required to have a comprehensive understanding of the technical aspects related to biofuel production processes, given the flammable and hazardous properties associated with biofuels. Training initiatives should encompass various renewable energy technologies, such as biofuels, to guarantee a comprehensive understanding of the sector (Zilouchian and Abtahi, 2012). Similarly, a study by Narwane et al. (2021) observed that biofuel producers require government support for entrepreneurship and training.

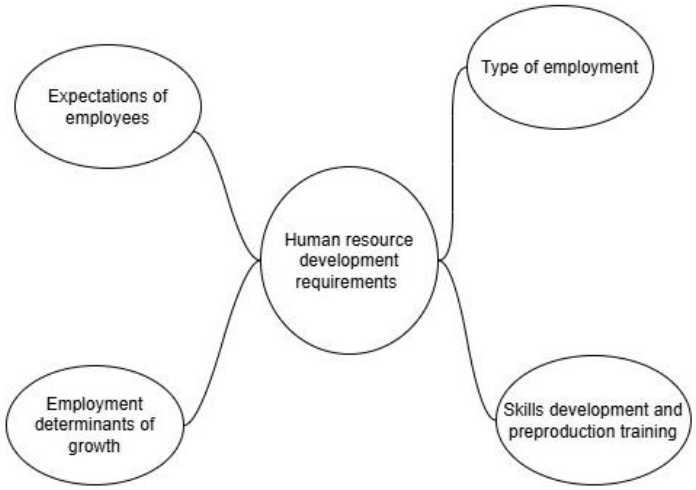

Figure 2. Themes emerging from human resource development requirements.

Employment determinants of growth were the third emerging theme, with participants saying that employment prospects are determined by the market demand for biofuel. The factors influencing the expansion of employment in their organizations were questioned by the participants. According to Neuwahl et al. (2008), the impact of biofuel production on employment is dependent on various factors. The majority of participants stated that increased demand for biofuel leads to an expansion of production, which in turn calls for an increase in human resources. The business would then have greater space for opportunities as a result. Numerous participants agreed that rising demand for biofuels drives employment growth by causing businesses to grow and create additional work opportunities. These responses support literature in that the production of biofuels can stimulate economic development in rural areas by generating employment opportunities in agriculture and service sectors. This is especially noticeable in areas where biorefineries are integrated into the local economy and society, as demonstrated by Heijman et al. (2019) in their study in Hungary. Thus, the results showed how the market's demand for biofuel shapes job prospects in the industry. The last theme was that of expectations of employees. They all (12) stated that they expect their staff members to put forth a lot of effort, meet their goals for output, and provide high-caliber work. Saleem (2022) emphasized that by employing waste materials and generating additional jobs, the growing biofuel sector would strengthen the financial standing of rural communities. Furthermore, participants expressed that they need to ensure that they, as well as their employees, are proactive and reach all the set targets. In essence, the success of the biofuel sector in Limpopo relies on the accessibility of feedstock, market supply and awareness, training and educational resources, as well as government support. When these empowering elements are in place, market demand would likely increase, which in turn could lead to an increase in job opportunities.

5. Conclusion

In summary, the effectiveness of biofuel production in generating employment and promoting LED is a complex issue, including environmental, social, and economic aspects. Although biofuel production can contribute to the development of rural

economies and the diversification of agriculture, it also presents environmental challenges and social consequences that must be addressed through appropriate policies and regulations. Nevertheless, biofuel production can provide significant economic advantages to local communities. The responses further highlight the importance of training, both for the producers and employees involved in the biofuel industry. This is also important to not only enhance the capabilities of the employers and employees, but to ensure the sustainability of the production processes and reduce the possible environmental harm. By highlighting the potential for job creation and the importance of human resource development, this research shows that biofuel production can be used as a driver for sustainable rural development and LED in the region. Furthermore, it underscores the importance of aligning biofuel initiatives with local needs and capacities, ensuring that the benefits of biofuel production are maximized for the community.

5.1. Implications for policy

Support from the government is needed to address the needs for human resource development and to boost the empowering elements that promote the commercialization of biofuel production. It became evident through the responses that the biofuel producers are still heavily reliant on government support. This suggests that policies should rather look at incentives than purely relying on financial gain as a driver. Through providing incentives, it could reduce and prevent government dependency. A possible strategy to enhance the use of biofuel would be to set up collection points in each town and provide financial incentives to people for every liter of spent cooking oil they gather. Also, policies should consider the environmental aspects of the region to ensure that the production of biofuel occurs within the natural carrying capacity of the environment. For producers, BBI-facilitated mediation is crucial in helping them build relationships within the biofuel community. These networks have many benefits, including the ability to learn more and give producers the chance to investigate the development of biofuel feedstock in greater detail. Moreover, the production of biofuel can provide young people with important practical training experiences as well as employment opportunities in rural regions.

5.2. Limitations and areas for future studies

The study does have limitations, with the main limitation being that it was limited to biofuel producers in the province of Limpopo. Future studies could include a comparative study between more regions. Future research can examine the reliability of biofuel produced by all biofuel manufacturers to ascertain its safety for usage. The type of employment that is created is another aspect that may be explored in the future.

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Institutional review board statement: The study was conducted in accordance with the Declaration of Helsinki, and was obtained from the School of Economics Ethics Committee at the University of Johannesburg, for data collection from December 2022 to December 2024. Ethical clearance code 22SECO079.

Informed consent statement: Informed consent was obtained from all subjects involved in the study

Conflict of interest: The authors declare no conflict of interest.

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