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How Much Is Too Much Debt for South Africa? A Threshold Nonlinear Autoregressive Distributive Lag (T-NARDL) Perspective

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Since the global financial crisis, South African fiscal authorities have acquired debt at a faster rate compared to other economies, which, according to recent growth theory, implies that the economy has a lower debt tolerance or threshold level than previously thought. Our study presents country-specific debt threshold estimates for the South African economy based on reduced form regressions derived from an endogenous growth model of public debt that incorporates public investment as a channel through which debt can influence economic growth. We estimate the reduced form regressions using the threshold nonlinear autoregressive distributive lag (T-NARDL) cointegration model which we apply to quarterly time series spanning from 1960:q1 to 2020:q4. We identify debt thresholds of 47 percent which are much lower than those predicted by previous panel-based studies. Similarly, the corresponding public investment threshold estimate of 2.8 percent is lower than that prescribed by previous literature. However, our study shows that both public debt and public investment are too high to be growth enhancing and we provide policy recommendations based on these findings.

Key Words: optimal debt, optimal public investment, economic growth, endogenous growth model, threshold nonlinear autoregressive distributive lag (T-NARDL) model, South Africa
JEL Classification: C22, C51, E63, O47

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Introduction

The economic recession which emerged from the ongoing coronavirus pandemic has resurrected fears of a looming global debt crisis, which could assimilate in a similar fashion to how the 2009 global recession

led to the 2010 European sovereign debt crisis. In response to the experienced sharp plunges in gross domestic product (GDP), primarily caused by the abrupt 'shutting down' of economies worldwide, many governments rolled out fiscal stimulus packages, partially financed by loans obtained from international governing bodies such as the International Monetary Fund (IMF) and World Bank, and acquired huge debt in the process. By the second quarter of 2021, a handful of developing and emerging economies defaulted on their sovereign debt (e.g. Argentina, Ecuador, Ethiopia, Lebanon, Zambia) and it is expected that more emerging economies are at sovereign risk of default (Arellano, Bai, and Mihalache 2020).

In the case of South Africa, which is the focus of our study, the levels of debt are not as high as those in other emerging or industrialized economies and yet the sharp increase in debt-to-GDP ratios from 38.2% (2010) to 68.7% (2020) indicates that, over the last decade, the country has accumulated debt faster in comparison to more industrialized counterparts/nations (see table 1). To mitigate the effects of COVID-19, the South African government rolled out a R500-billion 'extraordinary coronavirus budget' (10% of GDP), of which a significant portion has been financed through government debt. The BRICS New Development Bank (NDB) loaned the country $1 billion in June 2020 and in July 2020 the IMF approved a further $4.3 billion loan. Notably, government expenditure programmes supporting the economy through the pandemic have attained some level of success, as economic growth rebounded from −55.7% in the second quarter of 2020 to 66.1% in the fourth quarter. However, given the countercyclical fiscal approach adopted by the Ministry of Finance in response to the pandemic, both the budget deficit and the public debt have exceeded their 'targets' and are expected to sharply rise in the future (Bhorat et al. 2020). To cushion the adverse effects of rising debt, the South African government has committed itself to stabilizing debt so that it peaks at 87 percent by 2023–2024 and starts declining thereafter (Burger and Calitz 2021).

The question our paper poses is 'Are South African fiscal authorities trying to stabilize debt at levels which would compromise long-term economic growth?' This question begets a more specific empirical question of 'how much debt is too much debt for the South African economy'? To answer these questions, we use the T-NARDL framework to capture the nonlinear dynamics of the reduced form regression extracted from the endogenous debt-growth model which encompasses both public debt

TABLE 1 Debt-to-GDP Ratios of 2010 and 2020 for Select Countries

Country	2010	2020	Country	2010	2020
South Africa	34.7	83.0	UK	62.6	84.4
Brazil	51.8	75.8	Argentina	55.4	102.0
Russia	9.0	14.6	Canada	81.3	117.8
India	65.6	69.6	France	85.3	115.7
China	33.9	66.8	Germany	82.5	69.8
Japan	207.7	266.2	Italy	119.2	155.8
Zambia	77.9	91.9	Spain	60.5	120.0
US	91.2	107.6			

NOTES Based on data from World Bank (https://data.worldbank.org/indicator).

and public investment thresholds. One appealing feature of the model framework is that the optimal levels of debt and public capital are not universal for all economies and are dependent on certain economic factors such as the growth rate of public debt and the share of public investment in government expenditure. We further consider this framework suitable in the context of the South African economy since recent empirical evidence by Ncanywa and Masoga (2018) and Burger and Calitz (2021) confirm that public investment is an important channel through which public debt can influence economic growth in South Africa. However, these studies fall short of identifying optimal levels of public investment and debt which maximize economic growth, which is a shortcoming our study overcomes.

The rest of the study is presented as follows. The next section of the paper provides a brief review of the associated literature. The third section outlines the theoretical framework of the study whilst the fourth section outlines the T-NARDL model used to estimate the public debt and public investment thresholds. The empirical analysis is presented in the fifth section of the paper and then the study is concluded in the sixth section in the form of policy implications.

Brief Review of Associated Literature

Traditional economic theory speculates that debt can either be growth-enhancing (i.e. Keynesian hypothesis), growth-retarding (i.e. debt overhang hypothesis) or exert neutral effects on growth (i.e. Ricardian-equivalence hypothesis) (Akanbi 2016; Dombi and Dedák 2019; Mhlaba and Phiri 2019; Rahman, Ismail, and Ridzuan 2019; Yared 2019). Numerous

empirical studies have reconciled these opposing views on the effects of debt on growth by assuming that debt only retards growth after it has crossed some optimal threshold level of debt (Smyth and Hsing 1995; Pattillo, Poirson, and Ricci 2002; Chen and Lee 2005; Reinhart and Rogoff 2010; Cecchetti, Mohanty, and Zampolli 2011; Chang and Chiang 2012; Checherita-Westphal and Rother 2012; Baum, Checherita-Westphal, and Rother 2013; Checherita-Westphal, Hallett, and Rother 2014; Herndon, Ash, and Pollin 2014; Pescatori, Sandri, and Simon 2014; Casares 2015; Égert 2015; Chen et al. 2017; Gómez-Puig and Sosvilla-Rivero 2017; Kamiguchi and Tamai 2019; Bouchrara, Rachdi, and Guesmi 2020; Bentour 2021).

Some of this literature has included South Africa in their empirical analysis and notably, the optimal debt threshold estimates obtained in previous studies are above the current debt-to-GDP ratio of 70 percent, which implies that South African fiscal authorities have not acquired too much debt and have some 'fiscal space' to acquire more debt to enhance economic growth (Eberhardt and Presbitero 2015; Chudik et al. 2017; Bitar, Chakrabarti, and Zeaiter 2018; Ndoricimpa 2017). Only a few more recent studies which include South Africa as part of the analysis argue otherwise (Chen et al. 2017; Ndoricimpa 2020; Law et al. 2021).

After surveying and scrutinizing the available empirical literature which has previously estimated optimal debt thresholds for the South African economy (see table 2 for a summary of this literature), we observe that the suggested optimal debt levels based on these previous studies may be biased towards the country and further deliberation on the subject matter is necessary. We present three main reasons supporting our views.

Firstly, we observe that most previous South African studies are panel based, which include South African data amongst a host of high debt outlier economies and generalize the estimated threshold as being applicable to all observed economies (Caner, Grennes, and Koehler-Geib 2010; Eberhardt and Presbitero 2015; Chudik et al. 2017; Arčabić et al. 2018; Bitar, Chakrabarti, and Zeaiter 2018; Mensah et al. 2019; Ndoricimpa 2017; 2020; Liu and Lyu 2021; Law et al. 2021). We argue that the panel data approach masks the country-specific dynamics underlying the true debt-growth relationship for the South African economy. By conducting a country-specific analysis for South Africa we more effectively 'separate the wheat from the chaff' in estimating an appropriate debt threshold for the economy.

TABLE 2 Summary of Associated Literature

Author	Countries	Period	Method	Results
Cordella, Ricci, and Ruiz-Arranz (2005)	79 developing countries (including SA)	1970–2002	Panel Threshold Autoregressive Model	Debt overhang threshold at 15–30% and debt irrelevance threshold at 70–80%.
Caner, Grennes, and Koehler-Geib (2010)	75 developing and 26 industrialized economies	1980–2008	Panel Threshold Autoregressive Model	Optimal debt of 77% for entire sample and 64% for developing countries.
Eberhardt and Presbitero (2015)	118 (including SA)	1960–2012	Kink regression and Nonlinear Autoregressive Distributive Lag model	Optimal debt in range of 60–90%.
Égert (2015)	29 developed and 21 emerging economies (including SA)	1960–2009	Multiple-regime Panel Threshold Autoregressive model	Debt threshold of 60–90% for emerging economies.
Chen et al. (2017)	65 countries (including South Africa)	1960–2014	Panel Smooth Transition Regression model	Debt threshold of 59.72%.
Chudik et al. (2017)	40 countries (including South Africa)	1965–2010	Panel Threshold Autoregressive Distributive Lag model (PTARDL)	30–60% for developing economies. No universal debt threshold once common observed factors are accounted for. Debt trajectory is more important for relationship.

Continued on the next page

Secondly, most previous studies including South Africa in their analysis do not rely on sound theoretical foundations which dictate the channels through which the nonlinear debt-growth relationship emerges. We note that previous studies have either estimated bi-variate regressions with no control variables (Égert 2015; Chudik et al. 2017; Mensah et al. 2019) or have estimated multivariate regressions with inconsistent control

TABLE 2 *Continued from the previous page*

Author	Countries	Period	Method	Results
Ndoricimpa (2017)	38 African countries	1980–2010	Panel Threshold Autoregressive Model	Debt threshold of 92.78%.
Arčabić et al. (2018)	185 OECD and non-OCED countries	1960–2009	Panel Threshold Autoregressive Model	Debt threshold of between 26.68–80.71% for OECD countries and between 43.24–106.33% for non-OECD countries.
Mensah et al. (2019)	38 African countries	1970–2015	Panel Threshold Autoregressive Distributive Lag model	Optimal debt in range 50–80%.
Ndoricimpa (2020)	39 African countries	1980–2012	Panel Smooth Transition Regression model	Debt threshold of 74.3%.
Bouchrara, Rachdi, and Guesmi (2020)	36 countries (SA included)	1990–2013	Panel Smooth Transition Regression model	The effect of debt on growth is dependent on institutional quality.
Law et al. (2021)	71 developing countries (including SA)	1984–2015	Panel Threshold Autoregressive Model	Debt threshold of 51.65%.

variables, or include covariates which are selected based on 'generalizations' of growth theory (Bitar, Chakrabarti, and Zeaiter 2018; Eberhardt and Presbitero 2015; Arčabić et al. 2018; Ndoricimpa 2017; 2020; Liu and Lyu 2021; Law et al. 2021). In our study, we follow the strategy of Chen et al. (2017) who apply optimization techniques to derive reduced form econometric regressions from an endogenous growth model which theoretically sets the foundation for the nonlinear debt-growth dynamics. We use the reduced form regressions to dictate the growth covariates included in our econometric specification when estimating optimal debt thresholds for the South African economy.

Thirdly, many previous studies rely on rather inflexible econometric models such as 'quadratic' or 'kink' regression models (Liu and Lyu 2021), the panel threshold autoregressive (PTAR) framework (Cordella, Ricci, and Ruiz-Arranz 2005; Caner, Grennes, and Koehler-Geib 2010; Ndoricimpa 2017; Arčabić et al. 2018; Law et al. 2021) and the panel

smooth transition regression (PSTR) model (Ndoricimpa 2020). For instance, Law et al. (2021) criticize the quadratic term modelling strategy which, as argued by the authors, overestimates the optimal debt threshold level. Moreover, the PTAR and PSTR nonlinear econometric models ignore important long-run and short-run cointegration relations depicted by dynamic growth theory and these econometric models are considered inflexible since they are exclusively compatible with stationary time series.

To the best of our knowledge, only the studies of Eberhardt and Presbitero (2015) and Mensah et al. (2019) have used the more flexible nonlinear autoregressive distributive lag (NARDL) model to investigate long-run and short-run asymmetric cointegration effects between debt and growth for panels inclusive of South African data. Eberhardt and Presbitero (2015) and Mensah et al. (2019) use predetermined thresholds of 60–90 percent and 50–80 percent, respectively, to model threshold debt-growth effects within the nonlinear cointegration framework. Consequentially, these studies are only able to confirm a range over which the optimal debt threshold can lie but fail to 'pinpoint' the exact optimal debt threshold level, which is a shortcoming our study empirically addresses.

In our study, we make use of the threshold nonlinear autoregressive distributive lag (T-NARDL) model of Greenwood-Nimmo, Shin, and van Treeck (2011) to estimate the optimal debt threshold for the South African economy within a nonlinear cointegration framework. Note that whilst the NARDL framework of Shin, Yu, and Greenwood-Nimmo (2014), by default, assumes a 'zero' threshold value, the T-NARDL model of Greenwood-Nimmo, Shin, and van Treeck (2011) extends this framework by using the grid search methods and threshold testing procedures described by Hansen (2000) to obtain and validate optimal 'non-zero' threshold points. Despite the empirical appeal of the T-NARDL in endogenously determining optimal threshold points within a NARDL cointegration framework, its empirical application has been very limited and to the best of our knowledge, only the pioneering paper of Greenwood-Nimmo, Shin, and van Treeck (2011) has previously applied the T-NARDL model in the context of modelling 'non-zero' threshold points in the Canadian Phillips curve.

Theoretical Model

In this section of the paper we present the three-sector (i.e. government, households and production) endogenous growth model of Chen et al. (2017) which we adopt as our theoretical framework. Within the model,

government size comprises both public consumption and public investment, which play substantially different roles in affecting steady-state growth. On one hand, public debt, alongside tax, is used to finance public investment which enters directly into the production function together with labour and private capital investment. On the other hand, public consumption enters directly into the consumption demand function alongside private or household consumption, which, in turn, is optimized by the household sector.

Within the model, public investment and public consumption can stimulate economic growth by being complementary (i.e. crowding-in effects) to private investment and private consumption, respectively, or can be harmful towards growth through crowding-out effects of investment and consumption (i.e. substitution effects). This induces nonlinear dynamics within the model in which public investment/consumption positively affects growth until an optimal level is reached, of which beyond this level, adverse effects begin to emerge. Similarly, public debt used in financing public investment will only be growth enhancing until a certain optimal debt threshold level. The model allows us to use optimization techniques to determine unique optimal levels of public debt and investment in the model which are then estimated using suitable econometric models.

GOVERNMENT SECTOR

The model assumes that government's total expenditure (G_t) is composed of government consumption ($G_{c,t}$) and government investment ($G_{k,t}$), i.e.

$$G_t = G_{c,t} + G_{k,t}, \tag{1}$$

where government investment is financed by net tax receipts (i.e. $\tau(Y_t - rD_t)$) and public debt ($\dot{D}_t + rD_t$), such that the government's capital accumulation function can be specified as:

$$\dot{G}_{k,t} = \phi G_t - \delta G_{k,t} = \phi[\tau(Y_t + rD_t) + \dot{D}_t - rD_t], \tag{2}$$

with τ denoting the tax rate, D denoting government debt, and r denoting the real interest rate.

Household Sector

The households within the model are assumed to face an infinite horizon economy and optimize the following intertemporal utility function:

$$U(C_t^*) = \int_0^{\infty} [\frac{(C_t^*)^{1-\sigma}}{1-\sigma}] e^{-pt} dt, \tag{3}$$

where p is a subjective discount factor, σ is the curvature parameter and C_t^* is the Keynesian effective demand function which incorporates both private and public consumption such that government directly affects the utility or welfare of households in the economy. Chen et al. (2017) propose that the demand function, C_t^*, be specified in Cobb-Douglas form to ensure that utility is increasing if public and private consumption are complementary, and that utility can decrease if private investment and public consumption are substitutes, i.e.

$$C_t^* = C_t^{\theta} G_{c,t}^{1-\theta}, \tag{4}$$

where C_t is private consumption. Further denoting W_t as household wealth, the household's budget constraint can be specified as:

$$W_{t+1} = (1+r)W_t + Y_t + rD_t - C_t - G_{c,t}. \tag{5}$$

The household's dynamic optimization problem can be solved by setting the marginal utilities of (1) and (4) equal to each other (i.e. $\text{MU}(G_t) = \text{MU}(C_t^*)$, where MU denotes the marginal utility) and by extracting the following condition from the Lagrangian solution:

$$C_t = \frac{\theta G_{c,t}}{1-\theta}. \tag{6}$$

PRODUCTIVE SECTOR

The production function is of augmented Cobb-Douglas form and specifies output (Y_t) as a function of household private capital, (K_t), labour (L_t) and government capital expenditure (i.e. $G_{c,t}$), i.e.

$$Y_t = AK_t^a L_t^{1-a-b} G_{c,t}^b, \quad 0 < a + b < 1, \tag{7}$$

where a and b are the elasticities of private and government investment, respectively.

In turn, private capital accumulation depends on private savings and capital depreciation:

$$\dot{K}_t = \phi(1-\tau)(Y_t - rD_t) - C_t - K_t. \tag{8}$$

And by incorporating equation (6) into (8), we derive the following motion equation of capital accumulation:

$$\begin{aligned} \dot{K}_t = \{&(1-\tau)(1+\tau\frac{D_t}{Y_t}) \\ &- \frac{\tau}{1-\tau}(1-\phi)[\frac{D_t}{D_t}\cdot\frac{D_t}{Y_t} - (1-\tau)\frac{D_t}{Y_t} + \tau]\}Y_t - \delta K_t. \end{aligned} \tag{9}$$

STEADY-STATE EQUILIBRIUM DYNAMICS AND OPTIMIZATION

To examine the steady-state equilibrium dynamics of the model, we take equations (2), (7) and (9) and re-specify them in per capita terms:

$$\dot{g}_{k,t} = \phi[\eta d_t - (1-\tau)rd_t + \tau]y_t - (\delta + n)g_{k,t}, \tag{10}$$

$$y_t = AK_t^a L_t^{1-a-b} G_{k,t}^b, \tag{11}$$

$$\dot{k}_{k,t} = [(1-\tau)(1-rd_t) - \frac{\theta}{1-\theta}(1-\phi)[\eta d_t - (1-\tau)rd_t + \tau]y_t - (\delta + n)k_t, \tag{12}$$

where $d_t = D_t/Y_t$ and $\eta = \dot{D}_t/D_t$. In the steady state, the growth rates of government expenditure, private capital and public capital are equal to zero (i.e. $\dot{g} = \dot{k} = \dot{g}_{k,t} = 0$) and the steady-state equilibrium per capita income, y^*, is solved as:

$$y^* = A[\phi(\eta d_t - (1-\tau)rd_t + \tau)]^{\frac{b}{1-a-b}}(\delta + n)^{\frac{b}{1-a-b}}\{(1-\tau)(1+rd_t) - \frac{\tau}{1-\tau}(1-\phi)[\eta d_t - (1-\tau)rd_t + \tau]\}^{\frac{b}{1-a-b}}. \tag{13}$$

From equation (13), the endogenous variables of interest are government investment and public debt as well as the elasticities of output with respect to private and public investment. A nonlinear relationship between output, public debt and public investment can be deduced, with the optimal level of public debt computed as the first derivative of steady state equilibrium output with respect to per capita debt, i.e.

$$\partial\frac{\dot{y}}{\partial d} = \frac{a + b(1-\phi)\tau\frac{\theta}{1-\theta} + \frac{(a+b)\tau - b(r-\eta)}{(1-\tau)r-\eta}(1-\tau)}{(a+b)\{\tau(1-\tau) + \frac{\theta}{1-\theta}(1-\phi)[(1-\tau)r - \eta]\}} = \frac{\partial^2(\frac{\dot{y}}{y})}{\partial^2 d} < 0, \tag{14}$$

whilst the optimal level of public investment is computed as the first derivative of steady state equilibrium output with respect to per capita debt, i.e.

$$\partial\frac{\dot{y}}{\partial d} = 0 = \frac{a}{a+b}[1 - \frac{1-\theta}{\theta}\frac{1}{\varpi}(1-\tau)(1+rd)] = \frac{\partial^2(\frac{\dot{y}}{y})}{\partial^2 d} < 0, \tag{15}$$

From equation (14), the optimal level of public debt is positively related with the output elasticity of public investment and total investment (private plus public capital) and with the intertemporal elasticity between

public and private spending as well as the share of public investment in total government expenditure, but negatively related to the growth rate of public debt. This implies that governments characterized by larger (smaller) shares of public capital in total public expenditure, more (less) productive capital expenditure and slower (faster) growth rates of public debt will have higher (lower) debt tolerance or debt thresholds.

Similarly, from equation (15), the optimal level of public capital is positively related with the output elasticity of the share of private investment in total investment (public and private investment) as well as with the total government expenditure size such that economies with more (less) productive shares of private capital in total investment as well as those with larger (smaller) total government spending will have higher (lower) public investment thresholds.

Econometric Modelling

To econometrically capture the nonlinear 'debt-growth' and 'public investment-growth' dynamics presented in the theoretical model, we make use of the T-NARDL model of Greenwood-Nimmo, Shin, and van Treeck (2011) which is a generalization of the NARDL model of Shin, Yu, and Greenwood-Nimmo (2014) applied to the case of unknown threshold decompositions. By taking the logarithms of the production function and incorporating debt and public investment threshold effects, we propose the following two baseline NARDL regressions which are portioned by debt and public investment, respectively:

$$\frac{\dot{y}_t}{y_t} = \alpha_0 + \alpha_1 \left(\frac{K}{Y}\right)_t + \alpha_2 \frac{Y_t}{L_t} + \alpha_3 \frac{G_{k,t}}{Y_t} + \alpha_4^{(+)} \left(\frac{D}{Y}\right)_t^+ + \alpha_4^{(-)} \left(\frac{D}{Y}\right)_t^- + \xi_{1t}, \tag{16}$$

$$\frac{\dot{y}_t}{y_t} = \beta_0 + \beta_1 \left(\frac{K}{Y}\right)_t + \beta_2 \left(\frac{Y}{L}\right)_t + \beta_3 \left(\frac{K}{Y}\right)_t + \beta_4^{(+)} \left(\frac{G_k}{Y}\right)_t^+ + \beta_4^{(-)} \left(\frac{G_k}{Y}\right)_t^- + \xi_2 t \tag{17}$$

and define the associated unrestricted error correction representation of NARDL regressions (16) and (17) as follows:

$$\Delta \left(\frac{\dot{y}}{y}\right)_t = \sum_{j=1}^{p} \rho_i \left(\frac{y}{y}\right)_{t-1} + \psi_1 \left(\frac{K}{Y}\right)_t + \psi_2 \left(\frac{Y}{L}\right)_t + \psi_3 \left(\frac{G_k}{Y}\right)_t$$

$$+\psi_{4j}^{+}\left(\frac{D}{Y}\right)_t^{+}+\psi_{4j}^{-}\left(\frac{D}{Y}\right)_t^{-}+\sum_{j=1}^{p-1}\lambda_i\Delta\left(\frac{\dot{y}}{y}\right)_{t-j}$$
$$+\sum_{j=0}^{q-1}\left(\phi_{1j}\Delta\left(\frac{K}{Y}\right)_t+\phi_{2j}\Delta\left(\frac{L}{Y}\right)_t+\phi_{3j}\left(\frac{G_k}{Y}\right)_t\right.$$
$$\left.+\phi_{4j}^{+}\Delta\left(\frac{D}{Y}\right)_t^{+}+\phi_{4j}^{-}\Delta\left(\frac{D}{Y}\right)_t^{-}\right)+\xi_t, \tag{18}$$

$$\Delta\left(\frac{\dot{y}}{y}\right)_t=\sum_{j=1}^{p}\rho_i\left(\frac{\dot{y}}{y}\right)_{t-1}+\sigma_1\left(\frac{K}{Y}\right)_t+\sigma_2\left(\frac{Y}{L}\right)_t+\sigma_3\left(\frac{D}{Y}\right)_t$$
$$+\sigma_4^{+}\left(\frac{G_k}{Y}\right)_t^{+}+\sigma_4^{-}\left(\frac{G_k}{Y}\right)_t^{-}+\sum_{j=1}^{p-1}\lambda_i\Delta\left(\frac{\dot{y}}{y}\right)_{t-j}$$
$$+\sum_{j=0}^{q-1}\left(\theta_{1j}\Delta\left(\frac{K}{Y}\right)_t+\theta_{2j}\Delta\left(\frac{Y}{L}\right)_t+\theta_{3j}\Delta\left(\frac{D}{Y}\right)_t\right.$$
$$\left.+\theta_{4j}^{+}\Delta\left(\frac{G_k}{Y}\right)_t^{+}+\theta_{4j}^{-}\Delta\left(\frac{G_k}{Y}\right)_t^{-}\right)+\xi_t, \tag{19}$$

where defining

$$\xi_{1t}=\frac{\dot{y}_t}{y_t}-\alpha_1\left(\frac{K}{Y}\right)_t-\alpha_2\left(\frac{Y}{L}\right)_t-\alpha_3\left(\frac{G_k}{Y}\right)_t-\alpha_4^{(+)}\left(\frac{D}{Y}\right)_t^{+}$$
$$-\alpha_4^{(-)}\left(\frac{D}{Y}\right)_t^{-}\text{ and}$$
$$\xi_{2t}=\frac{\dot{y}_t}{y_t}-\beta_0-\beta_1\left(\frac{K}{Y}\right)_t-\beta_2\left(\frac{Y}{L}\right)_t-\beta_3\left(\frac{D}{Y}\right)_t-\beta_4^{(+)}\left(\frac{G_k}{Y}\right)_t^{+}$$
$$-\beta_4^{(-)}\left(\frac{G_k}{Y}\right)_t^{-}$$

the asymmetric error correction term in equations (18) and (19) can be computed as ξ_{1t-1} and ξ_{2t-1}, respectively, and the asymmetric long-run parameters are computed as $\alpha_1=-(\psi_1/\rho)$, $\alpha_2=-(\psi_2/\rho)$, $\alpha_3=-(\psi_3/\rho)$, $\alpha_4^{+}=-(\psi_4^{+}/\rho)$, $\alpha_4^{-}=-(\psi_4^{-}/\rho)$ and $\beta_1=-(\sigma_1/\rho)$, $\beta_2=-(\sigma_2/\rho)$, $\beta_3=-(\sigma_3/\rho)$, $\beta_4^{+}=-(\sigma_4^{+}/qrho)$, $\beta_4^{-}=-(\beta_4^{-}/\rho)$ for equations (18) and (19), respectively. To estimate the debt and public investment thresholds, we follow Greenwood-Nimmo, Shin, and van Treeck (2011) and decompose

the 'debt' and 'public investment variables' into partial sum processes employing a non-zero threshold, γ, which we respectively define as:

$$\left(\frac{D}{Y}\right)^{+} = \sum_{j=1}^{i} \frac{D}{Y} I_{\cdot(D/Y<\gamma)} = \max\left(\frac{D}{Y}, \gamma\right),$$
$$\left(\frac{D}{Y}\right)^{-} = \sum_{j=1}^{i} \frac{D}{Y} I_{\cdot(\frac{D}{Y}>\gamma)} = \min\left(\frac{D}{Y}, \gamma\right), \tag{20}$$

$$\left(\frac{G_k}{Y}\right)^{+} = \sum_{j=1}^{i} \frac{G_k}{Y} I_{\cdot(G_k/Y<\gamma)} = \max\left(\frac{G_k}{Y}, \gamma\right),$$
$$\left(\frac{G_k}{Y}\right)^{-} = \sum_{j=1}^{i} \frac{G_k}{Y} I_{\cdot(G_k/Y>\gamma)} = \min\left(\frac{G_k}{Y}, \gamma\right), \tag{21}$$

where γ is an unknown threshold parameter responsible for regime-switching behaviour, which can be consistently estimated using the following minimization criterion, i.e.

$$\hat{\gamma} = \text{argmin}_{\gamma \in \text{D}} Q(\gamma). \tag{22}$$

Once the optimal threshold level, $(\hat{\gamma})$, is obtained, the significance of the threshold estimate is verified by using the following likelihood ratio (LR) tests, i.e.

$$\text{LR} = \frac{\text{SSR}_0 - \text{SSR}_1(\hat{\gamma})}{\hat{\sigma}^2}, \tag{23}$$

where SSR_0 and $\text{SSR}_1(\hat{\gamma})$ are the residuals from the linear ARDL model and the T-NARDL model, respectively, and $\hat{\sigma}^2$ is the regression error variance. Note that the LR test is non-standard since the threshold parameter is unidentified under the null hypothesis of linearity. We therefore make use of the bootstrap method described by Hansen (2000) to simulate the asymptotic distribution of the LR statistic and construct p-values from the bootstrap that are asymptotically valid.

Besides the tests for LR threshold effects, there are three additional 'nonlinear cointegration' tests, suggested by Shin, Yu, and Greenwood-Nimmo (2014), to which we subject our T-NARDL model regressions. First, there is the F-test for adjustment asymmetry which evaluates the null hypothesis of $\rho = \psi = \psi_1 = \psi_2 = \psi_3 = \psi_4^+ = \psi_4^+ = 0$ (eq. 20) and $\rho = \sigma_1 = \sigma_2 = \sigma_3 = \sigma_4^+ = \sigma_4^+ = 0^-$ (eq. 21) against the alternative of $\rho \neq \psi_1 \neq \psi_2 \neq \psi_3 \neq \psi_4^+ \neq \psi_4^+ \neq 0$ (eq. 20) and

$\rho \neq \sigma_1 \neq \sigma_2 \neq \sigma_3 \neq \sigma_4^+ \neq \sigma_4^+ \neq 0$ (eq. 21). These hypotheses are evaluated using a test statistic denoted as F_{PSS}. Second, there are tests for long-run or reaction asymmetry which test the null of no long-asymmetry effects ($\alpha_4^+ = \alpha_4^-$ for eq. (18) and $\beta_4^+ = \beta_4^-$ in eq. (19)) against the alternative of significant long-run asymmetries ($\alpha_4^+ \neq \alpha_4^-$ for eq. (18) and $\beta_4^+ \neq \beta_4^-$ in eq. (19)) and the test statistic evaluating the null hypotheses is denoted as W_{LR}. Thirdly, there are tests for short-run asymmetries which test the null of no long-asymmetry effects ($\sum_{i=0}^{q-1} \phi_j^+ = \sum_{i=0}^{q-1} \phi_j^-$ for eq. (18) and $\sum_{i=0}^{q-1} \theta_j^+ = \theta_{i=0}^{q-1} \theta_j^-$ for eq. (19)) against the alternative of significant long-run asymmetries ($\sum_{i=0}^{q-1} \phi_j^+ \neq \sum_{i=0}^{q-1} \phi_j^-$ for eq. (18) and $\sum_{i=0}^{q-1} \theta_j^+ \neq \sum_{i=0}^{q-1} \theta_j^-$ for eq. (19)) and the test statistic evaluating the null hypotheses is denoted as W_{SR}.

Data, empirical analysis and diagnostics

DATA

The data used in this study has been solely sourced from the SARB online statistical database on a quarterly frequency over the period 1960:q2 to 2020:q2 and the span of our data is determined by the collective availability of the time series. We source 6 series from the database, namely, economic growth rate (KBP6006Z), gross fixed capital accumulation as a percentage of GDP (KBP6282L), labour productivity of non-agriculture (KBP7014L), total net public debt as a percentage of GDP (KBP4117), total public investment (KBP6006Z), and real GDP at constant prices (KBP6006Z). We use the last two times series to compute a measure of public investment as a percentage of GDP, i.e. public investment divided by GDP.

The summary statistics and the unit root tests are reported in tables 3 and 4, respectively. From table 3 we observe some stylized facts for South Africa such as the combination of low growth – low debt averages observed over the sample period. Moreover, judging from the statistics, growth and labour productivity have had relatively high volatility (compared to their averages) whilst debt and the remaining variables exhibit less volatility. Lastly, note that *p*-values Jarque-Bera (J-B) statistics obtained for all series indicate that the variables are non-normal, implying that their distributions of the individual series are nonlinear and hence justifying the use of nonlinear econometric methods to establish any debt-growth relationships. From table 4, we use the conventional ADF test and its more powerful alternative, the DF-GLS test, to establish the

TABLE 3 Summary Statistics of Time Series

Variable	Description	Mean	Sd	Min	Max	J-B*
$\partial Y/Y$	GDP growth rate	2.2627	5.5584	-51.7000	21.7000	0.0000
K/Y	Gross fixed capital formation as a % of GDP	21.4146	4.1998	15.0000	32.1000	0.0830
Y/L	Labour productivity	79.1508	21.9887	39.800	105.600	0.0463
D/Y	Total net debt of national government as a % of GDP	36.0203	8.2729	21.600	63.500	0.0120
GK/Y	Government investment capital as a % of GDP	3.9686	1.7111	2.0377	8.5865	0.0000

NOTES * p-value.

TABLE 4 Unit Root Test Results (First Differences)

Variable	ADF		DF-GLS	
	Int	Int + trend	Int	Int + trend
$\partial Y/Y$	−15.0540(2)***	−15.0632(2)***	−14.8039(1)***	−5.3624 (1)***
K/Y	−16.7403(1)***	−16.7338(1)***	−16.7379(1)***	−6.7658(2)***
Y/L	−19.1220(2)***	−19.1187(2)***	−7.6505(1)***	−9.6126(1)***
D/Y	−4.5314(4)***	−5.0365(4)***	−3.4180(3)***	−3.2035(4)***
GK/Y	−20.4762(1)***	−20.4326(1)***	−3.6724(4)***	−9.6656(1)***

integration properties of the series. Note that we only present the unit root tests on the first differences of the series since the T-NARDL model is compatible with a mixture of I(0) and I(1) variables. The unit root tests confirm that none of the series are integrated of order I(2) which allows us to proceed with our empirical analysis. Our entire empirical analysis has been conducted in EViews 10.

GRID SEARCH FOR DEBT AND PUBLIC INVESTMENT THRESHOLDS

Following the modelling process prescribed by Greenwood-Nimmo, Shin, and van Treeck (2011), we begin our analysis by performing the grid search for the threshold level of debt and the associated threshold level of public investment. To recall, this involves estimating NARDL regressions for all possible values of the threshold and reporting the SSR obtained from each estimated regression. For the debt threshold regression, we estimate regressions over threshold values of 25% and 60%, whilst for the associated public investment threshold, the grid search is per-

formed/conducted over values of 2% and 8%. Note that increments of 1 percent and 0.1 percent are used in the grid search for optimal debt and public investment levels, respectively.

Figures 1 and 2 present scatterplots based on the findings from our grid search for the optimal threshold levels of debt and public investment, respectively. Note that in both plots, the *x*-axis presents the selected threshold point and the *y*-axis presents the corresponding RSS of the NARDL estimated at each threshold point. Further note that the optimal lag length for each estimated NARDL regression used in the grid search is obtained via a minimization of the modified SC information criterion. For public debt threshold we plot the RSS for 27 estimated regressions (figure 1) whilst for public investment thresholds we plot the RSS for 58 estimated regressions (figure 2) and it is clear to see that the RSS is minimized at a threshold level of 47% for public debt and 2.8% for public investment, respectively.

From figure 1, we observe that our estimated debt threshold of 47% differs from most of the threshold estimates obtained in previous South African-related literature. Eberhardt and Presbitero (2015) find the optimal debt threshold to lie between 60% and 90% for 118 countries inclusive of South Africa using the threshold autoregressive distributive lag (TARDL) model. Using similar methodology applied to 38 African countries, Mensah et al. (2019) find the optimal debt threshold to lie at a lower range of 50% and 80%. Égert (2015) estimates a Panel Threshold Autoregressive (PTAR) model and finds a much lower threshold of 30% for a panel of 21 emerging economies inclusive of South Africa whilst Ndoricimpa (2017; 2020) finds two different thresholds of 92.78% and 74.3% for a sample of 29 African countries using Panel Threshold Autoregressive (PTAR) and Panel Smooth Transition Regression (PSTR) models, respectively. Law et al. (2021), more recently, estimate a debt threshold of 51% for a sample of 71 developing economies using the PTAR model.

Altogether, our estimated debt threshold of 47% is within the lower boundary of the range suggested by Mensah et al. (2019) and is comparable to the 51% threshold more recently estimated by Law et al. (2021), and yet differs significantly from the 30%, 93% and 74% estimated thresholds found in the studies of Eberhardt and Presbitero (2015) and Ndoricimpa (2017; 2020), respectively. As dictated by our endogenous growth model introduced in the third section of the paper, the optimal level of public debt is positively dependent on the output elasticity of public (and private) capital as well as on the elasticity of substitution between public

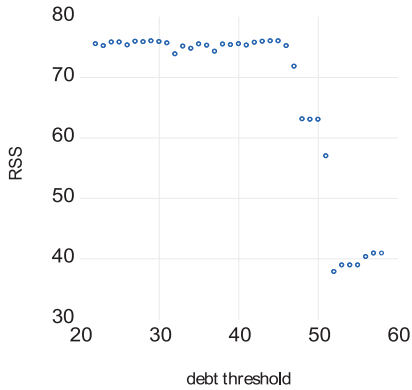

FIGURE 1 Grid Search for Optimal Public Debt Threshold

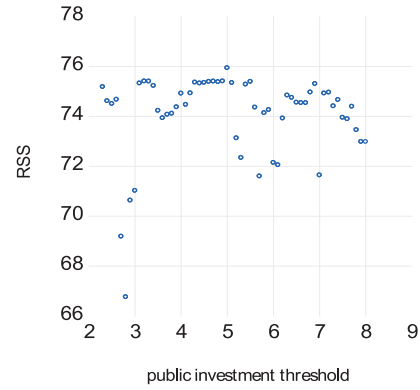

FIGURE 2 Grid Search for Optimal Public Investment Threshold

and private spending, and yet negatively dependent on the growth rate of public debt. The lower threshold estimate obtained for South Africa is thus expected since, as shown in the introduction, the growth rate of public debt over the last decade has been higher compared to other emerging and developed economies. Moreover, higher crowding effects of public capital on private capital, as documented by Biza, Kapingura, and Tsegaye (2015) and Makuyana and Odhiambo (2018) for South Africa, would reduce the elasticity, and hence productivity, of public and social (private plus public) capital, resulting in a lower tolerance or threshold debt level compared to those estimated in previous panel-based studies.

Similarly, in figure 2, we observe that the estimated public investment-to-GDP threshold of 3% is much lower than the threshold obtained in previous studies. For instance, Abounoori and Nademi (2010) estimate a public investment threshold of 8% for Iran using a TAR model. On the other hand, Fosu, Getachew, and Ziesemer (2016) estimate an optimal public capital threshold of 10% for 33 African countries inclusive of South Africa whilst Chen et al. (2017) make use of the PSTR model to estimate a public investment threshold of 16% for 65 economies inclusive of South Africa. As dictated by our endogenous growth model, the optimal level of public debt is dependent on the response of private capital to social capital as well as the ease of substitution between government and private capital. Our obtained lower public debt threshold implies that the South African economy is characterized by low responsiveness of private capital to total capital and low levels of substitutability between input factors in the public and private sector.

TABLE 5 T-NARDL Estimates at Optimal Public Debt of 47%

Panel A: Long run estimates			Panel B: Short-run and ECM		
Coefficient	Estimate	*t*-statistic	Coefficient	Estimate	*t*-statistic
C	2.4318	3.2990***	$\Delta\partial Y/Y(-1)$	−0.1389	−1.5806
$(D/Y)^-$	0.1256	3.2990***	$\Delta\partial Y/Y(-2)$	0.0381	0.4656
$(D/Y)^+$	0.0524	1.6100	$\Delta\partial Y/Y(-3)$	0.1456	2.3749**
K/Y	2.0312	0.3349***	$\Delta(D/Y)^-$	−0.4384	−2.1087*
Y/L	0.1051	1.6198	$\Delta(D/Y)^+$	−0.4434	−2.1567
G_K/Y	−0.8447	−3.2929***	$\Delta K/Y$	0.1356	0.8781
C	2.4318	3.2990***	$\Delta K/Y(-1)$	−0.7282	−3.2239***
			$\Delta K/Y(-2)$	−0.3450	−2.2318**
			$\Delta Y/L$	0.0098	0.3205
			$\Delta Y/L(-1)$	−0.0665	−2.2241**
			$\Delta G_K/Y$	−0.0819	−1.0550
			$\Delta G_K/Y(-1)$	0.2368	2.7416***
			$Ect(-1)$	−0.9784	−10.0053***

NOTES ***, **, * denote the 1%, 5%, 10% critical levels, respectively. A Newey-West estimator is used to obtain HAC standard errors.

T-NARDL ESTIMATES

Having obtained our optimal debt and public investment thresholds, in this section of the paper we present the associated TARDL regression coefficient estimates. Tables 5 and 6 present the TARDL model estimates for the optimal debt and public investment thresholds, respectively, with panel A presenting the long-run regression estimates whilst panel B presents the short-run and error correction model estimates.

From table 5, the long-run partitioned coefficients of the debt variable dictate the form of nonlinearity in the debt-growth relationship. Note that the (D/Y)pos variable which accounts for the debt dynamics in the upper regime of the regression model, produces an insignificant estimate whilst the (D/Y)neg which captures the debt dynamics in the lower regime of the model produces a positive and 1 percent statistically significant estimate of 0.126. By interpretation, the results imply that when the debt-to-GDP ratio exceeds 51 percent, debt exerts no effect on economic growth, whereas when debt is below its threshold level, a unit decrease in debt is associated with a 0.126 percent improvement in growth.

We observe that the nonlinear debt-growth dynamics described by our

TABLE 6 T-NARDL Estimates at Optimal Public Investment of 2.8%

Panel A: Long run estimates			Panel B: Short-run and ECM		
Coefficient	Estimate	*t*-statistic	Coefficient	Estimate	*t*-statistic
C	1.3199	0.86878	$\Delta\partial Y/Y(-1)$	−0.1145	−1.012
$(G_K/Y)^-$	0.4466	2.2569**	$\Delta\partial Y/Y(-2)$	0.0296	0.3158
$(G_K/Y)^+$	0.2082	1.3646	$\Delta\partial Y/Y(-3)$	0.1253	1.9774*
K/Y	2.1101	6.7256***	$\Delta(G_K/Y)^-$	−5.0949	−5.7239***
Y/L	−0.0306	−0.7827	$\Delta(G_K/Y)^-(-1)$	−2.4896	−2.6363***
D/Y	4.6658	1.4226	$\Delta(G_K/Y)^+$	−4.8715	−5.8831***
			$\Delta(G_K/Y)^+(-1)$	−1.9834	−2.2389**
			$\Delta K/Y$	0.2432	1.5498
			$\Delta K/Y(-1)$	−0.6170	−25574**
			$\Delta K/Y(-2)$	−0.2987	−1.7914
			$\Delta D/Y$	−26.4400	−1.2460
			$\Delta D/Y(-1)$	−33.5100	−1.5634
			$Ect(-1)$	−1.0022	−7.9281***

NOTES ***, **, * denote the 1%, 5%, 10% critical levels, respectively. A Newey-West estimator is used to obtain HAC standard errors.

results presented in table 5 differ from those predicted in previous South African-related literature. On one hand, Ndoricimpa (2017; 2020) and Law et al. (2021) find debt to be insignificantly related with growth below their estimated debt threshold and negatively (significantly) related with growth above the threshold. On the other hand, Chen et al. (2017) find debt to harm growth below a 59% threshold whilst above this threshold debt significantly harms growth. Moreover, Eberhardt and Presbitero (2015), Chudik et al. (2017) and Mensah et al. (2019) find that a negative and significant relationship emerges only within a threshold range of 60–90%, 50–80% and 30–60%, respectively.

In linking the empirical debt dynamics reported in table 6 to the endogenous growth model dynamics introduced in the third section of the paper, we find that below the public debt threshold of 51%, public investment financed by debt is complementary to private investment and therefore growth enhancing, which is a finding consistent with the Keynesian view of large deficits being expansionary for the economy through effective public investment expenditure. However, once the threshold is crossed, public investment financed by increased debt begins to crowd

out private investment and hence higher levels of debt become insignificant towards economic growth; this is reminiscent of the Ricardian-equivalence hypothesis described in Barro (1989).

We now turn our attention to the T-ARDL estimates for the public-investment threshold regression reported in table 6 and observe similar nonlinear dynamics for the public investment-growth relationship. Note that the $(G_K/Y)^-$ coefficient estimate of 0.44 is statistically significant at a 1 percent critical level whilst the $(G_K/Y)^+$ variable produces a statistically insignificant estimate and these results imply that only below the 2.7 percent threshold is public capital growth enhancing whilst above this level, public investment is insignificantly related with economic growth. We further note that these dynamics differ from those presented in related literature. For instance, Abounoori and Nademi (2010) estimate a threshold of 8% for Iran and find that public capital is insignificant below and above the threshold level. For a sample of 33 African countries, Fosu, Getachew, and Ziesemer (2016) find that the positive effect of public investment outweighs the negative taxation effect (i.e. from taxes used to finance public investment) below the threshold of 9–10% whilst the adverse tax burden outweighs the private capital effects above the threshold. Similarly, Chen et al. (2017) find that below the public investment threshold of 16%, public capital is positively related to growth through its crowding-in effects on private investment whereas above the optimal level, public capital is negatively related with growth through crowding out effects of private investment. Our results differ from this previous literature in that we do not find a negative relationship between public capital and growth in either of the regimes of the T-NARDL model and hence the relationship is not 'inverted U-shaped' as hypothesized by the nonlinear 'BARS' curve between government size and growth.

Overall, the flexibility of the reduced form regression derived from the endogenous growth model allows for heterogeneity in estimating debt and public investment thresholds for different economies and in our case, the estimate thresholds of 51% and 3%, respectively obtained for South Africa, are much lower compared to the threshold estimates obtained in previous panel-based studies. Moreover, the nonlinear dynamics observed between (i) public debt and growth, and (ii) public investment and growth, differ from those of previous studies and yet remain in sync and complement each other. In this sense, we find significant and positive debt-growth and public capital-growth relationships below their estimate thresholds and yet, above these estimated thresholds, both relationships

TABLE 7 Optimal Public Investment

Panel A: Nonlinear coint. tests			Panel B: Residual diag. tests		
Coefficient	(1)	(2)	Coefficient	(1)	(2)
Threshold (LR test)	16.6023**	17.0549**	J-B	0.4512 (0.7981)	0.5287 (0.7677)
Ftest	13.9160***	8.7377***	SC	0.0484 (0.9528)	0.1639 (0.8493)
WLR	9.9736***	6.6977	ARCH	1.4694 (0.2304)	1.0669 (0.4050)
WSR	2.6474	2.3564	RESET	1.3614 (0.2261)	0.0457 (0.8315)

NOTES Column headings are as follows: (1) T-NARDL (debt threshold regression), (2) T-NARDL (public investment threshold regression). ***, **, * denote the 1%, 5%, 10% critical levels respectively.

simultaneously turn insignificant. Moreover, the sign and significance of the coefficients of the covariates do not differ, with physical capital being positively related with growth whilst human capital is insignificantly related with growth in both estimated regressions.

DIAGNOSTICS

So far, the empirical analysis has focused on identifying the threshold values of public debt and public investment and presented the corresponding T-NARDL model estimates for both models, but we have yet to test the validity of the estimated threshold points and associated threshold model regressions. Table 7 reports the tests statistics for nonlinear cointegration (panel A) as well as for the diagnostic tests performed on the residuals of the estimated T-NARDL regressions (panel B).

In panel A of table 7, we report the findings from our LR test for threshold effects, the bounds test statistic for nonlinear cointegration (FSYG), and the Wald statistic for long-run (WLR) and short-run (WSR) asymmetries, and based on the reported statistics for both T-NARDL models, we find evidence supporting significant threshold effects, significant nonlinear bounds cointegration effects and significant long-run asymmetries. Note that both models produce insignificant short-run asymmetric effects, implying that the nonlinearity between debt-growth and public investment-growth is strictly a long-run phenomenon.

In panel B of table 7, we present the residual diagnostic test for normality, autocorrelation and heteroscedasticity, and the reported Jarque-Bera

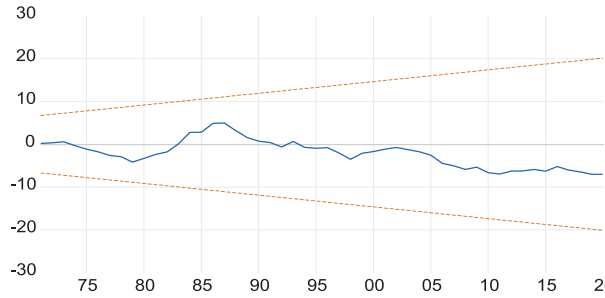

FIGURE 3
CUSUM – Debt Threshold (blue – CUSUM, orange – 5% significance)

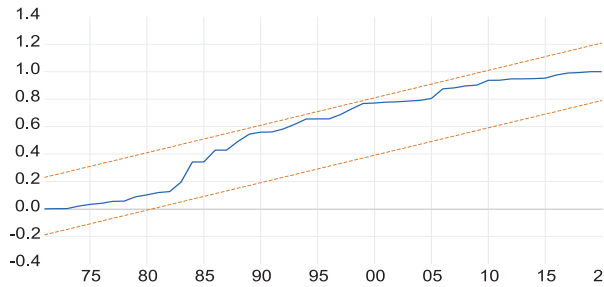

FIGURE 4
CUSUMSQ – Debt Threshold (blue – CUSUMSQ, orange – 5% significance)

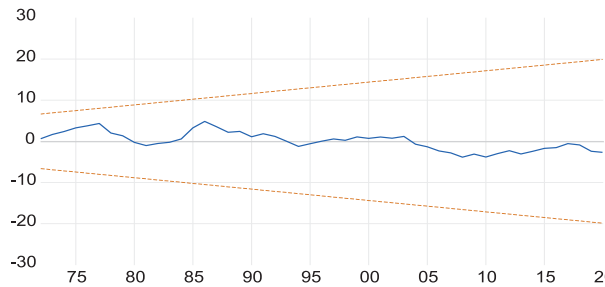

FIGURE 5
CUSUM – Public Investment Threshold (blue – CUSUM, orange – 5% significance)

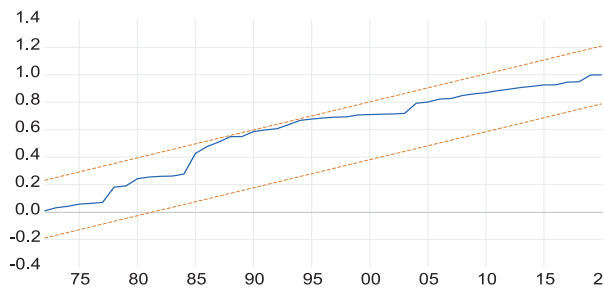

FIGURE 6
CUSUMSQ – Public Investment Threshold (blue – CUSUMSQ, orange – 5% significance)

(J-B), Breusch-Godfrey (χSC) and ARCH statistics (χARCH) evidence of well-behaved (with properties), homoscedastic regression errors in both estimated T-NARDL models. Moreover, we also report the tests statistics for correct functional form, and the reported RAMSEY test statistics (RE-

SET) provide evidence in favour of our T-NARDL regressions being the correct functional form and not requiring a higher-order functional form to fit the data. Lastly, we plot the CUSUM and CUSUMSQ plots for both regressions in figures 3–6, respectively, and both plots provide evidence of stable regressions at a 5 percent critical level.

Conclusions

The coronavirus pandemic has placed tremendous strain on the South African fiscal budget and debt-to-GDP levels are expected to reach historically high levels of 88% by 2022. Even though these levels are not as high as those experienced in other developed economies such as the US and Japan, there is much concern since South African fiscal authorities have acquired debt at a faster rate compared to other emerging and industrialized economies, particularly in the post 2007/08 financial crisis era. Recent empirical literature has speculated that the relationship between debt and growth is nonlinear such that debt acquired by fiscal governments is only harmful once it has crossed some optimal or tolerance level, when it starts to crowd out public investment. Moreover, new growth theory speculates that such tolerance levels of debt and public investment can depend on fiscal factors such as rate of acquired debt which would suggest that governments who acquire debt at faster (slower) rates have lower (higher) tolerance levels and there does not exist a universal debt or public investment threshold for different economies with different fiscal positions.

In our study, we provide country-specific debt and public investment threshold estimates for the South African economy based on reduced form econometric regressions derived from an endogenous growth model of public debt, public capital and economic growth. We make use of the TARDL model applied to quarterly time series collected between 1960:Q2 and 2021:Q2 to estimate the optimal threshold points as well as to capture the asymmetric debt-growth and private capital-growth relationships dictated by the theoretical model.

Our empirical analysis points to threshold estimates of 47% for the debt-to-GDP ratio and 2.8% for the public investment-to-GDP ratio, and only below these thresholds are public debt and private capital growth enhancing. On one hand, the debt-to-GDP ratio crossed has been predominantly below its threshold during the entire sample period of 1960 to 2021, and only began to cross the threshold level of 47% in 2017 (see figure 7).

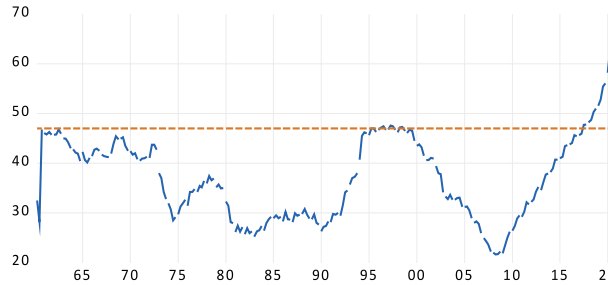

FIGURE 7

Performance of Public Debt Compared to Threshold Level (blue – net debt as 5% of GDP, orange – threshold level)

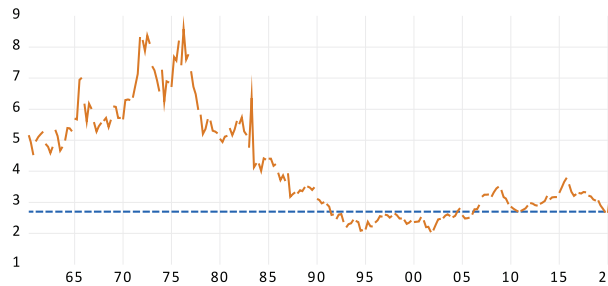

FIGURE 8

Performance of Public Investment Compared to Threshold Level (orange – government investment as 5% of GDP, blue – threshold level)

On the other hand, the public investment-to-GDP ratio has been predominantly above its 2.8% threshold from the 1960's to the early 1990's, and from the early 1990's to the mid-2000's public capital has been below its threshold. However, subsequent to the global financial crisis, public capital lies above its threshold level and since 2017 has maintained an upward trajectory (see figure 8).

To conclude our study, we provide key policy insights and recommendations derived from our empirical analysis. Firstly, our study finds that South Africa's debt woes began a few years prior to the start of the COVID-19 pandemic and previous related literature has over-estimated the country's tolerance level of debt. Secondly, our study recommends that fiscal authorities need to implement more rigorous policy measures than those which are currently proposed. For instance, the active approach to debt management and fiscal consolidation proposed by the national treasury in the 2020 Medium Term Budget Policy Statement (MTBPS) would need to include lower debt targets than those which are currently proposed. The aim of these policies should be to decrease the growth rate of debt levels to negative values, which in turn, would increase 'tolerance' levels of debt. Lastly, the government needs to find ways of balancing/stabilizing the public deficit by simultaneously reducing both the debt-to-GDP ratio and public investment-to-GDP ratio below their estimate thresholds

of 47% and 2.8%, respectively. One of the current propositions from the government is to decrease the size of government expenditure by freezing the public wage bill. Based on our findings, the government needs to go beyond freezing the public wage bill and should further reduce the share of public capital in government expenditure and place more emphasis on private capital and non-investment government expenditure items. This could be achieved by spending less money on 'non-performing' State Owned Enterprises and increasing privatization in key economic sectors such as energy and transportation.

One main shortcoming with our study is that we use an aggregated measure of government debt. In practice, public debt is often classified into external debt and internal debt, and there may be different thresholds or tolerance levels associated with different disaggregated classifications of debt. Consequently, we suggest two directions for future studies. Firstly, growth theorists could consider developing dynamic growth models which can distinguish between external and internal public debt as well as their steady-state dynamics used to determine their optimal points. Secondly, researchers could consider expanding the two-regime framework to incorporate multiple regime dynamics. These models can be estimated using more advanced econometric techniques such as the multiple threshold nonlinear autoregressive distributive lag model.

Data Availability Statement

All data used in the study is from the SARB online database. Since this data is only accessible to South African residents, we have not obtained permission from the SARB to share their data. We therefore provide the source codes of the time series in our data description.

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Designing a Conceptual Framework for Industry 4.0 Technologies to Enable Circular Economy Ecosystem

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The paper is aimed at developing an ecosystem that can be used within the domain of the circular economy on the foundation of Industry 4.0 technologies. The study emphasizes the importance of Industry 4.0 as a crucial element in the development of the circular economic ecosystem. The circular economic ecosystem is comprised of a business model, business strategies, and resources and capabilities supported by a circular economy framework. This study adopted literature review analysis and case studies as mythology to analyse and synthesize the latest trends and aspects developing within the framework of the circular economy. The major findings of this paper present a theoretical conceptual framework of a circular economic ecosystem that can be adopted at organizational level. The study also supplies a way forward for future studies in this research domain as there are several factors which are found but need to be explored.

Key Words: circular economy, industry 4.0, smart manufacturing, circular economy ecosystem
JEL Classification: L60, L69, M11, O14
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Introduction

The swift strides in the development of world's economy have empowered organizations to produce more efficiently and in large quantity. This has allowed organizations to reduce the costs that led to the development of competition in the consumer market. Consumer markets have been the foundation of the global economy since the industrial revolution. This has brought economic, environmental, and social challenges for the present and future generations. To meet the consumer demand, companies aim to shorten product lifecycles. However, it is an essential

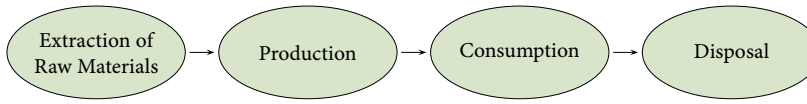

FIGURE 1 Linear Consumption Model (adapted from Bradley et al. (2018) and Kambanou and Sakao (2020))

consequence of this that the lifespan of products is constantly decreasing, thus encouraging re-purchase. This has led to the development of the so-called linear consumption model (Bradley et al. 2018; Kambanou and Sakao 2020).

This linear consumption model generates huge losses in both production and consumption (see figure 1).

The concept of a circular economy is wide and several aspects have been explored thus far. These include ecology, zero waste, clean production and closed loop. In the literature, several definitions of 'circular economy' can be found. However, this paper is specifically focused on circular economy, digital technologies integration and a circular business model. The phrase 'circular economy' first surfaced in the literature in the nineties and the initial concept was based on the idea of transition from linearity to circularity of economy. According to Momete (2020), literature is flooded with 'circular economy' after 2016, with an overlap of several discussion points among the concepts of circular economy, green economy, and sustainable production. The concept of a circular economy gained popularity after organizations started giving attention to greater sustainability. Bjørnbet et al. (2021) argue that the concept of a circular economy comes from the concept of closed-loop industrial ecology. Industrial ecology explains the industrial ecosystem which enhances consumption of materials to the optimal level and decreases waste to the minimal level. Rossi et al. (2020) also argue that the literature emphasizes that sustainability might drive organizations towards a circular economy, having innovation as an intermediary. Kazancoglu et al. (2021), Marjamaa and Mäkelä (2022), and Chauhan, Parida, and Dhir (2022) argue that the circular economy is an alternate socio-techno economic approach for a sustainable future. According to Luoma et al. (2022), the shift towards a circular economy is critical to reduce harmful environmental impacts. The aim in implementing a circular economy is to turn the linear consumption model *take-make-use-discard* into loops to extend product service lifecycle via reusing and recycling.

Guzzo, Rodrigues, and Mascarenhas (2021) have defined a circular

economy as 'a set of advanced production and consumption systems that lead humanity towards sustainable development. It relies on the systematic implementation of strategies to reduce resource usage while enhancing value creation.' Bjørnbet et al. (2021) also define a circular economy as 'an industrial economy which is restorative by intention and design.' Hermann et al. (2022) have defined a circular economy as 'one that is regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption.'

The concept of circular economy needs more scientific research to form one standard definition but there is a clear linkage present between circular economy and sustainability. Hence our study develops the understanding that the concept of a circular economy eliminates the idea of 'end of life' and replaces it with 8Rs: reduce, reuse, recover, recycle, remanufacture, refurbish, repurpose and redesign. The idea of transition requires a paradigm shift from the 'make, use, and dispose' concept to the idea of refurbishing, reusing, and recycling. A transition towards a circular economy can cause multiple complications within and outside organizations. However, these issues can be resolved by developing a circular business model and assessing it through simulations to make it error free before it is implemented in the real world.

According to Parida et al. (2019), the core objective of a circular economy is to reduce industrial waste by adopting reducing, reusing, and recycling strategies. According to Halonen, Majuri, and Lanz (2019), a circular business model should not be focused on how to reduce industrial waste as there is lots of literature available about this, but it should be focused on how to create customer value by offering products and services to the customers. This study aims to address this problem by offering a circular business model 'product-as-a-service' also known as a 'product service system' (PSS). According to Mastrogiacomo et al. (2021) and Li et al. (2022), PSS is defined as a combination of product and services to meet consumer needs through value. Li et al. (2021) argue that PSS backed by Industry 4.0 technologies is also called Smart PSS. The Industry 4.0 technologies provide a higher level of trackability of products and materials in the circulation and they also provide sufficient information about the product lifecycle. According to Bu et al. (2021), a smart PSS integrates products and services into a single-bundle solution. Prod-

ucts are networked through sensors to collect and transmit data to enable the manufacturer to provide value added services to the consumers. A smart PSS provides consumer satisfaction via product design modifications and extended product lifecycles. It helps to ensure the sustainable product lifecycle management.

This paper is divided into five sections. The second section is 'Literature Review;' here, the concept of a circular economic ecosystem is thoroughly discussed. The concepts of a circular business model, circular strategies, resources, and capabilities are also discussed in detail within the domain of a circular economic ecosystem. The third section is 'Circular Supply Chain of Business Model "Product-as-a-Service,"' where a circular supply chain is formulated which explains how this ecosystem will perform. A supply chain system is essential for the circular economic ecosystem. The fourth section is 'Theoretical Findings and Discussion;' here, a theoretical conceptual framework of a circular economic ecosystem is formulated which is based on our analysis of the literature review, and a discussion is undertaken about the findings. The last section is the 'Conclusion:' the study concludes with the idea that this paper provides a foundation for future studies in the field of circular economy and especially in the domain of the circular economic ecosystem.

Literature Review

Research articles have been selected from a wide research area to cover all the possible aspects of this paper. Sources such as Web of Science, Google Scholar, ScienceDirect and Scopus are used to gather research articles for this purpose. The research field of the circular economy is still a novel topic in the academic literature and yet more work must be done in this area of research. However, there is a lot of useful literature available which can be used as foundational pillars and guidelines for future studies. To the best of our knowledge, there is no conceptual framework available in the literature that can explain the circular economic ecosystem. We think it is a gap and we aim to formulate a conceptual framework to lay down a foundation for a circular economic ecosystem.

INDUSTRY 4.0 TECHNOLOGIES-ENABLED CIRCULAR ECONOMY ECOSYSTEM

Over the recent years the term 'ecosystem' has become quite popular among the academicians. Kamalaldin et al. (2021) define an ecosystem as 'the configuration system of a multilateral set of players required to

interact to materialize a focal value proposition.' An ecosystem is called a digital ecosystem when it is driven by the help of digital technologies; however, an ecosystem is called a circular economic ecosystem when it functions within the concept of a circular economy.

The role of Industry 4.0 in manufacturing organizations has been increasing drastically in the last few years. According to Sanchez, Exposito, and Aguilar (2020), there is a need for more advanced scientific studies to oversee transformation in the manufacturing industry so that it could be converted into smart manufacturing organizations. It will also help to answer core issues of digital transformation related to Industry 4.0 technologies. On the one hand, these advanced manufacturing technologies bring several challenges to an organization, such as integration among different departments, but on the other hand, these smart technologies also offer plenty of opportunities. According to Stornelli, Ozcan, and Simms (2021), these opportunities can help to improve the efficiency and productivity of a manufacturing organization. Factory floors can be transformed with the help of smart technologies like robotics and additive manufacturing to enable greater product customization and eventually to develop a digital ecosystem. Kamalaldin et al. (2021) argue that the core purpose of implementing digital technologies is to improve production efficacy and reduce costs and environmental impacts by augmenting operational and human capabilities. It can be done with the help of digital technologies like Artificial Intelligence (AI), Additive Manufacturing (AM), Internet of Things (IOT) and Big Data Analytics (BDA).

According to Parida et al. (2019), PSS is customer-centric and service-oriented in nature. For example, General Electric and Rolls-Royce sell their plane engines under performance-based service agreements to their customers. These agreements work on the 'power by the hour' principle and in this way, the manufacturer guarantees the performance of the engines in terms of reliability and availability of parts when needed. In another example, auto manufacturers in the UK sell their vehicles on lease under a mileage-per-year scheme to their customers. Customers pay reduced monthly payments if they agree to low mileage per year as per their lease agreement. It helps to increase the driving lifecycle of the vehicle and to reduce the residual value of the vehicle by reducing depreciation cost per year. Moreover, the vehicle will be protected by a full warranty by the manufacturer over the lease period.

The economy and society need further development, and sustainable value in a value chain seems to require manufacturing companies to move

from the current 3R (Reduce, Reuse, Recycle) to the 8R approach (3R+ Recover, Remanufacture, Repurpose, Refurbish and Repair), where economic, environmental, and social aspects are considered. This closed system offers a solution to the increasingly severe shortage of raw materials by providing a new perspective. The circular economy business model sees each component as the raw material for the next product generation, thus reducing the amount of waste generated during production (Bradley et al. 2018; A. Jabbour et al. 2019).

The circular economy is a system of production where the goal is to keep products, components, raw materials, and energy in a circular flow to increase, recreate and maintain value in the long run. To achieve a circular economy, companies need to overcome several barriers and value chain actors also need greater collaboration (A. Jabbour et al. 2019). The transition to a circular economy business model has an impact on both a company's business processes and decision-making. The novel approach requires a change in both product development and supply chains.

CIRCULAR ECONOMY AND INDUSTRY 4.0 LINKAGE

According to Dwivedi et al. (2022), organizations are increasingly adopting Industry 4.0 and circular economy concepts in their business practices. Ciliberto et al. (2021) argue that several studies in the literature indicate a circular economy and Industry 4.0 as the future of organization. According to Romero et al. (2021), circular economy and Industry 4.0 are two different concepts; however, in recent years they have evolved together. Dantas et al. (2021) argue that Industry 4.0 supports the circular economy in achieving responsible production and consumption. A circular economy focuses on restorative industrial production while Industry 4.0 acts as an industrial engine in this whole ecosystem. Kazancoglu et al. (2021) argue that the circular economy and Industry 4.0 are the two sides of the same coin, to elaborate the relationship between them.

The transformation towards a circular economy goes along with the digital technologies. These technologies include big data, Internet of Things and cloud computing. They can help to upscale workers' skills performing circularity-based operational decisions. They also support inflating the product lifecycle through predictive maintenance that helps to create value and reduce waste for consumers. According to Chauhan, Parida, and Dhir (2022), digital technologies are summarized as big data analytics, Internet of Things, cybersecurity, cloud computing, augmented reality, integration and collaborative robots. A study conducted

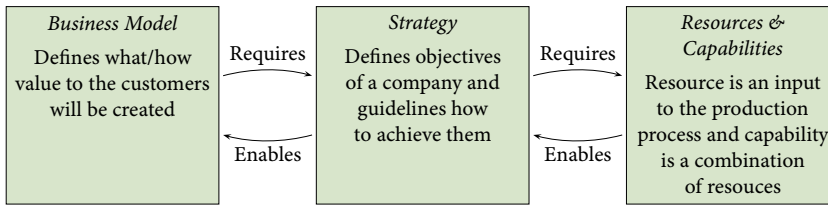

FIGURE 2 Circular Economy Framework (adapted from Halonen, Majuri, and Lanz (2019))

by Laskurain-Iturbe et al. (2021) shows that Industry 4.0 technologies have a positive influence on circular economy strategies. Another study conducted by Bag et al. (2021) shows a positive relationship between Industry 4.0 and circular economy capabilities.

Halonen, Majuri, and Lanz (2019) have developed a framework which can work with the circular economy. There are three main pillars of this framework, which are a circular economy business model, strategies, and capabilities. According to Halonen, Majuri, and Lanz (2019), their findings are too generic and there is a need to provide a framework which fits the circular economy criteria and its strategies. After an extensive literature review, a conceptual circular economy framework has been developed focusing on resources and capabilities. Resources like skills set and technology are the capabilities of an organization of doing something in a way in which others cannot. For example, manufacturing products at reduced cost while others struggle to compete; in other words, competitiveness.

In figure 2 it can be observed that first an organization needs to obtain or develop necessary resources and capabilities to develop strategies to formulate a business model that fits within the scope of a circular economy.

Circular Business Model

A systematic change is required to move towards a circular economy. Daou et al. (2020) argue that there are four fundamentals that need to be fulfilled to complete the transition process to a circular economy. These four fundamentals are *circular economy design, new business model, reverse cycles,* and *enablers.* This study focuses on only two fundamentals, new business model and enablers. C. Jabbour et al. (2019) also argue that implementation of a circular economy depends on a new business model and enablers. The concept of a circular economy is based on the three

fundamental pillars of sustainability which are environmental, economic, and social. Rossi et al. (2020) believe that a circular business model is a form of a sustainable business model but this does not account for the three basic pillars of sustainability. They define a circular business model as 'the logic of how an organization creates, delivers and captures value within closed circuits.' A circular business model can also be defined as one that 'create[s], capture[s] and deliver[s] value to improve resource efficiency through innovation.' It can be a complicated task to define a circular business model as all the aspects have to be accounted for in the definition.

According to Ranta, Aarikka-Stenroos, and Väisänen (2021), there are two research paths to explore a business model in the context of a circular economy. One is traditional business model innovation and the other is sustainable business model innovation. The goal of a business model is to maximize the opportunities for an organization and eliminate threats. A circular business model is supposed to provide improvements based on circular economy principles. According to Centobelli et al. (2020) and Hina et al. (2022), a circular economy business model has three dimensions of value proposition. These are value creation, value transfer and value capture. Neligan et al. (2022) argue that value proposition can deliver performance by using PSS along with Industry 4.0 technologies. Industry 4.0 can be linked to RESOLVE strategies as it is vital for the achievement of PSS. Ranta, Aarikka-Stenroos, and Väisänen (2021), Brendzel-Skowera (2021), C. Jabbour et al. (2019), Lewandowski (2016), Neligan et al. (2022), Pizzi, Corbo, and Caputo (2021), and Wasserbaur, Sakao, and Milios (2022) have presented six different business model strategies known as RESOLVE. These strategies include *Regenerate* (set of activities for restoring and repairing the ecosystem), *Share* (sharing resources between the users by renting, reusing and sharing services), *Optimize* (inflation of efficiency of resources through modern technologies), *Loop* (keeping materials in a closed loop by promoting recycling, remanufacturing and return of used products), *Virtualize* (process of delivering value without materialising it in a tangible product), and *Exchange* (adoption of new and advanced technologies through exchange of old renewable materials for advanced materials). These strategies assist organizations to formulate their business model. According to Han, Heshmati, and Rashidghalam (2020), a product-as-a-service business model can also be called a lease model. Organizations adopt cost-cutting strategies by product leasing against a subscription fee. Kolling et al. (2022)

argue that in a product service system tangible ownership of the product is transferred to the consumer; however, a range of services are offered throughout the product lifecycle to augment functionality, durability and sustainability to create value for the consumers.

Li et al. (2021) argue that Industry 4.0 has brought the circular economy and PSS together since a circular economy system provides a competitive advantage to PSS, and PSS provides product lifecycle management for a circular economy system. Farsi and Erkoyuncu (2021), Li et al. (2022), Tukker (2004), Kolling et al. (2022), and Reim, Parida, and Örtqvist (2015) distinguish three levels of the product service system (PSS):

1. *Product-oriented PSS:* A provider, in addition to the sale of the product, also agrees to provide a range of services related to the product.
2. *Use-oriented PSS:* A provider does not transfer the tangible ownership of the product but provides it under a rental or lease agreement. For example, bike/car rental/leasing companies selling a range of services while maintaining the ownership of the product for the whole rental/leasing time.
3. *Result-oriented PSS:* A provider agrees to provide certain results and outcomes rather than providing the tangible product to the consumer. For example, cleaning services or laundry services, where specific results are promised by the provider and no physical product is delivered.

This study focuses on product-oriented PSS and two case studies are given in the next section. The importance of linking services and physical products is also emphasized by Dawar (2013), so that firms using related activities and services do not lose a competitive advantage. On the contrary, they even increase their competitive advantage as the number of their consumers increases. According to this approach, the competitive advantage available to the company lies not only in the activities conducted by the company but also in the activities which the company outsources.

How the Product Service System Works

According to Kolling et al. (2022), PSS incorporates services like installation, maintenance, repair, software/hardware updates, remote monitoring, consultation, training, financial services, parts availability, home delivery, documentation, customer support, warranty, inspection and diagnosis. After the end of useful life, services continue, such as return, reuse,

recycle and remanufacture. Kolling et al. (2022) argue that several studies have concluded that PSS plays a vital role in a circular business model. In this business model, value creation can be enhanced by enhancing the product performance so that it exceeds customer expectations. Moreover, the additional services as maintenance can help to increase the product life cycle to a significant level. It will help to increase the length of flow of resources and subsequently increase the cycle for taking back the product for the purpose of reuse, recycle and remanufacture. Eventually, it will help organizations to develop and maintain long-term relationships with customers as well as suppliers.

Hyundai Blue Link – Case Study #1. Hyundai Motor Company has adopted this circular economy business model product-as-a-service, using one of the Industry 4.0 enabling technologies, the Internet of Things (IOT). With the help of IOT, Hyundai has managed to develop smart products which are continuously sending and analysing data in real time to improve customer experience not only with the product but also with the company in terms of after-sales services. Hyundai is providing a practical example of what Porter and Heppelmann (2015) have called smart connected products. Vehicles can send real time data of their operations to the manufacturer and receive software updates from manufacturers to avoid potential problems. In one example, in 2013, car batteries of a Tesla Model S caught fire when a metal object hit the car from the road. Tesla solved this issue by sending a software update so that cars could adjust their ground clearance according to the road conditions. In this way, products can continue to be in service for a longer period and customers will be able to establish long-term open-ended relations with the companies.

According to Porter and Heppelmann (2015), smart connected products need a completely new infrastructure to support this kind of business model. In our example, Hyundai did the same by establishing a completely new setup of remanufacturing and service stations. According to Han, Heshmati, and Rashidghalam (2020), they call it 'Blue Link.' In this model they let customers know that they have been provided with parts to reuse and with remanufactured parts after a recycling process. The customers with Hyundai Blue membership know that parts will be replaced when needed through a parts exchange system. It will help the company to reduce the use of natural resources for the purpose of manufacturing. The Blue Link Model is based on IOT. It starts when a customer buys a

new or second-hand car and subscribes to the service. Car owners usually receive information about the condition of engine, tyres, and other parts over time. They also receive notifications about when to change the engine oil and other consumables. Customers can also notify the company through a mobile app for car problems and they can be directed to the nearest service centre.

Lim et al. (2012) provide a concept to visualize the working product service model which they have called a 'product service board' and which they demonstrate through case examples. This study has developed a conceptual product service board based on the already given example of the Hyundai Blue Link Model to illustrate how a product service system works.

This service model helps Hyundai to obtain all necessary information about their vehicles and customers can maintain their cars for a longer time. What we have learned for this Hyundai Blue Member Model is that cars connected through IOT and other smart technologies can help to solve issues in time and extend the product life. According to Porter and Heppelmann (2015), manufacturing has gone beyond the physical product. Technologies like smart phones can help customers to receive real-time updates about their products and augmented reality which helps manufacturers to solve critical issues and diagnose faults in the products in the minimum time. All the collected information from products remains in the cloud and is analysed by the manufacturer to produce a product with better functioning and performance.

HP Device as a Service (DaaS) – Case Study #2. HP DaaS helps to reduce the costs and complexity of device management with the help of IT tools. It provides a range of services which include device lifecycle management, repair services and AI-driven analytics for predictive maintenance and payment plans. It is a simple solution that optimizes resources. DaaS is a business model that improves end user productivity and reduces cost. According to Knerl (2021), DaaS is a concept which is not just about buying a product but is also about end-to-end services. For example, when a customer purchases a laptop under the DaaS business model, HP will grant full access to sales consultants and tech support from setup to compatible devices throughout the lifecycle of the laptop. It also provides discounts for different software purchases along with the payment plans.

This model helps customers to save time servicing the device as it is already taken care of by DaaS. Customers can access the latest software and

TABLE 1 A Conceptual Product Service System Board Based on Hyundai Blue Member Model

	Define	Locate	Prepare	Confirm	Execute	Monitor	Resolve	Modify	Conclude
Partners							Insurance company		
Dedicated Infrastructure	An online portal is available equipped with Big Data and IOT technologies	Parking area		An ERP system that updates customer and car information		ERP system relays car info to customers regarding maintenance	Integration of car repair stations with EPP		Monitoring and updating car status via technology
Services	Online system is in place for booking process and after sale services			Assistance in the car leasing process			Car maintenance services		
Product Condition	Specific car model is available	Displayed at the parking space		Car condition confirmed as described in the company's car history	Car is leased out to the customer	Car condition is observed	Car maintenance and repair is required	Car maintenance and repair is done	Car is back in service or returned
Customer Activities	Explore a car to get on lease	Go to the company authorized dealership	Prepare all necessary documents	Complete car purchase process	Drive	Observe for maintenance and potential breakdowns	Go to the dealership for periodic maintenance and in case of breakdowns	Get the service done	Renew or Return the car at the dealership when lease contract expires

NOTES Adapted from Lim et al. (2012).

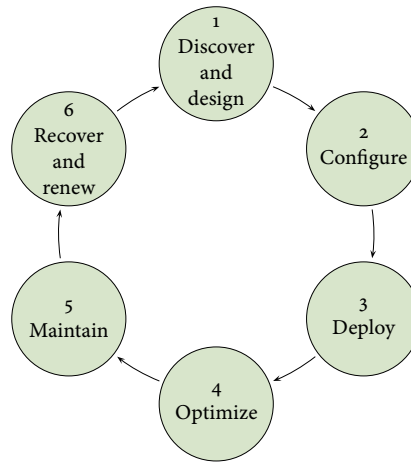

FIGURE 3

HP DaaS Business Model
(End to End Lifecycle Services)

devices and DaaS can help them to upgrade their device with a suitable monthly subscription plan. DaaS collects data about product usage on a continuous basis and sends reports to the end user, which helps to reduce the operational cost of the device. DaaS also comes with an updated version of antivirus software, which helps to protect the device from any kind of virus attack. DaaS helps to save costs in terms of setup, maintenance, repair, and support services.

HP DaaS provides actionable reports about the product to maximize the user experience. The reports include information regarding battery life, hard drive, CPU utilization, security compliance and software usage. This information helps to diagnose any issues with the device so that they can be sorted out in a timely fashion. The portfolio of services is provided from the start to the end of the product life cycle.

The HP DaaS business model can be seen in figure 3. In this product lifecycle, the first step is *Discover and Design;* HP provides consultation services to discover and design the best-suited software package for your device. Data from the current environment is collected to make the best decision for the customer. Services include hardware compatibility testing, application testing, dashboard analysis and recommendations. The second step is *Configure;* a tailor-made IT package is recommended and configured by HP to save the time and energy of their customers. The third step is *Deploy;* devices, along with the configured IT package, are deployed to reduce time, risks, and costs. HP DaaS manages everything from logistics to complete installation of devices. The fourth step is *Opti-*

mize; HP DaaS optimizes the user experience by resolving device issues promptly through HP consultation services. The fifth step is *Maintain;* HP DaaS offers wide range of global services to the end users related to coverage, protection, and support to keep costs to the minimum and improve the user experience. The sixth step is *Recover and Renew;* HP DaaS helps to secure data and offers fresh technology packs and devices that support sustainability to increase end user experience. It is a secure method to retire or repurpose your old devices.

Circular Strategies

According to Blomsma et al. (2019), there are plenty of circular economy strategy frameworks available in the present literature. However, all these strategies only answer issues related to diverse types of structural waste and do not address the problems that can arise from the transformation to a circular economy perspective. It is beyond the scope of this study to provide a complete landscape of frameworks for circular economy strategies. There are four distinct levels at which these frameworks can operate. These are the *Macro level,* where a circular strategy framework is applied on the industry level as a whole; the *Meso level,* which involves certain industrial or business sectors where circular strategies can be applied; the *Micro level,* where circular strategy frameworks can be applied at an organization level; and the *Nano level,* where the circular strategy framework is applied at the product or product group level within an organization.

This paper focuses on the Micro level where the PSS business model embedded with circular strategies is applied on organizational level. Liu et al. (2021) argue that PSS creates value by providing services from the production to the disposal of the product. The supportive services include maintenance, monitoring in real time, fault diagnostics, parts and functions upgrades and in-time availability of parts, while disposal and conversion services include recycling, remanufacturing and other end of life services for the purpose of circulation. According to Salvador et al. (2021), finding the right strategies is the most important aspect for implementing circular economy principles successfully.

The study is inspired by the circular economy strategy framework developed by Potting et al. (2017). This framework of circular strategies has defined and explained in detail the circularity levels and applications of these strategies. Table 2 presents a list of eight circular strategies along with their definitions. However, the first column, which mentions circularity level and application, needs an explanation. These strategies

TABLE 2 Circular Economy Strategies

Circularity Level & Application	Strategy	Definition
Low Economical Usage of Materials & End of Product life Management	R1 Recycle	The processing of materials to obtain same or lower grade.
	R2 Recover	The incineration of materials by using energy to recover.
Medium Extension of Products & Parts Lifespan	R3 Remanufacture	Use of parts of an old/defunct product to build a new product with same functionality.
	R4 Repurpose	Use of parts of an old/defunct product to build a new product with a different functionality.
	R5 Refurbish	Restoration of an old product and bringing it to up to date.
High Smart Product Usage	R6 Repair	Maintenance of a defective product so that it can be used with its previous functionality.
	R7 Reuse	Usage of a product by another customer which is still in good condition and performs original functions fully.
	R8 Reduce	Usage by consuming fewer natural resources and materials.

NOTES Adapted from Potting et al. (2017).

have been placed into different levels of circularity based on the business model PSS. A smart product enabled with an Industry 4.0 technology allows customers to reduce the usage of the product which leads to less consumption of natural resources that are required to utilize the product such as electricity, gas, or petroleum products. In the literature, 'reduce' is also defined as a reduction in raw material usage by the manufacturer. However, this study particularly deals with the reduction of the product's usage, since there are several manufacturing models already available such as JIT, lean manufacturing, and smart manufacturing, which deal in reduction of raw material. Therefore, this study supports the narrative that if the usage of a product can be reduced then its lifespan can be increased, hence the product will be fit to use and reuse for a longer period.

This leads to the next strategy which is reuse. A product is only fit for reuse if the first user properly maintains it. It relates to the third strat-

egy, repair, which also lies in the high circularity level. Only when a customer maintains and repairs the product in time, is it possible to reuse the product. Since products can be put to immediate reuse by following the strategies, that is why here the circularity level is high. The further a product moves back in the production line, the more the circularity level decreases. In the high circularity domain, the focus is on the smart usage of the product.

In the second domain of medium level circularity, the first strategy is refurbishing. When a product is old or damaged it is restored completely to make it look like a new product. On the other hand, if the product is too damaged to be restored then the manufacturer must repurpose or remanufacture a new product to serve a different or the same functionality, respectively. In this domain, the manufacturer must inject more resources to produce a new product from the defunct product, so here the level of circularity is medium. The third and last domain is the low level of circularity. Here, the manufacturer must use strategies like recycle and recover to manufacture a product from the initial phase of manufacturing. In this scenario, old and defunct products which are severely damaged are sent back to the raw material section of manufacturing where they are recycled to produce the same or lower grade materials.

Resources and Capabilities

According to Rovira et al. (2021), early signs of a digital economy were noticed in the US in the late nineties as the Internet started reshaping the traditional economy. This Internet usage brought high product quality as everything shifted online, from online shopping to online payments. That was the time when the customer service-oriented business model surfaced and gained popularity. In the 21st century, these digital transformations are playing a vital role in achieving competitive advantage. Business models and organizational structural designs must be in accordance with digitization. According to Rovira et al. (2021) the research indicates that big traditional companies can outperform digital start-ups if they incorporate digital technologies into their organizations.

An organization requires rethinking of its organizational structure when it decides to move from a product-centric business model to a service-centric business model. According to Ranta, Aarikka-Stenroos, and Väisänen (2021), digitization based on Industry 4.0 technologies can help organizations to implement circular economy business models. These technologies help companies to share data in real time so that

products and materials can be tracked within the supply chain, which can bring value to the end user of the product. The digital technologies were originally believed to be beneficial in manufacturing alone but Ranta, Aarikka-Stenroos, and Väisänen (2021) argue that now it has been realized that the digital technologies not only help to track materials in the supply chain but also support the product-as-a-service business model by reducing the need for product ownership.

According to Antikainen, Uusitalo, and Reponen (2018), the product-as-a-service model is instrumental in digital transformation and the circular economy. The combination of technologies like Big Data, Data Analytics, Internet of Things, and other similar technologies provide an opportunity to create and capture value through the circular business model. Now modern technologies allow manufacturers to produce smart connected products that enable products to be remanufactured, refurbished, or recycled. Antikainen, Uusitalo, and Reponen (2018) argue that it is an accepted fact that digitization is imperative for implementing a circular economy. However, there are limited studies that explain how digitization functions as an enabler in the transition towards a circular economy. Ranta, Aarikka-Stenroos, and Väisänen (2021) have also identified gaps in the literature related to lack of empirical evidence of how digital technologies benefit the circular economy and the role of digital technologies in the circular economy.

Antikainen, Uusitalo, and Reponen (2018) argue that the product-as-a-service model is not a circular business model by definition but the enabling digital technologies help to achieve similar objectives as to the circular economy. The use of digital technologies helps to implement circular systems and reduce material use. Smart technologies not only help to estimate the quality of the product to enhance the product life cycle but also help in the supply chain by facilitating product life cycle management. Ranta, Aarikka-Stenroos, and Väisänen (2021) argue that digital technologies like the Internet of Things, additive manufacturing, cyber physical systems, and cloud computing can play an essential role in the transition towards a circular economy and the product-as-a-service business model.

The concept of the circular economy gained popularity among businesses and policy makers in the context of sustainability. Kristoffersen et al. (2020) argue that digital technologies are vital in order to implement circular economic strategies and to track down products and materials while they are in the supply chain system. Digital technologies like the

Internet of Things can help to monitor the process flow of products and materials, while Big Data can help to identify which materials are going into waste and which can be re-used as a raw material. It can also help to reduce production time and optimize maintenance and energy consumption. According to Kristoffersen et al. (2020), a survey shows that 70% of organizations have considered adopting a circular economy business model but only 12% of them have successfully implemented a circular economy with digital technologies. It means that, due to lack of knowledge and awareness, the true potential of digital technologies and the circular economy has not been explored.

Digital technologies, which are also known as Industry 4.0, are transforming various areas within manufacturing. However, digital technologies are still in the developing phase as they fail to provide fundamental support within the manufacturing sector. According to Kristoffersen et al. (2020), a research study shows that there are three main barriers in the implementation of a circular economy. These are no interface design, difficulty upgrading old technology, and outdated synergy models. All these barriers can be removed by applying digital technologies, such as networking, the Internet of Things, and automation, respectively.

Circular Supply Chain of the Business Model 'Product-as-a-Service'

Bal and Badurdeen (2020) propose to develop a system where consumers can place end-of-life products at collection points where, after sorting, these products can be returned to the manufacturing companies. Thanks to the development of info-communication technology, new types of products are appearing in the markets that are reshaping the processes within which companies have operated so far. These new products are transforming supply chains and forcing companies to change (Porter and Heppelmann 2015). Designing the right processes involves returning end-of-life products to companies and processing them. Processing includes determining whether the product can be resold immediately after redesign and refurbishment or if the returned end-of-life product cannot be redesigned, refurbished, and needs to be disassembled; any raw materials and components that can still be used need to be integrated into the next generation of products. In the case of products that are subsequently marketed after redesign and refurbishment, an important question is how consumers perceive these products. According to the research results, Porral and Mangin (2020) show that consumers have

a positive image about product safety when buying recycled products, while environmental impacts and perceived quality do not play a role in decision making.

End-of-life products returned to companies are transforming the company's inventory management, as it is difficult to predict how many products will be returned or how many of them will be resold after redesign and refurbishment. The number of raw materials and parts to be incorporated into the next product generation is also difficult to predict. IOT and smart connected products can be a great help in solving these issues as they can provide continuous feedback to companies on consumer habits. Therefore, the role of production planning and control (PPC) in the circular economic model is important. This is due to changes in PPC, such as remanufacturing and refurbishment of the product. According to C. Jabbour et al. (2019), product return calculations are based on product quality, quantity, and production design.

Companies need to have the right infrastructure and processes in place to manage and store returned products as well as the right processes to dispose of raw materials and parts that are no longer usable. Product designers should therefore place particular emphasis on ensuring that the raw materials and components built into products can be used in as many product generations as possible. However, the next challenge concerns the inventory management and production planning department so that the circular economy allows raw materials and parts to come not only from suppliers, but also from the market through reverse logistics, such as the return of previously sold products (Dowlatshahi 2000; Sarkis, Helms, and Hervani 2010; Lembke 2002).

In the case of products that return to the company, it must be determined whether the product should be repaired or refurbished and then re-delivered to consumers. This can be economical for the company if the useful life period of the product has not yet expired and the cost of repair or refurbishment is recouped during the extended useful life period. If this is not economically viable, then the product must be disassembled and the extractable parts can be used in the next product generation. This disassembly and handling of raw materials and parts is an additional cost for the company, so it can be an effective solution only if the process is cheaper than producing new raw materials and parts.

This study developed a conceptual circular supply chain that can help to implement this business model. In this model we have explained how organizations can adopt a PSS business model in the context of a circular

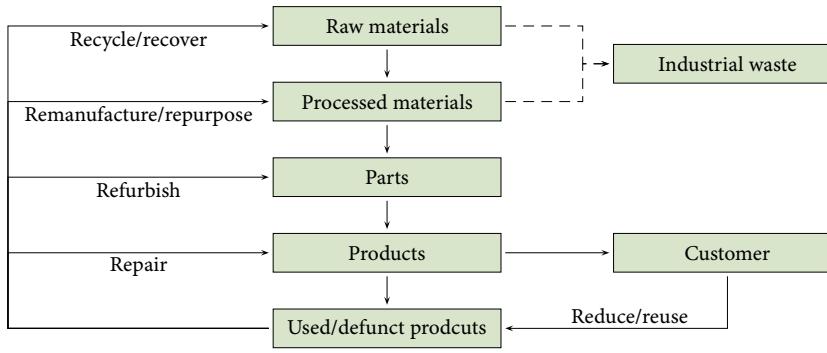

FIGURE 4 A Conceptual Circular Supply Chain of Business Model PSS

economy. It can be seen in figure 4 that organizations following a circular economy are taking back products from the customers and returning them to different sections, based on the condition of the product to perform functions like recycling, remanufacturing, redesigning, refurbishing, recovering, reducing, and reusing. However, if the parts are too damaged or worn out to be reprocessed or remanufactured, they can be sent to industrial waste site to be dumped.

Theoretical Findings and Discussion

The theoretical results in this study have been extracted from the extensive analysis of the present literature. The paper has developed a conceptual theoretical framework of a circular economic ecosystem which can be seen in figure 5. As this study is primarily focused on the circular economic business model based on Industry 4.0 technologies at the organizational level, these are the areas explored.

It can also be seen in figure 5 that the circular economic ecosystem is based on three foundational pillars. The first foundation is a business model which is PSS; its characteristics are also highlighted. The second foundation is strategy. Strategies can be devised as several levels but this study is focused on the micro level only and this level is further explored accordingly. We formulated R strategies which are further categorized based on their circularity level. The third foundation is resources and capabilities. They are also explored and this study believes that all resources and capabilities are essential for any organization's success. However, only Industry 4.0 technologies are further elaborated since these are the primary concern in this paper.

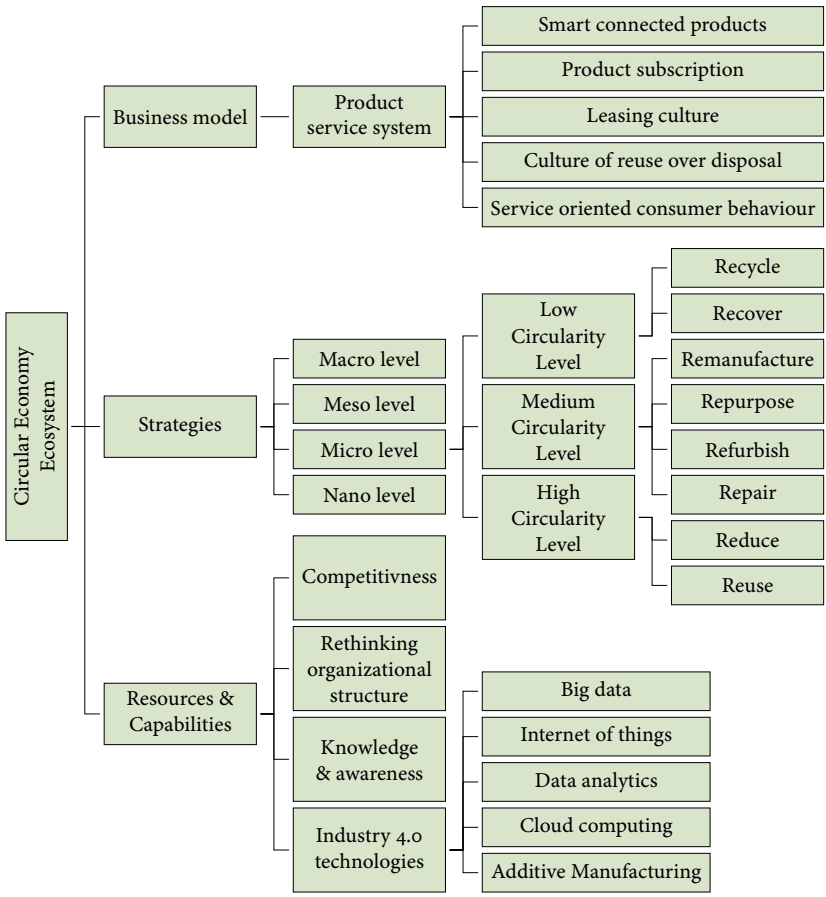

FIGURE 5 Industry 4.0 Technologies-Enabled Circular Economy Ecosystem Framework

RESOLVE strategies can only be achieved by applying PSS along with modern technologies. This study presents a framework for a circular economy business model that is successful and sustainable for organizations. Organizations should implement PSS backed by Industry 4.0 based on RESOLVE strategies. The study identified two gaps, which are lack of a circular economy ecosystem and lack of empirical evidence. This paper provides a theoretical circular economic ecosystem to fill this gap.

However, this study does not provide empirical evidence but has presented two case studies to support the argument that PSS is the most suitable business model for a circular economy ecosystem.

Conclusion

This paper is aimed at exploring a new dimension of production economics in the domain of the circular economy. This study has extensively analysed the literature to explain the traditional business model and problems linked to it. The study also examines the historical evolution of the circular economy as it was first introduced as reverse logistics in the academic literature. The concept of the circular economy brings sustainability when it is implemented through Industry 4.0 enabled digital technologies. These technologies help to increase production efficiency by reducing costs. Digital technologies can help to create a digital ecosystem which can help to form an ecosystem based on the circular economy and enabled through digital technologies. After the literature review, this study also discussed in detail that there are three basic business models that are suitable for the circular economy, but this paper chooses 'product-as-a-service' as it is best suited for the implementation of R strategies which are circular economy strategies.

The extensive analysis of literature reveals that the circular economy and Industry 4.0 are both associated with sustainability. This paper formulates its theoretical findings by devising a theoretical framework to connect the circular economy and Industry 4.0. In this framework a business model 'product-as-a-service' based on circular strategies which are implemented through Industry 4.0 technologies. A product service system is explained in the paper to help the reader understand how it works. A total of 8Rs are given along with their circularity level. These strategies are being implemented with the help of digital technologies, as the literature emphasizes that digital technologies can help an organization to outperform against its rivals.

This paper also has its own practical implications related to the implementation of circular strategies along with the business model. The product-as-a-service model adopted by Hyundai Motor Company is successful; however, it requires a paradigm shift in the organizational philosophy. The importance of the circular supply chain is that it allows us to get possession of the product which is used as a service by the customer. With the help of smart technologies, the manufacturer can track the maintenance record and forecast future maintenance of the product as well. Product-as-a-service is a practical approach but it also requires a paradigm shift in consumer buying behaviour.

As far as managerial implications are concerned, related to the circular

strategies and product-as-a-service business model, it is a managerial job to forecast the expected number of products returned to the manufacturer so that it can be determined how many products will be produced using R strategies and how many new products will be produced to meet customer demand. Then a production plan can be devised accordingly by the start of every production year. It will help organizations to manage and balance supply and demand issues.

A regulatory and legal framework is also required to protect consumer rights and ensure that the manufacturer provides all the services agreed upon to the consumer. It is the most important factor because if the manufacturer fails to provide a service, then the product service model will fail, too, and consumers will not subscribe to products-as-a-service. A regulatory framework will also force the manufacturer to follow R strategies and force consumers to use the product in compliance with R strategies.

There are a few limitations to this study, which includes lack of empirical data as few organizations follow the product-as-a-service model. In the future, researchers might be able to analyse empirical data based on manufacturers following product-as-a-service. This paper provides a sturdy foundation for further research in the domain of the circular economic ecosystem as there are opportunities to explore the circular business model, specifically product-as-a-service. The relationship between Industry 4.0 technologies and the circular economy is also a wide subject, hence new dimensions can be researched in this domain. Future researchers can also explore the economic viability and profitability of the product-as-a-service model in other industries.

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Institutional Investors' Preferences in Green Bonds and ESG Criteria: A Focus on German-Speaking Europe

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The aim of this paper is to study the influence of the current regulatory environment on the investment decisions of sustainability-oriented institutional investors within the German-speaking region of Europe. Through the use of a structured questionnaire, aimed at institutional investors, this paper presents detailed insights into the preferences of investors when purchasing green bonds, bonds that contribute to reducing or preventing adverse effects stemming from climate change. After analysing our sample of 179 participants, it is demonstrated that the credibility of a green bond is a basic prerequisite for an investor to purchase such an instrument. Additionally, the attractiveness of green bonds is influenced by financial factors such as tax incentives as well as the interest rate environment. Furthermore, this paper studies the influence of environmental, social and governance (ESG) strategies on green bond investment decisions, where it is revealed that the environmental pillar is the most important for investors.

Key Words: green bonds, ESG, institutional investors, investor preferences, conjoint analysis, socially responsible investing
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Introduction

According to the Climate Bond Initiative (2019), green bonds are any type of bond instrument (and other debt instruments) where the proceeds or an equivalent amount will be exclusively applied to finance or refinance, in part or full, new or existing eligible green projects that are aligned with the four core components of the Green Bond Principles (GBPS), which are voluntary process guidelines (International Capital Market Association 2021). According to Ehlers, Mojon, and Packer (2020, 31), 'Green

bonds are a plain vanilla fixed-income product that offers investors the opportunity to participate in the financing of "green" projects that help mitigate climate change and help countries adapt to the effects of climate change.' Green bonds have similar features to regular bonds of the issuing entity, including credit risk and size. Because of the standard financial features and the dedication to climate change, they are of interest to a broad range of purchasers, ranging from retail and high-net-worth investors to institutional investors, thus covering both non-professional as well as professional investors. A key feature of these bonds valued by many investors is the due diligence process that the issuer of green bonds conducts to identify and monitor 'green' projects (Reichelt 2010, 7). Several possibilities exist for the labelling of a bond as 'green.' Firstly, it can be 'self-labelled' and be marketed accordingly. Secondly, bonds can be rated by rating providers, of which the two most prominent examples are the GBPS and the Climate Bonds Standard.

Although evidence that green bonds enable issuers to achieve better conditions compared to common bonds is not widely available through the current literature (Karpf and Mandel 2017; Fatica, Panzica, and Rancan 2021; Flammer 2021), the increasing demand from sustainability-oriented investors on the environmental, social and governance (ESG) and socially responsible investing (SRI) spectrum has the potential to lead to lower costs of capital for initiatives in the future (KPMG 2015; Baker et al. 2018; Zerbib 2019). To channel vast amounts of capital into sustainable initiatives, investment products must appeal to institutional investors with a sufficient amount of assets under management, such as pension funds, endowments, asset managers and sovereign wealth funds. Additional investment needed to meet the climate challenge – for clean energy infrastructure, sustainable transport, energy efficiency and forestry – amounts to approximately US $700 billion per year globally, which vastly exceeds the capability of the public sector (Bhattacharya, Oppenheim, and Stern 2015, 12).

As the proceeds of a green bond are assumed to be used for initiatives that contribute to a more sustainable and liveable planet, green bonds are a fitting instrument to finance the costs associated with meeting the commitments of the 2015 Paris Climate Agreement and, therefore, are heavily sought after. This growth is necessary to achieve targets of the 2015 Agreement for 2030. Europe alone is estimated to need €180 billion in additional investment annually to achieve these targets (Fatica, Panzica, and Rancan 2021, 2688). Therefore, green bonds as an investment category

offer a vast untapped potential to access capital for sustainable initiatives. Over the last decade, green bonds have been gaining interest as an asset class, as large investors such as pension funds and sovereign wealth funds started to allocate more assets to sustainable investments and are either voluntarily or, to some extent, legally obliged to sustainably invest their assets (Della Croce, Kaminker, and Stewart 2011, 12).

As the current market constellation is primarily governed by market-oriented institutions and by voluntary practices instead of 'hard'-law-based regulations, sustainability-based commitments are vulnerable to 'greenwashing, 'in other words, the use of the green bonds' proceeds for profit- or brand-enhancing reasons (Grene 2015; Deschryver and Mariz 2020). Moreover, with increasing doubt about whether green bonds function as a credible instrument to mitigate the adverse effects of climate change and pollution, the entire regulatory fabric of the green bond market may suffer from systemic legitimacy deficits in the eyes of investors, stakeholders and regulators (Deschryver and Mariz 2020).

The aim of this paper is to research the influence of the current regulatory constellation on the investment decisions of sustainability-oriented investors. As large portions of the current laws are governed primarily by market-oriented institutions alongside voluntary practices, as stated previously, we present proposals for a further improvement and partial redesign of existing green bond frameworks. By employing a structured questionnaire that was disseminated in the German-speaking region of Europe, we provide a further edge by focusing particularly on the behaviour and preferences of investors from this area. Furthermore, we distinguish between professional and non-professional investors as well as existing knowledge regarding sustainable investments, thus enabling us to critically observe different types of investor groups.

This paper provides detailed insights into the preferences of sustainability-oriented investors. By focusing not only on a particular region of Europe but also considering participants' investment expertise and professional background, we critically assess differences and similarities between investor groups. Consequently, we provide insights that contribute to shaping the future regulatory environment of green bond markets and help these markets provide trustworthy, accessible, and attractive investment instruments to overcome current and future climate-related challenges.

With 179 participants contributing to this survey, among them both beginning and experienced institutional investors, this survey presents the

preferences of a diversified sample stemming from the German-speaking part of continental Europe. The outcomes of this research provide detailed insights that are not only useful for regulators to enhance the functioning of the green bond market but also enable investment advisors and fund managers to further improve their offerings, based on the criteria desired by investors.

Following the introduction, this paper proceeds with a brief overview of theoretical concepts related to green bond markets. Afterwards, the methodology is explained in detail, and the results are elaborated upon in the following chapter. Finally, our conclusion is presented alongside limitations to this research and proposals for future study.

Theoretical Positioning

SUSTAINABLE INVESTMENTS

The attention focused on sustainable investments has increased significantly over the past decade. Starting with more ethical and sustainability-oriented equities, this market development has also reached significance within the green bond market, drawing attention from largely institutional investors, with the retail market following at a safe distance. Besides non-monetary motives, the financial motive to invest in instruments offering both monetary and non-monetary returns is the most frequent and important motivation from an equity-market and ESG-focused perspective (Amel-Zadeh and Serafeim 2018). For the green bond market, however, the so-called 'green bond premium' – which enables issuers to issue a green bond at a price higher than its actual fundamental worth, thus resulting in a lower yield for investors – contradicts the aforementioned research, as it indicates that investors are willing to sacrifice returns for investments with strong green credentials.

Sangiorgi and Schopohl (2021), who researched the reasons why institutional investors buy green bonds, pioneered studies in this field. However, since their study is one of only a few on the topic of investor preferences regarding green bonds, our research contributes to the literature by including a regulatory lens. By doing so, we critically examine the current regulatory constellation as well as its influence on the investment decisions of institutional investors. Furthermore, we limit the geographical scope to include only the German-speaking area of Europe to reflect a rather homogeneous population and to minimize any cultural differences that might cause distortion in the answers provided.

THE CASE OF GREEN BONDS

Since at least 25% of pension funds' assets are allocated to fixed income, bonds as an investment category offer a huge untapped potential to access capital for sustainable initiatives. In recent years, green bonds have been gaining interest as an asset class, as large investors such as pension funds and sovereign wealth funds tend to be more inclined to purchase lower-risk investments that provide a steady, inflation-adjusted income stream. Additionally, these funds are either voluntarily or, to some extent, legally obliged to sustainably invest their assets (Della Croce, Kaminker, and Stewart 2011, 12). This trend is enabling the development of more liquid infrastructure asset classes including green bonds, of which an estimated $257.7 billion were issued in 2019 worldwide (Dorfleitner, Utz, and Zhang 2022, 798).

Existing green bond standards comprise various voluntary standardization measures including criteria regarding their definition, eligibility, disclosure, transparency and impact reporting. Although the market for green bonds is still relatively young, various definitions for green bonds have been developed at the national and international levels. Additionally, various tools to certify green bonds as 'green' have been implemented. While the GBPS provide a basis for the certification of green bonds, the question remains how 'green' the bond itself is, as the GBPS do not take a stand on which initiatives produce the greatest benefit. The Climate Bonds Standard by Climate Bond Initiative has taken on this task by providing a stricter assessment in this respect. However, subscribing to these standards is not necessary, therefore leaving the option to issuers to avoid this process entirely (Climate Bond Initiative 2019), which is not negative per se for the market perception of green bonds, as was the case with US municipalities issuing green bonds at a premium (Baker et al. 2018). In addition to these internationally adopted standards, national standards have been established – for example, in China – and soon, the EU plans to provide their own green bond standards as well. These actions are leading the market away from one universally accepted standard and creating a more heterogeneous environment from an investor's perspective.

Moreover, the largely voluntary character of green bond certification, verification and monitoring is not beneficial for the current market structure. Research results thus far indicate that voluntary reporting by bond-issuing companies or reporting based on a voluntary self-commitment does not have an emission-reducing effect. Furthermore, a major issue

for sustainability-oriented investors is the ability to recognize an honest commitment on the part of the issuer to use the proceeds in an environmentally friendly way, thus not greenwashing the proceeds (Fatica, Panzica, and Rancan 2021, 5).

ENVIRONMENTAL, SOCIAL AND GOVERNANCE IN FOCUS: LITERATURE REVIEW ON INVESTORS' ESG PREFERENCES

A study by Duuren, Plantinga, and Scholtens (2016) investigated conventional asset managers' preferences for ESG factors, and the findings revealed that most asset managers use ESG information as an analysis and investment opportunity rather than at the company level. The study revealed that governance factors are dominant among investors. The authors observed that asset managers were given clear instructions about how to address individual ESG dimensions, while 60% of the investors received clear instructions and paid close attention to governance factors only. Consequently, the social and environmental factors shared the same result. In addition, the study observed that the domicile of the investor has a significant impact on the results. For example, managers in the United Kingdom and the United States place low emphasis on the environmental and social factors, whereas these factors are more highly valued by European managers. Finally, the portfolio structure and strategy vary among investors. The UK managers rely more on red flagging, while European managers focus primarily on limiting the investment universe (Duuren, Plantinga, and Scholtens 2016, 525–33).

More recently, Amel-Zadeh and Serafeim (2018) also revealed that the application of ESG information is material from a financial perspective, which means it could have a significant impact – either positive or negative – on a company's business model and value drivers, significantly impacting investment value. Additionally, the vast majority of investors who apply the ESG information are institutional investors, not retail investors. Finally, the study observed that an investor's origin and background are reflected in the purchase decision. For example, if the investor is from a country with significant corruption, then they will consider and address this issue. In contrast, an investor from a country that suffers from environmental problems would consider this as a decision factor (Amel-Zadeh and Serafeim 2018, 87–103).

INSTITUTIONAL INVESTORS AND CLIMATE RISKS

In general, institutional investors believe that climate-related risks have important financial implications for their portfolio firms (Ilhan et al.

2019). This is in line with evidence from studies that examine the financial implications of climate risks (Ilhan et al. 2019; Baldauf, Garlappi, and Yanellis 2019; Addoum, Ng, and Ortiz-Bobea 2020). According to Ilhan et al. (2019, 34), institutional investors consider these risks because of financial and non-financial reasons.

According to Orsag (2015), institutional investors can be grouped into passive and active investors. The former adopt strategies aimed at outperforming the market. The latter are focused on achieving a profit based on long-term growth. Within the available literature, the role of institutional investors, measured as the extent to which these investors are able to influence management, is debated and no clear picture whether investors are typically active, or passive, exists (Maug 1998; Cornett et al. 2007). More recent research suggests institutional investors rather employ a long-term oriented, passive, focus (Mehrani, Moradi, and Eskandar 2017), which is also reflected in the passive portfolio management style adopted by institutional investors (Nix and Chen 2013). Due to the long-term investment horizon, institutional investors have a particularly strong interest in corporate governance (McCahery, Sautner, and Starks 2016). Based on Chung, Elder, and Kim (2010), good corporate governance reduces information asymmetry, thus reducing agency costs and, according to Djundjek Kokotec (2022), leading to better business performance and increased firm value.

HYPOTHESIS DEVELOPMENT

Summarizing, equity and green bond investors differ with regard to their intentions when investing in sustainable instruments, despite the largely self-governed character of the green bond market. Further, institutional investors in particular tend to have strict guidelines when investing capital, with a clear preference for governance-related factors when selecting investments. Considering the above-mentioned statements, we can derive the hypothesis:

> *Institutional investors consider governance issues to be more important than environmental or social issues.*

Methodology

This research paper is of a qualitative nature, with the research method applied being a structured questionnaire. Although surveys have several drawbacks, such as response bias, selection bias and attribution bias, it is the preferred method for my research, as the data and insights related to my research questions cannot be addressed by archival data. As Dichev

et al. (2013, 2) suggest, 'Surveys . . . allow researchers to (i) discover institutional factors that impact practitioners' decisions in unexpected ways and (ii) ask key decision makers directed questions about their behaviour.' The questionnaire was disseminated exclusively to institutional investors in the German-speaking countries in Europe (Germany, Austria, Switzerland and Liechtenstein). The questionnaire was disseminated and administered online based on the arguments provided by Saleh and Bista (2017), which relate to ease of use, quick response and costs involved.

Due to the relative novelty of green bonds as a financial instrument and the limited knowledge regarding retail investors' approaches to green bond investments, the nature of this research is rather exploratory.

To successfully capture investors' preferences for financial products, the conjoint analysis measurement was implemented (Zinkhan and Zinkhan 1990, 31–2). This method gained popularity beginning in 1971 and was widely used to solve diverse issues in the consumer market. The conjoint approach offers various types of methods depending on the needs of the study (Orme 2009, 1–5).

A choice-based conjoint (CBC) analysis was selected for this study in light of its capabilities and the purpose of this paper. CBC demonstrates superiority compared to other methods when multi-attribute products are considered and highlights important differences in choices (Vriens, Oppewal, and Wedel 1998, 1–3). The respondents at first familiarize themselves with the product's features and then make a preferred choice (Orme 2009, 1–6).

SURVEY DESIGN

The 25-question survey, which included a CBC analysis, focused on the characteristics of green bonds and their effect on the investment decision. As suggested by Sargent (1993), behavioural finance has emerged as a response to difficulties faced by the traditional paradigm. The traditional paradigm assumes that, in the case of our paper, investors make perfectly rational decisions (Bloomfield 2010). Additionally, the development of conjoint analysis and its role in behavioural finance has demonstrated advancement in financial psychology (Clark-Murphy and Soutar 2005, 6–12).

Table 1 illustrates the attributes selected for this survey and their underlying levels. The green bond attribute represents the four choices of investment opportunities: green bond, secured by assets as compared to standard bonds; green revenue bond, secured by income-producing

TABLE 1 Levels and Attributes Applied

Attributes	Level 1	Level 2	Level 3	Level 4
Green bond	Green bond (secured by assets, compared to standard bonds)	Green revenue bond (secured by income-producing projects)	Green project bond (secured by project assets and a balance sheet)	Green securitized bond (secured by a larger asset pool)
Rating (score)	A (0.75–1.00)	B (0.50–0.75)	C (0.25–0.50)	D (0.00–0.25)
5-year average return	9%	7%	5%	3%
Investment objectives	Environmental issues	Social issues	Governance issues	Other

projects; green project bond, secured by project assets and a balance sheet; and green securitized bond, secured by a larger asset pool. The options aimed to confront the respondent with four investment opportunities in green bonds. The rating (score) attribute provides a brief evaluation of a hypothetical investment opportunity consisting of four levels: (A) 0.75–1.00, (B) 0.50–0.75, (C) 0.25–0.50 and (D) 0.00–0.25, where A represents the most favourable rating, B the second most favourable, et cetera. The five-year average return attribute consists of four levels of annual returns: 3%, 5%, 7% and 9%. Investing in sustainability is considered an art of long-term performance (Kurtz and Dibartolomeo 2011, 95). Therefore, according to Gutsche and Ziegler (2016, 8), the five-year average return has proved to be a successful measure. The investment objectives attribute consists of four levels: environmental issues, social issues, governance issues and other issues. Table 1 presents the respondents' choices regarding green bond attributes and levels.

SURVEY PARTICIPANTS

As suggested by Lohr (2019), a representative sample should mirror features of the entire population. Based on the characteristics of this study, the intent of which is to identify and assess preferences of investors, the sample exclusively consists of institutional investors residing in German-speaking regions of Europe: Switzerland, Austria, Germany and Liechtenstein. To ensure a high response rate among institutional investors, the questionnaire was distributed through social media, such as LinkedIn and WhatsApp, as well as through email and other digital media. After data cleansing, a total of 179 respondents completed the survey.

Results

RESPONDENT STATISTICS SUMMARIZED

According to the applied software, 386 potential respondents viewed the survey, and among this number, a total of 229 participants started the survey but 50 did not provide complete answers, leaving 179 completed surveys. Therefore, the dropout ratio constituted 22%.

Overall, nearly 75% of the respondents are male, and 34% are between the ages of 31 and 40. Furthermore, the participants, on average, possess at least a bachelor's degree and tend to have either very few or no sustainable or green bond investments. However, 62% of the respondents said they are typically in favour of green bonds and ESG investments. With very few self-employed and even fewer unemployed, the respondents typically are employed (168 of the 179) and earn between CHF 50,000 and CHF 100,000 annually. The majority of our sample (57%) consider themselves beginners in the institutional investment realm, possessing some knowledge. Another 27% are experienced institutional investors, with the remainder rating themselves as advanced or professional institutional investors.

From a geographical perspective, most respondents are from Germany, thereby reflecting the large population this country has within the European German-speaking area. Compared to the other countries, German investors do not significantly support green bonds and ESG investments, with the respondent pool split 50–50 regarding these assets. By contrast, Liechtenstein investors – who comprise 18 of the 179 responses, thereby making up 10% of the sample – display the highest support for sustainable and green bond investments, being unanimously in favour of green bonds and ESG. Furthermore, more than half of Liechtenstein participants consider themselves advanced investors and earn, on average, the highest annual income. They invest the greatest amount in sustainable and green bond investments as well. Both Liechtensteiners and Swiss participants are well educated, with 61.11% and 65.38%, respectively, having earned master's degrees. This educational level is also reflected in the annual incomes earned.

IMPORTANCE OF GREEN BOND ATTRIBUTES

Table 2 presents the responses regarding the importance of green bond attributes provided by the institutional investors from German-speaking regions in Europe who answered the survey. The importance of rating

TABLE 2 Attribute Importance

Attribute importance	Percentage
Green bond type	5.09
Rating (score)	39.94
5-year average return	32.04
Investment objectives (E, S, G)	22.93

TABLE 3 Best and Worst Profiles Selected by Institutional Investors in Germany, Austria, Liechtenstein and Switzerland

Attributes	Best Profile	Worst Profile
Green bond type	Green securitized bond secured by a larger asset pool	Green project bond secured by project assets and a balance sheet
Rating (score)	A (0.75–1.00)	D (0.00–0.25)
5-year average return	9%	3%
Inv. objectives (E, S, G)	Environmental issues	Other

(score) was deemed the greatest by 39.94% of respondents. This confirms that the rating (score) has a predominant influence when an investment opportunity is being considered. However, not far behind is the five-year average return, rated as most important by 32.04% of respondents. This indicates that the financial performance is one of the key factors considered when investing. The attribute investment objectives E, S and G was rated most important by 22.93%, indicating that investors are also aiming for sustainability. The least important attribute for respondents proved to be the green bond type, with only 5.09%, which means that the given attribute is highly insignificant when an investment opportunity is being considered.

Table 3 displays the best and worst profiles generated by the conjoint analysis. The best profile indicates that the given combination of levels has been chosen most frequently by the respondents. In contrast, the worst profile has been selected by the fewest respondents. In reference to table 3, we can observe that the most frequently selected best profile consists of the following levels: green securitized bond, secured by a larger asset pool; A (0.75–1.00); 9%; and environmental issues. It is interesting to note that the most appreciated rating (score) is also the highest rating from the choices provided, and the five-year average return is the highest offered return on investment from the choices. This indicates that investors are

TABLE 4 MaxDiff Scaling versus Investors' Choice (%)

Attributes	Investors	MaxDiff backtesting
Green bond type	5.09	13.64
Rating (score)	39.94	22.73
5-year average return	32.04	46.59
Investment objectives (E, S, G)	22.93	17.05

seeking the highest return on their investment. Finally, environmental issues are considered to be the most important attribute level in contrast to other objectives such as social or governance.

In contrast, the worst profile includes the following attribute levels: green project bond, secured by project assets and a balance sheet; D (0.00–0.25); 3%; and the other investment objective. These choices indicate that an investment targeting objectives other than ESG is the least interesting to the respondent, as are the lowest return rate and the lowest rating (score). Finally, a green project bond, secured by project assets and a balance sheet, is a least interesting green bond type among other choices provided.

Table 4 displays the results obtained by means of conjoint analysis and presents the most important attribute levels by investor choice as well the results of the MaxDiff. With reference to the methodology section, MaxDiff encompasses the procedure that works through multiple sets of choices, where survey respondents are asked to select two attributes that they rate as the most and least important (Auger, Devinney, and Louviere 2007, 304). This procedure has a straightforward benefit, where respondents can immediately select from the choices provided, which, in this case, are the attributes of a conjoint analysis. As a result, with this procedure we are able to backtest the choices made in the conjoint analysis.

The results indicate that the most important attributes remained rating (score) and five-year average return. However, the five-year average return gained even higher significance, from 32.04% to 46.59%, making it the most important attribute in MaxDiff, whereas the most important attribute by the investor's choice in the conjoint analysis was rating (score). Investment objectives remained third, however, declining slightly from 22.93% to 17.05%. Finally, green bond type remained the least important in both the conjoint analysis and the MaxDiff scaling (5.09% against 13.64%).

The results show that the highest score (score range from 1.00–5.00) goes to air and water pollution from the environmental pillar, with 4.16.

TABLE 5 Factors Influencing the Investment Decision

Influencing factor	(1)	(2)	(3)
Penalizing capital requirements for high-carbon assets	3.63	0.93	0.86
Tax incentives	3.74	1.03	1.06
Subsidies	3.41	0.98	0.97
Mandatory climate-related financial disclosures (e.g. adoption of Task Force on Climate-Related Financial Disclosures)	3.41	0.95	0.89
Regulatory and legislative trends	3.38	0.89	0.79
Broadly accepted and enforced official minimum standards for green definitions and criteria set	3.49	0.95	0.91

NOTES Column headings are as follows: (1) mean, (2) standard deviation, (3) variance.

In contrast, the lowest score of 2.66 is for executive compensation from the governance pillar. The environmental pillar received the highest overall score with 19.45, followed by the social pillar with 17.91 and the governance pillar with 15.08. It can clearly be seen that the most important pillar is the environmental, meaning that the results coincide with the outcome of the conjoint analysis, where investors indicated that environmental issues are the most relevant when they make their investment choices.

Overall, the survey respondents placed importance on the positive and credible fundamentals of a green bond as well as the transparency of a green bond issuer. They also indicated that external review, inclusion in major indices and certification under the Climate Bonds Standard enhance a green bond's attractiveness. In contrast, survey respondents care less about the availability of impact reporting, post-issuance transparency and detailed use-of-proceeds disclosure.

The main policy mechanism that is perceived to enhance the investments undertaken in green bonds are tax incentives, with preferential capital treatment for low-carbon assets ranked second. In general, however, respondents indicated positivity towards the enhancing effects of the listed policy mechanisms. Additionally, rising interest rates could further support an increased appetite for green bonds.

In summary, survey respondents said they consider each listed factor that could enhance green bond investments to have some importance, with no factor scoring a mean value lower than 3.38. However, tax incentives and penalties for high-carbon assets appear to be of the greatest importance for a future increase in green bond investments.

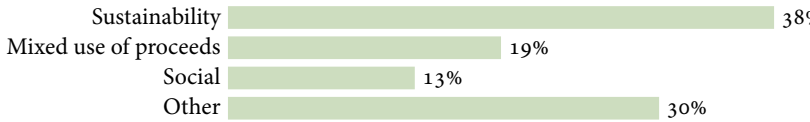

FIGURE 1 Green Bond Experience of Respondents

Figure 1 illustrates the survey respondents' purchasing behaviour regarding green bonds. On a portfolio level, 38.42% of survey respondents said they have bought sustainability bonds, and another 30% said they have purchased a bond whose type is not listed in the survey.

PRE- AND POST-ISSUANCE PREFERENCES

On an investor level, 40.56% of participants said they are more inclined to buy a green bond if the issuer has issued a green bond in the past. Nevertheless, 51.11% indicated that they do not have a preference regarding past issuances. In contrast, a large majority of participants emphasized the importance of a trustworthy investment of proceeds after issuance of a green bond, with 88.44% of respondents indicating they are unwilling to buy a green bond if it is not guaranteed that proceeds will be allocated to green projects (47.78% of respondents), or that they would be completely opposed to buying such a bond (40.56% of respondents).

When already invested in a green bond, 45.56% of participants said they would sell the bond if post-issuance reporting was poor, and 38.33% said they would consider selling. Only 16.11% said they would keep the bond.

Discussion

The hypothesis that is studied within the scope of this paper is whether institutional investors consider governance issues to be more important than environmental or social issues. The aim of the research paper is to incorporate ESG into green bonds, by studying the preference of institutional investors regarding each separate pillar of ESG. This was made possible with the application of the CBC analysis. The results indicate that institutional investors from the German-speaking regions of Switzerland, Liechtenstein, Austria and Germany consider environmental issues to be predominant in their investment universe, contradicting literature on institutional investors (Chung, Elder, and Kim 2010; McCahery, Sautner, and Starks 2016). Consequently, the hypothesis statement, which posits that governance issues are more important than environmental and social considerations, is rejected. The key performance indicator (KPI) choices

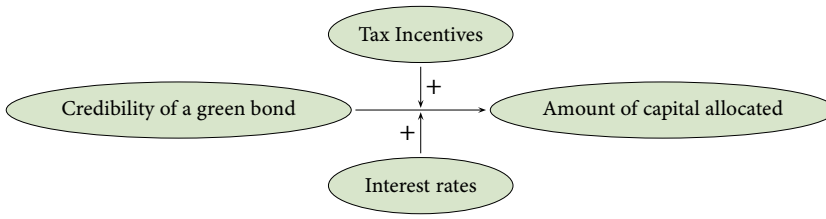

FIGURE 2 Moderating Model Depicting the Relationship Between Credibility and Amount of Capital Allocated

supported the results, which illustrated the dominance of the environmental pillar. Air and water pollution scored the highest compared to other KPIs. In fact, the governance pillar and its underlying KPIs scored the lowest, which again proves that the hypothesis did not hold. The KPI from the social pillar that scored the highest was human rights, and in the governance pillar, it was ethics and corruption.

Although investors consider each policy mechanism in the questionnaire to be at least somewhat important, the monetary part appears to be of special importance to investors, as the effect of tax incentives reveals. Furthermore, the general interest rate environment influences the decision of investors to invest in green bonds, as depicted by the model in figure 2.

As can be derived from the model, the independent variable, which is the credibility of a green bond, drives the decision to allocate capital to such a bond. The level of interest rates as well as tax incentives granted moderate this relationship in a positive manner, thus, the higher the interest rates and the more attractive the tax incentives, the larger the amount of capital allocated. Interestingly, the sustainability aspect plays an insignificant role in the amount of capital allocated towards a green bond, when this bond is already deemed as 'credible,' therefore fulfilling the sustainability requirement. This is in line with governance on a firm-level, as researched (Chung, Elder, and Kim 2010; McCahery, Sautner, and Starks 2016).

Conclusion

Overall, this research has demonstrated that investors are open to green bond investments. This openness is not just a 'given' factor, as investors do expect some sort of guarantee regarding the allocation of green bond proceeds towards green investment after issuance – with a significant

part of our sample even being explicitly opposed to 'deceiving' bonds – which is also reflected in the willingness to sell green bonds in the case of poor post-issuance reporting. Regardless of substandard allocation or deficient post-issuance reporting, market participants are strict regarding the trustworthiness of green bonds, leading to a green bond issuer's reputation being at stake when it fails to fulfil its promises, thereby risking negative financial implications for investments of institutional investors. Whether an issuer has released a green bond previously does not play a significant role in this behaviour, although past issuances do depict a signal of trust, contributing to governance-related aspects. Within the regulatory environment of green bonds, certification as set out under the Climate Bonds Standard enhances attractiveness for investors, who, despite it being a requirement under this standard, tend to care less about the availability of detailed impact reporting and use-of-proceeds disclosures. The latter contradicts expectations base on available literature on a firm-level.

Looking at the specific nature of green bonds, with governance-related aspects being built into the financial instrument itself, the governance criterion is assumed to be fulfilled, with green bonds in turn providing assurance regarding the financial implications of climate-related risks. Therefore, we conclude that, under the condition of governance requirements being fulfilled, environmental aspects prevail in the investment decision.

LIMITATIONS AND SHORTCOMINGS

A useful definition of limitations can be explained as systemic bias that falls outside a researcher's control and may have a negative influence on the outcome (Price and Murnan 2004, 66). Nevertheless, according to Chasan-Taber (2014, 219), many authors do agree that limitations are inevitable and will arise at some point during research. Variables of chance, confounding possibilities and multiple biases are the three major issues that a researcher must address (Chasan-Taber 2014, 220). The validity concept, which was originally proposed by Campbell and Stanley (1963), influenced the way in which researchers perceive their papers. The concept refers to how accurately a method measures what it is intended to measure. Many practitioners accept the fact that multiple factors may threaten a study's validity and that many issues may remain unresolved. External validity is the main concern, especially if it relates to the theoretical part of the research (Calder, Phillips, and Tybout 1982, 240). Given

the available literature on the topic of green bonds and ESG, recent studies have focused more on the performance-based rating or scores as well as the performance of sustainable indexes. The focus of this research is to investigate preferences of German-speaking institutional investors from Germany, Switzerland, Liechtenstein and Austria. That said, the research settings are crucial, as they are supported by external validity (Chasan-Taber 2014, 234–5). However, this study's sample, consisting of Swiss, Liechtensteiner, Austrian and German institutional investors after cleansing, may be considered low. Due to additional factors or a set of factors, internal validity may also be compromised, and this may lead to an inaccurate estimate of the true association between exposure and outcome (Skelly, Dettori, and Brodt 2012, 9). This may affect the relationship that was found among German, Austrian, Swiss and Liechtensteiner institutional investors, and could be due to uncontrolled factors that may or may not have occurred during this research. A difference in the sample could also have a negative effect on the overall plausibility of an outcome.

Although each question was clearly worded, some survey respondents may have encountered a language barrier that impeded their ability to fully understand the questions. This could be caused by some defects in the process design, also referred to as design bias (Price and Murnan 2004, 66). The overall approach of this research deviates from the theory and focuses more on the factors that influence investment decisions. Consequently, there is a possibility that this led to unforeseen answers, especially with the least experienced investors. Finally, regarding the questionnaire, investors had an idea of what the researcher required as well as the overall goal of the study. Therefore, this could have led to a biased outcome, as the reaction of respondents may have been provoked.

In this paper we explicitly shed light on the behaviour of institutional investors. By doing so we limited the scope of this paper to reflect only people who are assumed to display the highest affiliation with investments. Although the survey was designed in a highly structured and self-explanatory manner, some respondents may not have been as knowledgeable about sustainable investment and detailed green bond specifics as others were. This situation could lead to self-selection bias, which is seen as the complementary type of selection bias (Schlegelmilch 1997, 50). Bias may have been encountered within sociodemographic features, as respondents may be unwilling to disclose annual income, for example. Finally, the questionnaire was prepared in a way to help respondents deviate from the theory and focus more on practical implications.

RECOMMENDATIONS FOR FUTURE RESEARCH

Several recommendations for future research can be provided based on the outcome of this research paper. With reference to the study made by Amel-Zadeh and Serafeim (2018), which revealed that origin and background are significantly important in the decision-making process, this could be an interesting area to research in future. This study paves the way for future research to be conducted on investor preferences of green bonds in combination with mainstream sustainability concepts such as ESG and Sustainable Development Goals. As the sample used in this paper is rather small compared to the size of the population of the region covered, it is recommended to increase the scale of the sample by also including non-business participants and financial resources available for conducting future studies.

Furthermore, since we explicitly covered only the German-speaking regions of continental Europe, it is recommended to include additional regions to study any regional differences regarding investor preferences. Moreover, Sustainable Development Goals could be substituted for ESG to determine the preferences within the investment universe. Finally, the main method applied was the CBC analysis, which is not widely used in the financial industry. However, given its potential in confronting respondents, this analysis may adopt new attributes and levels such as investment strategies and other KPIs.

The results of this research should be of interest to many scholars and practitioners in the field of sustainability, which may include institutional investors, retail investors and financial institutions in general. This study highlights the importance of sustainability as well as issues surrounding the concept. Consequently, financial institutions may apply this knowledge to promote sustainable funds and other green investment instruments.

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Business Intelligence Enabling Competitiveness: A Multi-Theoretical Analysis of South African Metals Manufacturers

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The competitiveness of the South African metals manufacturers is under the spotlight, since new investments in the metals and engineering industry in South Africa have been poor, and growth in the Chinese trade has had a negative competitive effect on domestic metals manufacturing output and employment. The purpose of the study was to determine how supportive the business intelligence process is in enabling successful competitiveness in practice. A theoretical model was designed and empirically tested by metals manufacturers, where four theories were selected to act as mediators between the business intelligence process and successful competitiveness. This study tested four hypotheses by applying Spearman's rank-order correlations and a structural equation model. A total of 63 responses were received and analysed. The study found that the building blocks of the business intelligence process combined in a single factor do not directly lead to successful competitiveness, but only when all the theories' principles, combined into a single factor, act as mediators.

Key Words: business intelligence, knowledge-based view, metals manufacturers, resource-based view, sustainable development, theory of constraints
JEL Classification: M15, L61
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Introduction

This study investigates how the business (competitive) intelligence process enables successful competitiveness (competitive advantage) in the

South African metals manufacturing industry. Four theories were included in a theoretical structural model together with the business intelligence process as the independent variable and *successful competitiveness* as the dependent variable. The approach was not *per se* to test the theories, but rather to analyse them as a possible link between the building blocks of the business intelligence process and successful competitiveness. Consequently, these theories incorporated specific questions in a questionnaire that aggregates the principles of each theory. The selected theories, which were all employed in various business intelligence studies are (i) the resource-based view that states that organisational resources are essential to create sustainable competitive advantage (Polidoro and Toh 2011), (ii) the knowledge-based view that considers knowledge in itself as a resource (Wang, He, and Mahoney 2009; Le Roux and Oosthuizen 2010), (iii) the theory of constraints that highlights the most important limiting factors or constraints in firms that prohibit the achievement of goals and are usually identified and systematically addressed until these constraints no longer limit firms (Goldratt 1990), and (iv) the theory of sustainable development that focuses on 'development that meets current requirements without compromising future requirements' (United Nations 1987).

Business intelligence is aimed at gaining a strategic competitive advantage (Porter 1980). Although there are many ways to understand the concept of business intelligence, an encompassing definition is 'the legal collection and analysis of information regarding the capabilities, vulnerabilities and intension of business competitors conducted by using "open sources" and ethical inquiry' (https://www.scip.org/). Typically, there are six building blocks found in the competitive intelligence process, namely (i) planning and focus, (ii) collection, (iii) analysis, (iv) communication, (v) process and structure, and (vi) organisational awareness and culture (Dishman and Calof 2008).

South African metals manufacturers were selected to be the main focus of the study, as their competitiveness is currently under the spotlight due to limited new investments and a drop in the production efficiency of fixed capital (Chibanguza and Noise 2017). Furthermore, there is a perception in South Africa that the growth in the Chinese trade (accounting for more than half of the global metals consumption) has had a negative competitive effect on domestic metals manufacturing output and employment, which resulted in, according to Swansy (2016), demands for increased protection from Chinese imports.

This paper is a unique part of a greater study that investigated metals manufacturers in South Africa in order to develop a business intelligence framework to enhance their sustainability. Accordingly, the purpose of this paper was to determine how supportive the business intelligence process is in enabling successful competitiveness in practice. In achieving this, a theoretical model was designed and empirically tested. Firstly, a direct relationship was tested between the business intelligence process and successful competitiveness, followed by analyses where the theories' principles were included to serve as mediators. The theoretical contribution of this study is found in the conclusion about the mediating role of the combination of selected theories to support the business intelligence process, which may enable successful competitiveness.

In the next section, the design of the theoretical model is discussed, including the conceptual frame that indicates the different paths and the hypotheses to be tested. This is followed by the design of the empirical study, results, testing the hypotheses and a concluding discussion thereof.

Theoretical Model

THE BUILDING BLOCKS OF THE BUSINESS INTELLIGENCE PROCESS

The business intelligence wheel, developed by Dishman and Calof (2008), indicates that there are a total of six building blocks (BB), classified into two categories, in business intelligence, namely:

Core building blocks:

- BB1 (Planning and focus), which entails decisions about what information is available, as well as for what purpose(s) and from which resource(s) it was collected.
- BB2 (Collection), during which required data for a competitive intelligence exercise is collected, aligning various sources and acquisition methods.
- BB3 (Analysis), during which the collected information is converted into *actionable intelligence* from which strategic and tactical decisions can be made.
- BB4 (Communication), during which the created intelligence is communicated to those with the appropriate responsibility.

Supporting building blocks:

- BB5 (Process and structure), which requires appropriate policies, procedures and infrastructure to enable effective contribution to the intelligence system.
- BB6 (Organisational awareness and culture), i.e. enabling/empowering companies to utilise their intelligence efforts successfully.

Companies should know how to remain competitive and how to anticipate and react to changes inside and outside the industry. In order to manage such a challenge, companies should have a process in place to turn data into information, and information into actionable intelligence, from which strategic and tactical decisions can be made. These processes of gathering data and turning raw data into intelligence are fundamental aspects of conducting business (Laudon and Laudon 2012).

For hypothesis building and testing, the researchers developed a number of statements to measure the practical application of each of the six building blocks included in the business intelligence process. According to the researchers' judgement, four statements were developed for each building block, which can be viewed in table 1.

SELECTED THEORIES

The theoretical model of this paper entails a combination of four selected theories, primarily centred on key factors impacting continued sustainability, namely the resources of human capital, knowledge, and natural capital, as well as cognisance of possible constraints in which the organisation may operate.

The first theory is T1 (Resource-based view), which states that organisational resources and capabilities are essential to ensure the creation of a competitive advantage (Kessler 2013; Wang, He, and Mahoney 2009). A common measure that reflects the status of resource utilisation is indexes to measure production efficiency. With reference to this study, the average index rating for 2015 and 2016 for the iron and steel products subsector was well below the full capacity norm, which is indicative of lower efficiency and lower productivity (Chibanguza and Noise 2017). To measure and test the importance of the resource-based view for companies in the metals manufacturing industry (with special reference to human resources), the following was posited:

- The effective application of human resources will lead to a competitive advantage; and

- Companies apply human resources effectively to attain a competitive advantage.

Secondly, T2 (Knowledge-based view) refers to the deployment of knowledge as a resource (Wang, He, and Mahoney 2009; Peters et al. 2016). As such, business intelligence provides a framework of knowledge to organise coordinated activities in a group, to analyse and share information, and to incorporate active collection techniques (Streamcrest 2003). Therefore, companies should actively involve their employees as a key part in organisational knowledge, as intellectual capital becomes more accepted as being a valuable resource for a sustainable, successful economic future (Auer 2004). To measure and test the knowledge-based view for companies in the metals manufacturing industry, two statements were posited:

- Companies know certain competitive aspects *better* than their competitors do; and
- Companies know certain competitive aspects *sooner* than their competitors do.

Thirdly, T3 (Theory of constraints) refers to a managerial framework for continuous improvement where the *weakest link* is regarded as the largest constraint, which should be addressed first (Kessler 2013). It highlights the most important limiting factors in companies that prohibit them from being competitive (Goldratt 1990). To measure and test aspects of the theory of constraints in the metals manufacturing industry, the following were posited:

- Companies regularly identify their most debilitating constraints; and
- When companies identify their most debilitating constraints, such constraints are addressed until they are no longer inhibiting factors.

Finally, the declaration of the World Commission on Environment and Development (United Nations 1987) makes it clear that T4 (Sustainable development) emphasises that (economic) development should be pursued with a sense of shared responsibility towards future generations. According to Seliger (2007), sustainability is directed at enhancing the living standard of humans while ensuring the continued availability of natural resources for future generations. To measure and test aspects of sustainable development (with specific reference to natural resources) for companies in the metals manufacturing industry, the following were posited:

- Companies are sensitive to matters pertaining to sustainable development; and
- Companies incorporate the principles of sustainable development in their operations.

COMPETITIVENESS IN THE SOUTH AFRICAN METALS AND ENGINEERING INDUSTRY

The South African metals manufacturers form part of the manufacturing industry and are a combination of the metals industry and the engineering industry (Lundall, Maree, and Godfrey 2008). According to the current economic sector census, the metals and engineering industry covers 29 percent of the manufacturing industry footprint (Statistics South Africa 2017). The fortunes of the metals and engineering industry correlate with the South African economy (Chibanguza and Noise 2017), and as such, growth in the South African economy is an important prerequisite for the metals and engineering industry. Unfortunately, the human resource utilisation in the metals and engineering industry can be considered a drawback, as is illustrated by the labour cost increase of 81 percent (2005 to 2015), while labour productivity increased by only 12 percent (Statistics South Africa 2017), thereby creating a competitively unsustainable situation.

South Africa is typically considered a mineral-rich country, and China, as one of the fastest developing countries in this era, requires South African minerals as part of its growth strategy. There is, however, a perception that the growth in Chinese trade has had a negative competitive effect on domestic manufacturing (Swansy 2016). It is widely accepted that competitiveness brings improved performance (Du Plessis et al. 2015), and a healthy state of competitiveness is of critical importance to the good health of South African metals manufacturers. To measure the successful competitiveness of the metals manufacturers, seven statements were developed and divided into four themes, namely (i) resource utilisation, (ii) the so-called China effect, (iii) performance, and (iv) globalisation. The inclusion of the seven statements was further motivated during the pilot study phase when industry experts voiced important viewpoints.

In order to test the *resource utilisation,* the following was posited:

- The effective application of human resources will lead to a competitive advantage in the South African metals manufacturing industry.

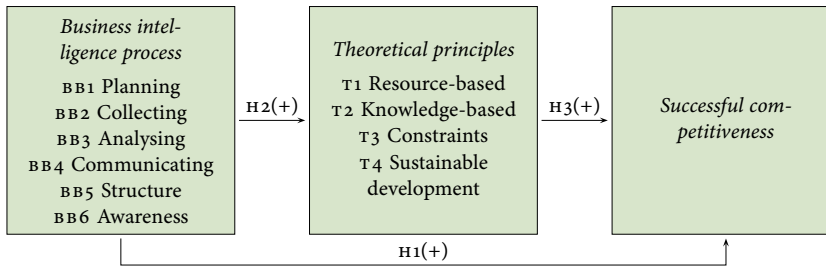

FIGURE 1 Conceptual Scope

Regarding the *China effect,* the study posited:

- South African companies in the metal manufacturing industry will have a better competitive position in relation to China if the level of competitive intelligence in the company increases; and
- South Africa's trading with China is benefitting South African companies in the metal manufacturing industry.

To test *performance,* the study posited:

- The efficiency of South African companies in the metal manufacturing industry can be significantly improved; and
- The competitiveness of South African companies in the metal manufacturing industry can be significantly improved.

In terms of *globalisation,* the study posited:

- The global trading market is benefitting South African companies in the metal manufacturing industry; and
- South African companies in the metal manufacturing industry are cognisant of the competition laws of the countries of their clients.

CONCEPTUAL FRAME AND HYPOTHESES

Figure 1 provides a frame for the broad conceptual scope in which the study was concluded. Each of the six building blocks in the business intelligence process is to be tested to enable successful competitiveness, while the theoretical principles are employed as mediators. Note that the theoretical model is not the destination, but rather the vehicle to clarify the theories' relationships.

As exhibited in figure 1, the study firstly argues that when the building blocks of the competitive intelligence process are adequately accomplished, it will be directly related to (H1) enabling successful competitiveness, and (H2) enhance the principles of the four selected theories. With

such theories as the mediators, it can also be argued that (H3) the adequate accomplishment of the theoretical principles will be related to the successful enabling of competitiveness. A correlation analysis of the relationship between the above hypotheses (H1, H2 and H3) should allow the study only to conclude upon the size and the direction of the relationship. Therefore, the study's second argument is that more insight can be gained by analysing (H4) how the building blocks enable successful competitiveness via the four theories' principles. Therefore, a structural equation model analysis may further support the refinement of the selected theories and to improve the practical value of the study.

Design

The target population was the metals manufacturers in South Africa. The metals manufacturing fraternities employed 38,860 workers in quarter 4 of 2016 (Statistics South Africa 2017), of which approximately 15 percent are employed in management, engineering and other supervisory roles (C. Dednam, e-mail to author, 14 July 2017), the latter of which were targeted. The questionnaire was distributed via two employer representative organisations, namely SEIFSA (Steel and Engineering Industries Federation of Southern Africa) and SAISI (South African Iron and Steel Institute). The request to the employer representative organisations was twofold, namely (i) to send the questionnaire to its member employers, and (ii) to request that the questionnaire be distributed by the employers in their organisations.

In developing the questionnaire, the researchers were guided by a questionnaire that tests business intelligence practices as developed by Saayman et al. (2008) as well as suggestions obtained during the literature review and the pilot study phase. This article reports on (i) the demographic information, (ii) the business intelligence process, (iii) testing the application of the selected theories, and (iv) competitiveness in practice. In all cases, statements were posed that requested responses on a five-point Likert scale ranging from strongly disagree (option 1) to strongly agree (option 5). In terms of structuring the questionnaire, the following should be noted:

- Firstly, in total, 24 statements were ordered to support the six building blocks (table 1). The first four statements from each of the six building blocks were followed progressively by the other statements in order to ensure continued reliability of the factor analysis to be followed.

- Secondly, the four theories each led to two statements that summarise the principles of the theory as posited with regard to the South African metals manufacturers (table 2). A similar practice as above was followed, where the eight statements for the final questionnaire were ordered by selecting the first statement from each of the four theories followed by the second statement, again to ensure continued reliability of the factor analysis.
- Finally, seven statements, representing what was posited with regard to the metals manufacturers, were developed from themes identified during the literature reviews and from views of experts, to evaluate the competitiveness in practice (table 3). Therefore, a variety of divergent statements were used to determine the degree of practising the broad themes identified, utilisation of resources, the China effect, performance and the global environment. Note that the statements are differently specified, i.e. for Statements E4, E6 and E7, a higher selection on the five-point Likert scale implies a higher degree of positivity and *vice versa*. Statements E1, E2, E3 and E5 show the opposite, where a higher score represents a higher degree of negativity and *vice versa*. Therefore, the respondents' answers to the latter four statements were reversed before they were used in the analyses.

The reliability and validity of the questionnaire were tested during multiple practical sessions, including a structured pilot study.

The results were analysed by means of a factor analysis, the purpose being to determine which items belong together. Confirmative factor analysis was used in sections where the four statements per building block and the two statements per theory, respectively, already form predetermined groups. Exploratory factor analysis was used where the seven divergent statements were posed to the respondents. The following guides were employed to interpret the factor analysis: Cronbach's alpha coefficients were used to gauge reliability and internal consistency (accepted values > 0.7); eigenvalues of factors and scree plots assisted with factor extraction (acceptable values > 0.5); communalities indicate the common variance present in a variable (a variable with no specific variance shows a communality of 1 and a variable that shares none of its variance with any other variable shows a communality of 0); and Kaiser-Meyer-Olkin (KMO) values were used to determine sample adequacy (acceptable values > 0.5) (Field 2009).

To test the relationship between all variables, the non-parametric approach of Spearman's rank-order correlation analysis was used. Correlation analysis was applied to test the first three hypotheses.

To test the fourth hypothesis, a structured equation model (SEM) was applied to explore the paths (i) directly from the building blocks to successful competitiveness, and (ii) from the building blocks to the theories and from the latter to successful competitiveness. SEM is based on the principles of chi-square analysis and interpreted accordingly. This model was tested through the collected data and the following pointers were used as a guide to the model fit: CMIN/DF (minimum sample discrepancy divided by the degrees of freedom) should be interpreted subjectively by the researcher; however, ratios as high as 3, 4 or even 5 are considered as still representing a good fit (Meuller 1996); CFI (comparative fit index) > 0.9 indicates an overall good fit (Meuller 1996); and RMSEA (root mean square error of approximation) should be less than 0.1 (Blunch 2008).

Results

RESPONSE

In total, 63 usable questionnaires were completed by respondents. The overall analysis of the completed questionnaires showed good KMOS and Cronbach's alpha coefficients, and it was recommended by the North-West University's Statistical Consultation Services that additional data collection was not necessary.

The respondents represent firms with fewer than 200 employees (48%), between 200 and 1,000 (27%), between 1,000 and 3,000 (14%) and more than 3,000 (11%). The respondents were mainly from management (76%) and specialists (13%), and 57 percent of the respondents are more than 50 years old. The respondents are highly experienced, with 76 percent who have been employed for more than 10 years in the metals and engineering industry.

BUSINESS INTELLIGENCE PROCESS

The six building blocks of business intelligence in section B of the questionnaire delivered one factor for each of the building blocks. The factor pattern matrixes for the aforementioned six building blocks/factors are shown in table 1. Building block, or factor, 6 obtained the lowest but acceptable KMO coefficient (0.604), the lowest first component eigenvalue of 47.87 percent, marginally below the 0.5 norm, and lowest Cronbach's

TABLE 1 Confirmatory Factor Analysis of Six Building Blocks

CI Building block	Factor statistics					(6)	(7)	(8)
	(1)	(2)	(3)	(4)	(5)			
BB1: Planning & focus	0.714	63.66	0.809	3.492	0.798	1	0.753	0.567
						7	0.875	0.766
						13	0.893	0.797
						19	0.645	0.417
BB2: Collection	0.718	58.38	0.710	3.387	0.725	2	0.269	0.072
						8	0.889	0.791
						14	0.857	0.734
						20	0.859	0.738
BB3: Analysis	0.823	73.45	0.876	3.426	0.909	3	0.884	0.781
						9	0.854	0.729
						15	0.782	0.612
						21	0.903	0.816
BB4: Communication	0.787	63.95	0.811	3.379	0.786	4	0.740	0.547
						10	0.805	0.649
						16	0.822	0.675
						22	0.829	0.687
BB5: Process & structure	0.727	58.01	0.766	3.302	0.802	5	0.824	0.679
						11	0.718	0.515
						17	0.736	0.541
						23	0.764	0.584
BB6: Awareness & culture	0.604	47.87	0.625	3.277	0.676	6	0.524	0.275
						12	0.698	0.487
						18	0.698	0.487
						24	0.816	0.666

NOTES Column headings are as follows: (1) KMO, (2) eigenvalue (%), (3) Cronbach's Alpha, (4) factor mean, (5) factor standard deviation, (6) question number, (7) loading, (8) communality.

Continued on the next page

alpha of 0.625, below the 0.7 norm, and also the lowest factor mean coefficient (3.277) of all six of the building blocks. The rest of the building blocks obtained good factor scores, i.e. KMOS between 71.4 percent and 82.3 percent, first component eigenvalues of between 58.01 percent and 73.45 percent, Cronbach's alphas between 71 percent and 87.6 percent, and

TABLE 1 *Continued from the previous page*

No.	Question
1	Our company plans what CI information we need
2	In our company CI information is analysed in order to achieve CI results
3	In our company CI information is analysed in order to achieve CI results
4	In our company reported CI information is passed on to decision-makers
5	Our company has structures whereby CI information can be reported
6	Our company has CI training available for our employees
7	The results of our CI efforts are such that it influences our company's strategic direction and decision-making
8	Collected information in our company is checked for accuracy and validity before being forwarded in our system
9	Collected information in our company is checked for accuracy and validity before being forwarded in our system
10	In our company we generally receive feedback of CI information
11	Our company maintains CI information in formal ICT systems
12	In our company we are encouraged to report information that can contribute towards our company's competitive position
13	In our company we focus on CI information gathering that will benefit us
14	In our company analysed information can be obtained from a variety of information management systems
15	In our company analysed information can be obtained from a variety of information management systems
16	In our company helpful information is frequently communicated upwards and downwards
17	We know how to collect information that could be of competitive value to our company
18	Our company encourages the sharing of information that could be to the advantage of our company
19	In our company we only gather specific information on which we base our CI
20	Our company continually analyses information to provide competitive advantages
21	Our company continually analyses information to provide competitive advantages
22	Non-sensitive CI findings are available to employees
23	We maintain profiles of our customers and competitors
24	Our office-bound employees understand what CI is

the factor means between 3.302 and 3.492. Except for Questions 2 and 6, all the communality values are mostly above or close to 0.5.

TABLE 2 Confirmatory Factor Analysis of the Selected Theories

No.	Statement	(1)	(2)	(3)	(4)
D1	The effective application of human resources will lead to a competitive advantage for my company	•			
D2	My company knows certain competitive aspects better than our competitors		•		
D3	My company regularly identifies our most inhibiting constraints			•	
D4	My company is sensitive to the matters around sustainable development				•
D5	My company applies human resources effectively such that it leads to a competitive advantage for my company	•			
D6	My company knows certain competitive aspects sooner than our competitors		•		
D7	Once my company identifies our most inhibiting factors we address it until it is not inhibiting any longer			•	
D8	My company incorporates the principle of sustainable development in our operations				•
Cronbach's Alpha		0.379	0.689	0.758	0.819
Component mean		3.540	3.532	3.640	
Component standard deviation		0.748	0.834	0.836	

NOTES Column headings are as follows: (1) theory 1: D1, D5, (2) theory 2: D2, D6, (3) theory 3: D3, D7, (4) theory 4: D4, D8.

MULTIPLE THEORIES

Table 2 shows the eight statements supporting the four theories (Section D of the questionnaire). An analysis of the spread of the responses and descriptive statistics of the eight statements supporting the four theories has shown that the means of the responses provided by the participants were higher than 3. This implies that the participants generally agreed with the statements.

The highest difference between two means per theory occurred in Theory 1 (0.6 = 4.2 – 3.6). In retrospect, it can be argued that it is only in the case of Statement 1 where the phrasing of the sentence is more general, whereas the rest of the statements in this section are phrased specifically to test the views of the participants with regard to 'my company.' It was, therefore, easier for the participants to agree with a more general statement than to evaluate a response based on the realities of their own company. Consequently, Statement 1 was eliminated from the study, espe-

TABLE 3 Exploratory Factor Analysis for Seven Divergent Statements

No.	Statement	(1)	(2)	(3)
E3	The efficiency of my company can be significantly improved	0.909		0.825
E1	The human resources (HR) capacity utilization of my company can be significantly improved	0.807		0.654
E5	The competitiveness of my company can be significantly improved	0.793		0.627
E2	My company will have a better competitive position in relation to China should my company's level of competitive intelligence (CI) increase	0.757		0.593
E6	The global trading market has benefits for our company		0.773	0.631
E7	Our company is cognizant of the competition laws of our clients' countries		0.748	0.559
E4	South Africa's trading with China has benefits for our company		0.714	0.509
Factor Cronbach's Alpha		0.835	0.605	
Factor mean		3.791	3.213	
Factor standard deviation		0.731	0.830	

NOTES Column headings are as follows: (1) factor 1, (2) factor 2, (3) communalities. Kaiser-Meyer-Olkin measure of sampling adequacy = 0.687, eigenvalue of component 1 = 38.93%, eigenvalue of component 1 and 2 (cumulative) = 62.83%.

cially when anomalies were also identified in further analyses. Therefore, its paired statement, Statement 5, was, treated as a stand-alone statement (T1.5). This is supported by the attempt to define a factor from Statement 1 and Statement 5 that resulted in a Cronbach's alpha of 0.379, resulting in the rejection of the factor. The remaining six questions are paired in three sets of two questions in the questionnaire to test for three theories (T2, T3 and T4).

COMPETITIVENESS

The seven arbitrary statements designed to test views on successful competitiveness in practice are shown in table 3. The exploratory factor analysis identified two factors.

Each factor component in section E loaded a minimum of 0.714 and communalities ranged from 0.509 to 0.909. The means of both factors calculated at more than 3, the mid-point of the Likert scale. The first factor focuses on 'my company' and can be considered a more inwardly focused perspective, which is renamed as Practical Competitiveness-

TABLE 4 Spearman's Correlation Coefficient (rho) Matrix

	BB1	BB2	BB3	BB4	BB5	BB6	T1.5	T2	T3	T4	PC-I	PC-E
BB1	1,00											
BB2	0.70**	1,00										
BB3	0.83**	0.77**	1,00									
BB4	0.70**	0.79**	0.73**	1,00								
BB5	0.73**	0.66**	0.80**	0.76**	1,00							
BB6	0.69**	0.80**	0.78**	0.82**	0.75**	1,00						
T1.5	0.46**	0.23	0.36**	0.26*	0.31*	0.33**	1,00					
T2	0.57**	0.54**	0.60**	0.46**	0.47**	0.52**	0.43**	1,00				
T3	0.59**	0.43**	0.62**	0.62**	0.63**	0.60**	0.53**	0.61**	1,00			
T4	0.56**	0.49**	0.55**	0.59**	0.49**	0.53**	0.50**	0.60**	0.80**	1,00		
PC-I	0.39**	0.23	0.19	0.24	0.22	0.27*	0.23	0.20	0.37**	0.28*	1,00	
PC-E	0.17	0.30*	0.26*	0.30*	0.13	0.23	0.14	0.09	0.22	0.25*	0.09	1,00

NOTES * Correlation is significant at the 0.01 level (two-tailed). ** Correlation is significant at the 0.05 level (two-tailed).

Internally focused (PC-I). The second factor looks at the bigger picture and can be considered a more outwardly-focused perspective, which is renamed as Practical Competitiveness-Externally focused (PC-E). The PC-I factor obtained a Cronbach's alpha of 0.835 and can be considered good, while the PC-E factor obtained a Cronbach's alpha below 0.7 and can be considered acceptable but not good.

TESTING HYPOTHESES

To test the first three hypotheses, the monotone relationship between variables was determined. Table 4 displays the non-parametric Spearman correlation (rho) between the variables.

The first hypothesis is partly supported, where the building blocks BB1 and BB6 are significantly positively related to PC-I. Furthermore, it is also supported where building blocks BB2, BB3 and BB4 are significantly positively related to PC-E.

Except for the non-significant correlation between BB2 and T1.5, the second hypothesis is supported, since there is a positive significant relationship between each of the building blocks of the business intelligence process and each theory's principles.

The third hypothesis is only supported where there is a positive relationship between T3 and T4 and PC-I, as well as T4 and PC-E.

TABLE 5 Regression Default Model: PC-I = Dependent Variable

			Estimate	SE	CR	*p*	Estimate*
Theories	←	BB	0.619	0.130	4.748	***	0.787
BB1	←	BB	1.000				0.893
BB2	←	BB	0.871	0.091	9.602	***	0.855
BB3	←	BB	1.190	0.101	11.795	***	0.933
BB4	←	BB	0.968	0.095	10.158	***	0.877
BB5	←	BB	0.988	0.097	10.164	***	0.877
BB6	←	BB	0.845	0.080	10.537	***	0.891
T1.5	←	T	1.000				0.624
T2	←	T	0.913	0.201	4.549	***	0.684
T3	←	T	1.393	0.248	5.618	***	0.936
T4	←	T	1.262	0.237	5.324	***	0.847
PC-I	←	T	0.575	0.299	1.923	0.054	0.441
PC-I	←	BB	0.001	0.220	0.004	0.997	0.001

NOTES * Standardised regression weights: default model. Model: CMIN/DF = 1.982; CFI = 0.929; RMSEA = 0.127.

To further shed light on the relationship where all variables are included, a structural equation model was built to test the collected data. Two models were tested, where the first unravels how the building blocks of the competitive intelligence process support PC-I directly and how they support PC-I through the mediation of the principles of the theories. The second model was similar, with the only difference being that PC-E replaced PC-I.

The researchers decided to test the six building blocks together against (i) PC-I (or PC-E) and (ii) against the four theories together, and (iii) test the four theories together against PC-I (or PC-E). The reason for this is that an analysis shows that Cronbach's alphas for the six building blocks and the four theories are 0.955 and 0.855, respectively. These high scores confirm that it is sensible to put the six building blocks and the four theories together in groups. A similar analysis to regroup PC-I and PC-E together was not realised, as a result of a very low Cronbach's alpha of –0.165, which confirms the original exploratory factor analysis to treat them as separate factors.

Table 5 exhibits the results as per AMOS, a part of the SPSS software where PC-I is the dependent variable, the grouped building blocks the

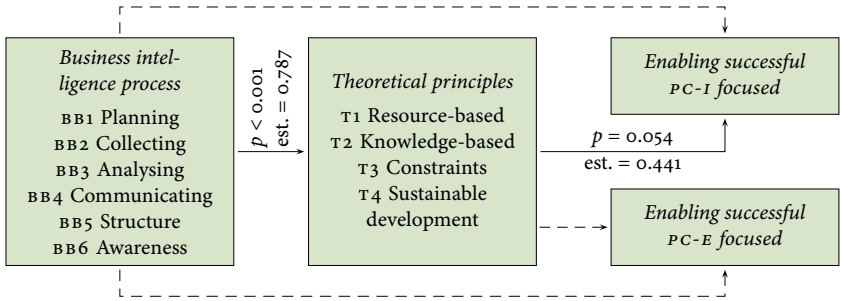

FIGURE 2 Structured Equation Model (dashed – insignificant path)

independent variable and the grouped theories the mediator. Table 5 can be interpreted as a regression analysis, where *** indicates a significance level of less than 1 percent. Note that the emphasis is on the relationship and that this model does not necessarily test for causality. There is a coefficient of 0.787 between the building blocks and theories, which is significant at 0.001. The coefficient between the theories and PC-I is 0.441 with a *p*-value of 0.054, slightly above the significance level norm of 0.05. However, it can be argued that for a small sample size such as this study, a 0.1 significance level may also be an appropriate norm. The direct link between PC-I and the building blocks indicates a coefficient of 0.001 and a *p*-value of 0.997, far above the 0.05 level, implying that a variation in PC-I is not attributable to a variation in the building blocks. This model fit to the data is good, where the CMIN/DF of the default model of 1.981 is good; the CFI level of 0.929 is also good, since it is above 0.9. The RMSEA of 0.127 is slightly higher than the norm of approximately 0.1. Finally, we concluded with this model, since further attempts to enhance it were not successful.

A similar model was built to fit the data, where PC-E is the dependent variable instead of PC-I. Unfortunately, the only good fit in that model was the link between the building blocks and the theories (with the same coefficient of 0.787 and a *p*-value < 0.001 as in the above PC-I dependent model). The relationships between the theories and the direct relationship between the building blocks and PC-E were not significant.

Figure 2 summarises the adjusted conceptual frame used in this study, where both the PC-I and PC-E are incorporated. From the figure, it is clear that the building blocks in the business intelligence process do not directly lead to PC-I. The competitive intelligence process only led to PC-I via the mediation of the theories. Furthermore, similar to the findings

in the multi-regression model, the competitive intelligence process does not lead directly or indirectly via the theories to enable PC-E.

Concluding Discussion

The purpose of the study was to determine how supportive the business intelligence process is in terms of creating sustainable competitiveness. This was done by testing its relationship directly with successful competitiveness in practice, and secondly, a similar relationship testing the involvement of the theories.

Many related studies confirmed that the business intelligence process is valuable in many regards (Olszak 2016), especially to improve competitiveness or competitive advantage (Peters et al. 2016). The study's first hypothesis (H1) was designed to conclude upon the direct relationship, without interventions of the theories, between the building blocks of the business intelligence process and successful competitiveness. Although the results from this study support some of the findings of related studies, the results also provide a refinement of such relationships to identify only specific areas of the business intelligence process that are related to successful competitiveness. Consequently, it is concluded that on a stand-alone basis, only BB1 (Planning and focus), and BB6 (Establishing an awareness culture), are positively related to enable successful competitiveness – internally focused, and BB2 (Collecting), BB3 (Analysing) and BB4 (Communicating) are positively related to enable successful competitiveness – externally focused.

The selection of four theories for the scope of this study was inspired by related works where they are associated with business intelligence and/or competitiveness (Polidoro and Toh 2011; Wang, He, and Mahoney 2009; Le Roux and Oosthuizen 2010; Goldratt 1990; United Nations 1987). The second hypothesis (H2) concluded that each of the building blocks is positively related to each of the theories, with the exception of BB2 (Analysis), which does not significantly correlate with T1.5 (Resource-based theory). Therefore, with this overwhelming evidence, this study concludes that these selected theories are appropriate in studying competitive intelligence/competitiveness.

The results from the third hypothesis (H3) support the view of Kessler (2013) and Goldratt (1990) that T3, the theory of constraints, which is a holistic approach, improves firms' performance and that it will lead to improved competitiveness. This study provides a refined view and concludes that, on a stand-alone basis, the theory of constraints is positively

related to successful practical competitiveness – internally focused. This study also supports views such as those of Porter (1980) that sustainable development relates to improved competitiveness, since this study concludes that, on a stand-alone basis, the principles of sustainable development relate positively to successful practical competitiveness, both internally and externally focused. Our study does not support findings that the resource-based view (Capron and Chatain 2008) and knowledge-based view lead to an increased competitive advantage (Meihami and Meihami 2014; Wang, He, and Mahoney 2009).

The structural equation model provided further insight, namely that the building blocks in the business intelligence process may be grouped together and the four theories may also be grouped together. Furthermore, the study provides further refinement that all the building blocks collected in the business intelligence process enable successful competitiveness – internally focused, only via the mediation of the combined theoretical principles.

To summarise, the study concluded that, without interventions of the theories, five of the six building blocks correlate with successful inwardly- and outwardly-focused competitiveness, and by including the theories, the building blocks correlate well with all the theories, and that two theories correlate with successful inwardly- and outwardly-focused competitiveness. From here, the conclusion can be made that the business intelligence process, with or without the mediation of the theories, *relates* to successful competitiveness. However, within the context of the structural equation model, the building blocks *enable* successful inwardly-focused competitiveness; however, they are somewhat incapable without the mediation of the theories.

This study's contribution to theory is emphasised in the conclusions above, where the roles of the theories are refined within the context of this study and all the variables included in the models. The practical implication of the study is that metal manufacturers are aware now of the significance or insignificance of paths between the boxes, including individual elements in and/or groupings of the boxes. To enable successful inwardly-focused competitiveness, companies in the metals manufacturing industry are encouraged to apply all six building blocks of the competitive intelligence process and to ensure that special attention is given to the first, i.e. planning and focus. Furthermore, the principles of all four theories investigated should be applied, with special attention to the theory of constraints and sustainable development.

The structural equation model could not identify factors that can enable successful competitiveness from an outward-looking perspective. Future studies may investigate which factors and theories may be an aid, for the industry in general and for South African metals manufacturers in particular, to enable successful practical outwardly-focused competitiveness.

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Koliko je preveč dolga za Južno Afriko? Ocene na osnovi modela Threshold Nonlinear Autoregressive Distributive Lag (T-NARDL)

Andrew Phiri in Asanda Fotoyi

Od svetovne finančne krize dalje so se južnoafriške finančne oblasti v primerjavi z drugimi gospodarstvi zadolževale hitreje, kar glede na teorijo rasti pomeni, da ima tamkajšnje gospodarstvo nižjo toleranco do zadolženosti oz. nižji prag zadolženosti, kot se je domnevalo v preteklosti. Naša raziskava predstavlja ocene praga zadolženosti južnoafriškega gospodarstva in temelji na reduciranih formah regresij, ki izhajajo iz endogenega modela rasti javnega dolga, ki vključuje javne naložbe kot kanal, prek katerega lahko dolg vpliva na gospodarsko rast. Ocenjujemo reducirane forme regresij, pri čemer uporabimo pragovni kointegracijski model z nelinearnim avtoregresivnim porazdeljenim zamikom (threshold nonlinear autoregressive distributive lag: T-NARDL) in ga apliciramo na četrtletne časovne intervale od prvega četrtletja l. 1960 do četrtega četrtletja l. 2020. Prag zadolženosti ugotavljamo na ravni 47 odstotkov, kar je precej nižje od napovedi prejšnjih panelnih raziskav. Podobno je tudi z oceno praga javnih naložb, ki znaša 2,8 odstotka in je manjši od tistega, o katerem je poročala dosedanja literatura. Vendar pa naša raziskava pokaže, da so tako javni dolg kot javne naložbe preveliki, da bi pospeševali rast, in na podlagi teh ugotovitev oblikujemo priporočila za politiko.

Ključne besede: optimalni dolg, optimalne javne naložbe, gospodarska rast, endogeni model rasti, pragovni kointegracijski model z nelinearnim avtoregresivnim porazdeljenim zamikom (threshold nonlinear autoregressive distributive lag model: T-NARDL), Južna Afrika
Klasifikacija JEL: C22, C51, E63, O47
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Oblikovanje konceptualnega okvira za tehnologije industrije 4.0 za omogočanje ekosistema krožnega gospodarstva

Muhammad Rahim Ejaz in Dániel Hegedűs

Članek je namenjen razvoju ekosistema, ki se lahko uporablja znotraj področja krožnega gospodarstva na temeljih tehnologij industrije 4.0. Raziskava poudarja pomen industrije 4.0 kot ključnega elementa v razvoju ekosistema krožnega gospodarstva, ki ga sestavljajo poslovni model, poslovne strategije ter viri in zmogljivosti, ki jih podpira ogrodje

krožnega gospodarstva. Pričujoča raziskava temelji na pregledu literature in študijah primerov z namenom analize ter sinteze najnovejših trendov in vidikov, ki jih razvijajo v okviru krožnega gospodarstva. Glavni prispevek tega članka je teoretski konceptualni okvir ekosistema krožnega gospodarstva, ki ga je mogoče uporabiti na organizacijski ravni. Članek nakazuje tudi pot za prihodnje raziskave na tem raziskovalnem področju, saj identificira več dejavnikov, ki jih je treba še raziskati.

Ključne besede: krožno gospodarstvo, industrija 4.0, pametna proizvodnja, ekosistem krožnega gospodarstva
Klasifikacija JEL: L60, L69, M11, O14
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Preference institucionalnih vlagateljev glede zelenih obveznic in kriteriji ESG: vidik nemško govorečih predelov Evrope

Deniss Rozkov in Hendrik A. Idema

Namen prispevka je proučiti vpliv trenutnega regulativnega okolja na naložbene odločitve trajnostno naravnanih institucionalnih vlagateljev v nemško govorečih predelih Evrope. Prek uporabe strukturiranega vprašalnika, namenjenega institucionalnim vlagateljem, daje prispevek podroben vpogled v preference vlagateljev pri nakupu zelenih obveznic, to je obveznic, ki prispevajo k zmanjševanju ali preprečevanju neugodnih učinkov, izhajajočih iz podnebnih sprememb. Na osnovi analize vzorca 179 udeležencev lahko trdimo, da je verodostojnost zelene obveznice osnovni predpogoj za to, da vlagatelj kupi tak instrument. Poleg tega na privlačnost zelenih obveznic vplivajo finančni dejavniki, kot so davčne spodbude in obrestne mere. Prispevek proučuje tudi vpliv okoljskih, družbenih in upravljavskih (ESG) strategij na naložbene odločitve glede zelenih obveznic in ugotavlja, da je za vlagatelje najpomembnejši okoljski steber.

Ključne besede: zelene obveznice, ESG, institucionalni vlagatelji, preference vlagateljev, conjoint analiza (analiza sestavljenih učinkov), družbeno odgovorno investiranje
Klasifikacija JEL: G02, F65
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Pomen poslovnih informacij za zagotavljanje konkurenčnosti: multiteoretska analiza južnoafriških proizvajalcev kovin

Herman Smit, Merwe Oberholzer in Pieter Buys

Konkurenčnost južnoafriških proizvajalcev kovin je trenutno v središču pozornosti, saj je bilo v Južni Afriki malo novih naložb v kovinsko

in strojno industrijo, rast kitajske trgovine pa je imela negativen konkurenčni učinek na domačo proizvodnjo kovin in zaposlenost. Namen raziskave je bil ugotoviti, kako podporen je proces zagotavljanja poslovnih informacij za uspešno konkurenčnost v praksi. Zasnovali smo teoretski model in ga empirično testirali pri proizvajalcih kovin, pri tem pa smo kot vmesnike med procesom zagotavljanja poslovnih informacij in uspešno konkurenčnostjo izbrali štiri teorije. Testirali smo štiri hipoteze z uporabo Spearmanovega koeficienta korelacije in z modeliranjem strukturnih enačb. Prejetih in analiziranih je bilo skupno 63 odgovorov. Raziskava je pokazala, da gradniki procesa zagotavljanja poslovnih informacij, združeni v enem samem dejavniku, ne vodijo neposredno do uspešne konkurenčnosti, ampak se to zgodi šele, ko načela vseh teorij, združena v en sam dejavnik, delujejo kot vmesniki.

Ključne besede: zagotavljanje poslovnih informacij, proizvajalci kovin, na znanju temelječ pogled, na virih temelječ pogled, trajnostni razvoj, teorija omejitev
Klasifikacija JEL: M15, L61
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