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ROADS TRANSPORT INFRASTRUCTURE AND TRADE FACILITATION IN SOUTH AFRICA: THE MONTE-CARLO SIMULATION APPROACH

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Abstract

Trade facilitation is effectively linked to the capacity of existing transport infrastructure. Therefore, the development of transport related infrastructure plays a pivotal role in ensuring that this policy is fully implemented. The primary objective of this current study is to empirically examine the extreme effects of roads transport infrastructure on the implementation of trade facilitation policy (trade simplification and harmonization) in South Africa. This follows the fact that almost 90 per cent of cargo in South Africa and other SADC countries is transported using roads transport. The Threshold Vector Error Correction Model (TVECM) is adopted in this current study to estimate nonlinear effects of roads transport infrastructure on trade facilitation policy. Moreover, this study employs the Ali-Mikhail-Haq copulas and uses the residuals of the TVECM to predict the extreme dependence between roads transport infrastructure and trade facilitation. The results obtained in this study discovered that an estimated TVECM (1) was a good framework for interpreting the co-movement of roads transport infrastructure and trade facilitation in South Africa. The study concluded that roads transport infrastructure has extreme effects on trade facilitation since the correlation margins of the variables are extremely tight. Therefore, without proper roads transport infrastructure in place, trade simplification and harmonization as stipulated in the trade facilitation policy will remain a challenge in South Africa. This will also have a detrimental effects on imports and exports of South Africa since trading will continue to be time consuming and costly.

Keywords: Government Infrastructure Development, Trade Facilitation, Threshold Vector Error Correction Model, South Africa

JEL Classifications: H54, F13, C15

1. Introduction

Trade facilitation, as a policy introduced by the World Trade Organization (WTO) to assist in reducing the “red tapes” that exist in moving goods and services across the borders, is effectively linked to the capacity of existing transport infrastructure. Therefore, the development of transport related infrastructure plays a pivotal role in ensuring that this policy is fully implemented. According to Ancharaz *et al.* (2011), adequate transport infrastructure assist in reducing the economic distance between countries and therefore facilitate the movement of goods, investment and labor. Moreover, adequate transport infrastructure reduces the cost of doing business in Africa since it accounts for 40 per cent of transport cost in intra-African trade for countries with maritime boundaries and 60 per cent for landlocked countries.

In South Africa and other African countries, poor regional economic integration and deficient roads and rails networks that connect countries throughout the continent remain a challenge. According to World Bank (2014), the previously used road networks to transport goods and services in and out of Africa have failed to create a regional network that could be utilized to facilitate intra-African trade. For instance, Southern African Development Community (SADC) as one of the biggest region in Africa is struggling to connect to the global market due to the deficient road network. This is due to the fact that SADC region sorely depends on roads transport infrastructure to move almost 95 per cent of their cargo. In other words, these roads infrastructure deficiencies in SADC are due to over usage of the existing roads with minimal investment in maintenance and development of new roads and other surface infrastructure such as rails.

According to World Economic Forum (WEF) (2015), inadequate roads transport infrastructure has always been listed as one of the top three factors that inhibits doing business in South Africa. The World Economic Forum further articulated that inadequate roads infrastructure has delayed South Africa in expanding its market and intensifying its exports since ports and world-shipping operation is not much of an option. Moreover, the incongruity between the available roads transport infrastructure and the growing demand for it in order to reduce inputs cost and transit time has negatively affected the ability of manufacturers in South Africa. According to World Bank (2018), it is too costly and time consuming to do business in South Africa as compared to other developing countries in Asia and Pacific. World Bank (2018) states that it takes 35.1 days and costs US$ 1904 to export a container in South Africa whilst it takes 23.1 days at the cost of US$ 909 in other developing countries.

It is therefore against this background that this study seeks to examine the extreme effects of government investment on roads transport infrastructure towards implementation of trade facilitation in South Africa. This study contributes to the existing body of knowledge since there is no study done in South Africa to assess the effects of roads transport infrastructure and trade facilitation. To ensure that this current study achieves its objective, the threshold cointegration framework and extreme value dependence approach are employed. The threshold cointegration framework is employed mainly due to the fact that it has been discovered and proved by Granger and Lee (1989) and Balke and Fomby (1997) that most of the macroeconomic variables correlate asymmetrically towards equilibrium. Therefore, it is noteworthy to pay attention when subjecting these variables to avoid reporting misleading findings that will influence policy decisions negatively.

This current study is organized as follows: Section 1 was introductory in nature, Section 2 discusses the review of supporting literature. Section 3 states the methodology whereas Section 4 presents the results. Finally, Section 5 has the conclusion and policy recommendation.

2. Literature review

Transactional costs at the border and behind the-border in African are considered high as compared to other continents. According to World Bank (2018), it is costly and time consuming to do business in Africa than other regions of the world. Moreover, according to World Bank (2014), on average, it takes three times for export to clear customs in Sub-Sahara Africa than in OECD countries. This transpires due to higher trade costs and poor national governance structures. However, with the implementation of trade facilitation policy, African and other Least-Development Countries (LDC’s) are expected to realize the biggest average reduction in trade costs since households will gain access to a greater variety of goods whilst companies will acquire inputs at a lower cost and better entry to foreign markets.

The effects of inadequate roads transport infrastructure on trade remains a concern and a leading discussion in academia and policy making in various Africa countries. This led to the emerging new empirical literature in the preceding decade. For instance, to calculate transport cost in Africa, Amadji and Yeat (1995) used the cost-insurance-freight and free-along-ship data of African export to the United States of America (USA) and discovered that the cost of transporting particularly processed commodities in Africa is 20 per cent higher that of other developing states in other continents. Therefore, Amadji and Yeat (1995) adopted the gravity model as a standard tool to analyze the bilateral trade flow and further discovered that deficient roads transport infrastructure remains a hindrance that results in increased transport costs.

Signifying how coastal and landlocked countries are noticeably affected by the high transport costs associated with poor infrastructure, Limao and Venables (2001) extended the gravity model to incorporate transport infrastructure and transport cost. Using the composition index for hard infrastructure, Limao and Venables (2001) confirmed that trade cost in intra-sub-Sahara Africa were significantly higher and the trade flows were considerably lower as compared to non-sub-Sahara African Countries.

Employing the meta-analysis and meta-regression technique, Celbis *et al.* (2014) examined the effects of public infrastructure in transportation and communication on trade. The results obtained confirmed that both quality and quantity of infrastructure could create trade barriers through increased transport costs. Moreover, Celbis *et al.* (2014) revealed that 1 per cent increase in development of adequate transport infrastructure would definitely increase exports by 0.6 per cent and imports by 0.3 per cent. These results were in line with the results obtained by Bouet (2008) subsequent to examining the impact of different types on infrastructure on trade. The study revealed that poor transport and communication infrastructure accounts for most of Africa's trade underperformance. Furthermore, the results exposed that hard infrastructure accounts for just about half of the transport cost penalties accepted by intra-sub-Sahara Africa trade, explaining the underperformance of the continental trade.

Other studies such as Mbekeani (2010) and Portugal-Perez and Wilson (2012) went as far as investigating how both soft and hard infrastructure affect trade in African countries. According to Mbekeani (2013), both infrastructures are playing a significant role in strengthening trade performance and lowering trade cost since physical infrastructure on its own is insufficient. Moreover, Mbekeani (2013) states that defective regulatory and administrative processes thwart the quality of transport network and further discourage trade. Portugal-Perez and Wilson (2012) also concurred with the results of Mbekeani (2013) subsequent to conducting a study using dataset covering 101 countries. The authors' results provide evidence that the physical infrastructure and information and communication infrastructure are increasingly important towards trade.

3. Methods and procedures

This section presents methods and procedures used to examine the extreme effects of government investment on roads transport infrastructure towards implementation of trade facilitation in South Africa.

3.1. Threshold cointegration framework

The methods and procedures employed in this current study conform to the analysis of time series data. Analyzing time series data assist in ensuring that the important measurements and different attributes are separated. According to Johathan and Kung-Sik (2008), the motivation behind time series is by large twofold: firstly, to comprehend the stochastic mechanism that offers ascend to an observed series. Secondly, to forecast the future values of a series in light of the historical backdrop of that series and perhaps, other related series. This current study therefore develops a novel analysis by reviewing a threshold vector error correction model (TVECM) as adopted from Lo and Zivot (2001) to estimate nonlinear effects of roads transport infrastructure on trade facilitation. The residuals of the TVECM will then be used to predict the extreme dependence using Ali-Mikhail-Haq copulas. According to Lo and Zivot (2001), a two regime TVECM is estimated as follows:

$$\Phi(L)\Delta x_t = \alpha_1 z_{t-1} 1\{z_{t-1} \le \gamma_1\} + \alpha_2 z_{t-1} 1\{z_{t-1} > \gamma_2\} + \mu + \varepsilon_t \tag{1}$$

where $t = 1,2,3,\dots,n$ and q^{th} order polynomial in the lag operator is denoted by $\Phi(L)$ which can be extended to be $\Phi(L) = I - \Phi_1 L^1 - \cdots - \Phi_q L^q$. The error correction term is defined as $z_t = x_t'\beta$ for a known cointegrating vector β. The threshold parameter $\gamma = (\gamma_1, \gamma_2)$ which satisfies the following condition $\gamma_1 \le \gamma_2$ and takes values on a compact set Γ is estimated.

The equation (1) with restriction that $\alpha_1 = \alpha_2$ and or $\gamma_1 = a\gamma_2$ is employed in this current study. The testing approach developed in this study is applied to the restricted model with a bit of modification. TVECM that is $\alpha_1 = \alpha_2$ under the restriction that both are nonzero, and that$\gamma_1 = \gamma_2$.

3.2. Estimation of a threshold parameter

Since the stationary distribution of a TVECM model does not have a closed form solution, Jonathan and Kung-Sik (2008) suggested that the estimation is often carried out conditional on the max(p,d) initial values where p is the order process and d is the delay parameter. According to Chan and Kutoyants (2012), the unknown threshold parameter denoted by $\gamma \in \Theta = (\alpha, \beta)$ is to be estimated. The aim here is to estimate this parameter from the values of $X^n = (X_0, X_1, \dots, X_n)$ by the method of maximum expectation (E-M) hence its likelihood function is given by

$$L(\Upsilon, X^n) = F_0(X_0)\left(\frac{1}{\sqrt{2\sigma^2\pi}}\right)^n e^{\left\{-\frac{1}{2\sigma^2}\left(\sum_{j=0}^{n-1} X_{j+1} - \rho_1 X_j \mathbb{1}_{\{|X_j| \le \gamma\}} - \rho_2 X_j \mathbb{1}_{\{|X_j| > \Upsilon\}}\right)^2\right\}}, \tag{2}$$

and the E-M for $\widehat{\Upsilon}$ is

$$\frac{SUPL}{\Upsilon, X^n}(\gamma, X^n) = \mathrm{Max}[L(\hat{\gamma}_n + X^n), \hat{\gamma}_n - X^n] \tag{3}$$

3.3. Dependence measures and copulas

Using the residuals of the estimated TVECM (p,d,q), where p and q are the parameters of a model and d is a delay parameter for a threshold, this study then estimates the extreme effects of government investment on roads transportation infrastructure on trade facilitation in South Africa. Having two random variables denoted by X and Y, the study list four desirable properties of a general, single number measure of dependence $\delta(X, Y)$ as:

$$\delta\,(X, Y) \;=\; \delta\,(Y, X).$$
$$-1 \;\le \delta\,(X, Y) \;\le\; 1.$$

$\delta\,(X, Y) = 1$ if X and Y are co-monotonic; $\delta\,(X, Y) = -1$ if X and Y are counter-monotonic.

If T is strictly monotonic, then $\delta\,(T\,(X)\,, Y) = \delta(X, Y)$for T is increasing $\delta\,(T\,(X), Y) = -\delta\,(X, Y)$ for T is decreasing. Note that the usual Pearson linear correlation only satisfies the first two properties but with the Spearman's-rho and Kendall's-tau all the four conditions are all satisfied.

3.4. The Ali-Mikhail-Haq (AMH) copulas

A combined distribution of a random variable can be expressed by copulas. Using copulas, a combined distribution can be articulated into marginal distributions of each variable; hence this study makes use of the Ali-Mikhail-Haq copula which was developed by Genest and MacKay (1986) with parameter $\delta, \delta \in [-1,1)$ and right boundary $\theta = 1$ and has the following generator

$$\psi(t,\theta) = \frac{1-\delta}{e^{t-\delta}}. \tag{4}$$

Here, $\delta = 0$ and $\psi(t) = t^{-1}$ corresponds to independence. Mächler (2014) discovered that both rank based association measures or correlations, Kendall's τ Spearman's ρ are montone in δ and hence have the same sign as δ. Let $F_1(x_{1t})$ and $F_2(x_{2t})$ to be the marginal distributions from a bivariate time series with $H(x_{1t}, x_{2t})$ being a joint distribution, Chong *et al*. (2017) then revealed that there exists a copula C with the following joint distribution function.

$$H(x_{1t}, x_{2t}) = C\big(F_1(x_{1t}), F_2(x_{2t})\big). \tag{5}$$

If $F_1(x_{1t})$ or $F_2(x_{2t})$ is continuous, then (4) shows the copula as $C(x_t)$. For the purpose of the current study, we then consider the elliptical copula. The inference function for margins (IFM) method of Joe (1997) which considers the estimation error from marginal distributions, is used for parameter estimation. The TVECM models the correlation parameter $\boldsymbol{\rho_t}$ by the transformed parameter $\rho_t = \frac{[1-e^{-f_t}]}{[1+e^{-f_t}]}$. The driving mechanism for the dynamic bivariate Gaussian copula is given by:

$$F_{t+1} = \omega + A_1 . \sum_{i=1}^{m} \Phi^{-1}\big(u_{1,t-i+1}\big)\Phi^{-1}\big(u_{2,t-i+1}\big) + B_1 f_t \tag{6}$$

$\Phi^{-1}(.)$ is the inverse of the normal distribution function, $u_{1,t}$ and $u_{2,t}$ are the probability integral which is transformed using the univariate marginals, and m is a positive integer that determines the smoothness of f_t. in (6). If the transformed marginals have the same sign, the correlation should increase. The reverse holds if the transformed marginals are of opposite sign (Chong *et al*. 2017). For $m = 1$, (6) reduces to:

$$F_{t+1} = \omega + A_1 . y_t + B_1 . f_t \tag{7}$$

where $y_t = \Phi^{-1}(u_{1t})\Phi^{-1}(u_{2t})$. Kojadinovic and Yan (2010) indicated that a time varying updating equation for $\boldsymbol{f_t}$ is obtained as follows:

$$f_t = \omega + A_1 \frac{2}{1-\rho_t^2}\left[y_t - 2\rho_t \frac{x_t - 2}{1+\rho_t^2}\right] + B_1 f_t \tag{8}$$

where $x_t = \Phi^{-1}(u_{1t})^2 + \Phi^{-1}(u_{2t})^2$. Both models in (7) and (8) are driven by y_t so that they are positively clustered around transformed marginals that lead to an increasing correlation parameter. The additional scaling factor $\frac{2}{1-\rho_t^2}$ in (7) is a consequence of modeling the transformed correlation parameter f_t rather than ρ_t directly. We can observe $\Phi^{-1}(u_{1t}) = 1$ and $\Phi^{-1}(u_{2t}) = 1$ or alternatively $\Phi^{-1}(u_{1t}) = 0.25$ and $\Phi^{-1}(u_{2t}) = 4$. In this case, the cross-product term $y_t = 1$ is the same and the recursion in (6) will cause f_{t+1} to be the same regardless of the two scenarios that we observed.

According to Chong *et al.* (2017), the behavior of f_{t+1} somehow depends on the current value of the correlation ρ_t. If the correlation is positive, the impact on the value of $(x_t - 2)$ is negative. In the case where the $(x_t - 2)$ term offsets part of the effect of $y_t - \rho_t$, then the latter has a positive value. If $y_t - \rho_t$has a negative value, however, the $(x_t - 2)$ term reinforces the magnitude of the TVECM step for negative ρ_t.

3.5. Dependence measures for multivariate extremes

The joint distribution of a set of factors can be isolated into their separate negligible disseminations and the reliance structure among them. As a result, the study changed the bivariate series (X, Y) to unit Fréchet marginals (S, T) as follows:

$$S = \frac{-1}{\ln F_X(X)}, \text{ and } T = \frac{-1}{\ln F_Y(Y)} \quad (9)$$

where F_x and F_Y are the respective marginal distribution functions for X and Y. The Fréchet transformation is used because of the widely documented fat-tail distributions for risk (Poon *et al.* 2003). Consequently, S and T have the distribution function $F(s) = e^{\frac{-1}{s}}, S > 0$ so that $\Pr(S > s) = \Pr(T > s) = s^{-1} + O(s^2), s \to \infty$. The variables (S, T) possess the same dependence structure as (X, Y) since:

$$\Pr(q) = \Pr(F(T) > q | F(S) > q) = \Pr\left(Y > F_Y^{-1}(q) \middle| Y > F_X^{-1}(q)\right) \quad (10)$$

Then, S and t are described as asymptotically dependent if they become zero when estimated as in (10). Values of $\Pr(q)$ greater than, equal to, and less than $1 - q$ indicate positive dependence, independence, and negative dependence, respectively, at percentile q (Poon *et al.* 2003).

4. Empirical analysis

Figure 1 below depicts a monthly-simulated government investment on roads transport infrastructure and trade facilitation in South Africa for the period of January 2001 to March 2019. It is evident that both series possess the same characteristics as they are moving towards one direction on the same wavelength. The movement and irregular patterns serve as a strong motivation to use these variables in TVECM and copula framework.

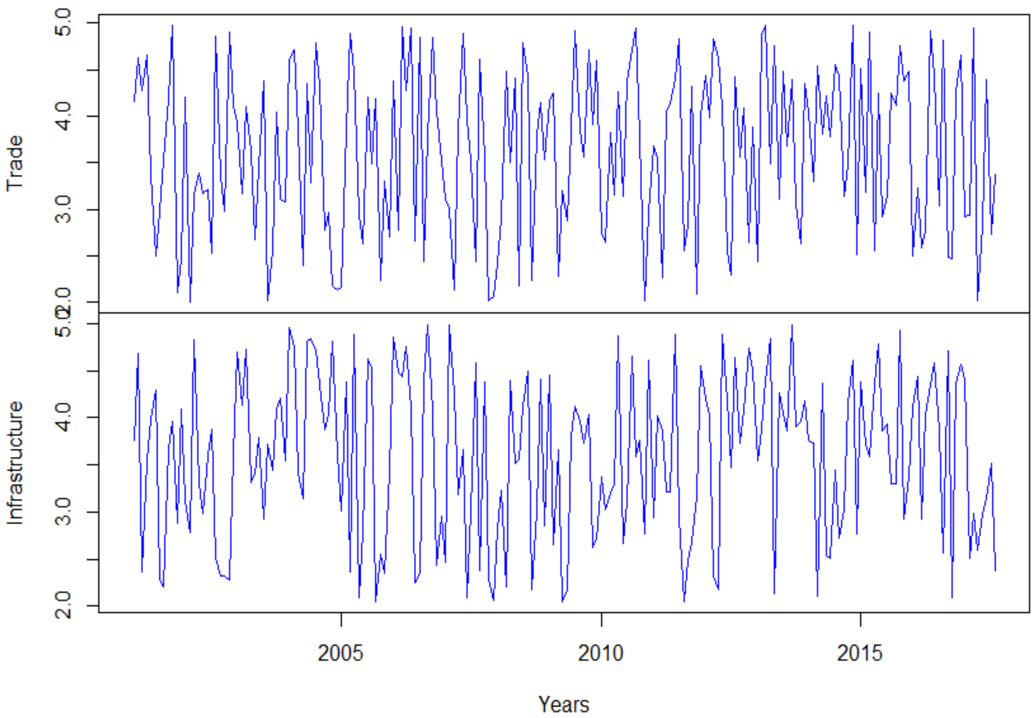

Figure 1. Simulated South Africa's road infrastructure and trade facilitation

4.1. Lagrange Multiplier (LM) test results

Prior to the TVECM estimation, the study employed the Lagrange Multiplier (LM) test to confirm the null hypothesis of linearity against nonlinearity in the variables. The results of a LM test are presented in Table 1 as follows:

Table 1. Estimated AR(1) models and nonlinear test

Trade Facilitation				
Parameter	**Coefficient**	**Std. Error**	**Test Statistic**	**Prob**
$\mathbf{C}$	95.676	0.271	14.532	0.001
α_1	8.229	0.0903	0.109	0.001
LM Test	108.53			0.001
Roads Transport Infrastructure				
$\mathbf{C}$	7.025	0.4549	135.12	0.001
α_1	-1.0065	0.0598	-0.0109	0.001
LM Test	65.509			0.001
Ali-Mikhail-Haq				
	Trade		**Infrastructure**	
	1		0.863	
	0.863		1	

It is evident in Table 1 that both trade facilitation and government investment on roads transport infrastructure are nonlinear since the LM test statistic is significant at 1%, 5% and even 10%.

4.2. TVECM model and extreme dependences

According to Ghassan and Banerjee (2015), the Johansen procedure sorely undertakes the cointegrating vector that remains constant during the sample period. However, this is misleading owing to the scientific progress, transformation in researcher's preference, economic crisis, policy or regime alteration and institutional development. As a result, this current study enhanced the Johansen Cointegration to accommodate data with structural breaks. The TVECM results are presented in Table 2 as follows:

Table 2. TVECM (1) model

Lower Regime	
Parameter	**Estimate**
δ_1	-20.117(0.0100)*
μ_1	30.89(0.6860)
Φ_{11}	21.50(0.0079)**
Φ_{21}	43.17(0.000)***
Upper Regime	
δ_2	-54.63(0.005)***
μ_2	-37.823(0.006)***
Φ_{12}	-41.56(0.045)*
Φ_{22}	48.04(0.001)***

Note: *** significant at 1% ** significant at 5%, *significant at 10%. Numbers in () are standard errors.

Applying threshold equation, the procedure yields a threshold parameter of $\gamma=0.09$. Based on this parameter, the TVECM (1) is divided into two regimes. The movement effects of roads transport infrastructure on trade facilitation are being captured by Φ_21 and Φ_22 which are found significant. These findings suggested that the fluctuations in South African investment towards roads transport infrastructure do have strong positive effects on the dynamics of trade facilitation.

The study proceeded to estimate supremum Wald statistic with 1500 bootstrapping replications. The results obtained indicated significant results at a critical value of 5%. This was an indication that there exists a nonlinear relationship between government investment on roads transport infrastructure and trade facilitation in South Africa. The results are presented in Table 3 as follows:

Table 3. Seo SupW bootstrap test

Seo's test	**Test Statistic**	**Critical Value**
supW test	504.0095	120.157

Using the residuals of the estimated TVECM, the study further examined the extreme effects between government investment on roads transport infrastructure and trade facilitation. Following Poon *et al.* (2003) and Kojadinovic and Yan (2010), the employed extreme value test is based on tail distribution of a TVECM and the results are presented in Table 4 as follows:

Table 4. Extreme value dependence test

Test	**Test Statistic**	**Prob**
Evd	23.096	0.008

It is evident from Table 4 that, there exists an extreme dependence between government investment on roads transport infrastructure and trade facilitation in South Africa. This is also confirmed by negative movements of δ_1 and δ_2 in Table 2.

4. Conclusion and policy recommendations

The primary objective of this current study was to examine the extreme effects of government investment towards roads transport infrastructure on trade facilitation in South Africa. The TVECM was employed to estimate the nonlinear relationship since it serves as an extension of the Johansen cointegration framework which assumes that the cointegration vector is constant throughout the sampled period. In this study, the Johansen cointegration framework was unfounded due to structural breaks in the South African economy. An estimated TVECM (1) was found to be good framework for interpreting the co-movement of government investment on roads transport infrastructure and trade facilitation nexus. This was observed through the SupW test which was significant 5% level of significance.

The results of the study further revealed that government investment towards roads transport infrastructure extremely affect trade facilitation in South Africa. Therefore, this study concluded that without proper investment on roads transport infrastructure trade simplification and harmonization in South Africa will remain challenged. Moreover, trade in South Africa will remain time consuming and costly. These results were in agreement with studies of Celbis *et al*. (2014), Bouet (2008) and Mbekeani (2013).

Therefore, this current study recommends that the government of South Africa should refocus or redirect its spending towards maintaining and development new roads infrastructure to simplify trade and boost economic growth. Furthermore, government of South Africa should resuscitate the existing rail networks to reduce the burden on road transportation. Investment in the transport infrastructure will further assist in reducing the unemployment rate of South Africa since quite number of people would be employed. This current study is of particular relevant in the light of the growing economies for achieving enhanced linkages.

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