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Navigating prosperity: the impact of seaport efficiency on economic growth in Ghana's maritime landscape

Joseph Antwi Baafi
Department of Economics, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Kumasi, Ghana

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Abstract

Purpose – This study aims to investigate the impact of seaport efficiency on economic growth in Ghana over the period 2006–2020.

Design/methodology/approach – Comprehensive methodology, diverse data analysis techniques, including Augmented Dickey–Fuller tests, autoregressive distributed lag (ARDL) modeling and Granger Causality, were applied to explore the intricate relationship between Seaport Efficiency and Economic Growth.

Findings – The findings reveal a statistically significant and positive association between seaport efficiency and GDP, underscoring the crucial role of efficient seaport operations in actively stimulating economic growth. Beyond seaport efficiency, influential factors such as capital, human capital, knowledge spillover and productive capacities were identified, contributing to the dynamics of economic growth.

Research limitations/implications – The Granger Causality Test solidifies seaport efficiency as a robust predictor of GDP fluctuations, emphasizing its significance in economic forecasting. Notably, this study contributes to the existing body of knowledge with its nuanced exploration of the intricate relationship between seaport efficiency and economic growth in the specific context of Ghana.

Practical implications – This study's implications extend beyond academia, offering invaluable guidance for policymakers and planners. It serves as a comprehensive roadmap for informed decision-making, emphasizing the pivotal role of efficient seaports in charting a trajectory for enduring and resilient economic progress in the nation.

Originality/value – While the broader theme has been explored in existing literature, the uniqueness of this study lies in its specific application to the Ghanaian context. The choice of Ghana, a nation where maritime transport handles over 90% of trade, underscores the significance of understanding seaport efficiency in this regional and economic setting. The study's originality is reinforced by incorporating diverse economic variables, aligning with recommendations for a comprehensive analysis of factors influencing port performance.

Keywords Seaport efficiency, Economic growth, ARDL modeling, Ghana, Maritime sector, Granger causality test

Paper type Research paper

1. Introduction

Seaports stand as vital gateways connecting nations to the global economy, serving as pivotal nodes for international trade, commerce, and economic development (Jung, 2011). These maritime hubs play an indispensable role in facilitating the movement of goods, fostering regional integration, and stimulating economic growth (Deen-Swarray *et al.*, 2014).

In the context of developing economies, such as Ghana, seaports assume heightened importance as conduits for resource utilization, job creation, and revenue generation. The intricate dynamics between seaport efficiency and economic growth hold the promise of reshaping national trajectories (Munim and Schramm, 2018) and positioning nations on the global stage.

The Republic of Ghana, nestled on the western coast of Africa, boasts a rich history and diverse culture (Ghana Overview: Development news, research, data | World Bank, 2023), while steadily carving a path towards economic prosperity and sustainable development. Against a backdrop of ambitious policy frameworks and strategic investments, Ghana has emerged as a beacon of progress in the West African region. At the heart of this progress is the maritime sector, with its seaports playing a central role in facilitating trade, spurring industrialization (Maria, 2018), and enhancing connectivity with international markets. The deliberate choice of Ghana as the research focal point stems from its strategic geographical location along the West African coast and its increasing significance in the regional economic landscape. Ghana's maritime sector, anchored by a network of seaports, emerges as a potent catalyst for economic growth. The nation's steadfast commitment to robust policy frameworks and substantial infrastructure investments presents a compelling rationale for investigating the impact of seaport efficiency on its economic trajectory; ie. an investment of 1.2bn dollars by Maritime Port Service in 2017 (Maritimafrica, 2022). Positioned as a beacon of progress in West Africa, Ghana's dynamic policy environment (Lamptey *et al.*, 2020) provides a fertile ground to explore how streamlined port operations can drive economic development in a region characterized by ambition and resilience. This study surpasses a mere examination of seaport efficiency; it aims to decipher the complex dynamics that position Ghana's maritime sector as a linchpin for broader socio-economic advancement. By unraveling the specific mechanisms through which seaport efficiency contributes to economic growth in the Ghanaian context, this research aspires to offer insights not only for Ghana's policymakers but also for the global discourse on the interplay between efficient port operations and sustainable economic development.

The importance of seaports in Ghana's development narrative is underscored by their multifaceted contributions. Not only do these ports serve as critical infrastructural nodes for global trade, but they also serve as catalysts for technological advancement, investment attraction, and employment generation (Bichou, 2014). The operational efficiency of these ports, which encompasses aspects such as cargo handling, customs processes, and logistics management (Korinek and Sourdin, 2011), can significantly influence the pace and sustainability of the country's economic growth. These ports also serve as vital gateways connecting nations to the global economy, playing a crucial role in international trade, commerce, and economic development (World Bank, 2023). This is particularly true for developing economies like Ghana, where seaports are essential conduits for resource utilization, job creation, and revenue generation (Deen-Swarray *et al.*, 2014). For example, revenue contribution of seaport was 265.39 million in 2021 and ports attracted a grant of 1.2 million dollars from the US in 2021 (Ghana Shipper's Authority, 2021).

The relationship between seaport efficiency and economic growth is a dynamic and intricate one, characterized by a multitude of interrelated factors (Jean-Paul and Notteboom, 2019). The ability of ports to swiftly clear goods, minimize congestion, and optimize supply chain processes has the potential to drive down transaction costs, encourage foreign and domestic investment (Sarkar and Shankar, 2021), and amplify the competitiveness of Ghana's industries in the global arena. Conversely, inefficiencies in seaport operations may lead to delays, increased costs, and trade bottlenecks, thereby exerting a dampening effect on economic growth and impeding the realization of development goals (Mlambo, 2021).

The empirical exploration of the linkages between seaport efficiency and economic growth in Ghana holds substantial implications for policy formulation, strategic planning, and sustainable development. This study aims to critically analyze the relationship between seaport efficiency and economic growth in Ghana over the period 2006–2020. It goes beyond mere scrutiny by aiming to provide well-founded policy recommendations. These recommendations are not only designed to enhance seaport efficiency but are also poised to act as drivers for sustainable economic growth. Furthermore, the study strategically positions the optimization of Ghana's maritime potential as a key factor for comprehensive socio-economic development in the region. This research contributes valuable insights to both academia and policymakers, offering an understanding of the dynamics at play in Ghana's maritime sector.

This research contributes to maritime economics, trade dynamics, and economic development in Ghana in several key ways. Firstly, it fills a gap by providing empirical evidence specific to Ghana on the link between seaport efficiency and economic growth. Secondly, it rigorously analyzes causation and mitigates endogeneity issues, ensuring methodological soundness in understanding the relationship between seaport efficiency and economic growth. Thirdly, the study aims to provide evidence-based policy recommendations for sustainable development, guiding stakeholders in maximizing the positive impact of seaport operations. Lastly, it seeks to enhance Ghana's maritime strategy and development roadmap by highlighting specific levers through which seaport efficiency can amplify economic growth. In terms of methodology, the Autoregressive Distributed Lag (ARDL) model is a suitable econometric method to use. The ARDL model is particularly well-suited for analyzing both short-term and long-term relationships in a dynamic framework (Lin and Li, 2020), which aligns with the nature of the research.

The originality of this study stems from its specific application to the Ghanaian context, offering a complex examination of the relationship between seaport efficiency and economic growth within the distinctive regional and economic setting of Ghana. While prior literature has explored the broader theme of port efficiency and its impact on economic development, the choice of Ghana as the primary focus contributes a novel perspective. According to UNCTAD, maritime transport is a critical component of Ghana's economy, handling over 90% of the country's trade. This underscores the significance of studying seaport efficiency in the Ghanaian context, given its pivotal role in the nation's economic activities (UNCTAD, 2020). The decision to focus on Ghana aligns with the growing recognition of the importance of Africa in global trade dynamics. As the African continent continues to experience economic growth and development, understanding the specific challenges and opportunities faced by countries like Ghana in optimizing seaport efficiency becomes paramount. This is in line with the findings of studies such as Notteboom and Rodrigue (2009) who emphasize the importance of considering the unique characteristics of individual ports and regions when studying port performance. Moreover, the study's originality is strengthened by its incorporation of diverse economic variables and their interplay in the analysis. While seaport efficiency is a central focus, the inclusion of variables such as capital, labor, human capital, knowledge spillover, customs and import duties, and trade indicators enhances the comprehensiveness of the investigation. This multi-dimensional approach aligns with the recommendations of scholars such as Talley (2017) who argue for a holistic examination of the factors influencing port performance. Incorporating a comprehensive set of variables relevant to the Ghanaian economic context not only adds depth to the study but also addresses the complexity of the relationship between seaport efficiency and economic growth in this specific region.

Generally, there are four main limitations of the study. These limitations are the availability of data for some years, generalizability (the findings of this study may be specific to the Ghanaian context and may not be readily applicable to other countries or regions with different economic structures, trade dynamics, and maritime policies), external factors and dynamic nature of efficiency (seaport efficiency is subject to changes over time due to technological advancements, policy reforms, and managerial practices. The study's static assessment of efficiency may not capture the evolving nature of port operations).

The rest of the study is as follows. Section 2 reviews various literature, section three deals with the methodology, and sections 4 and 5 present the results and policy implications.

2. Literature review

Efficient seaports serve as crucial nodes in global logistics networks, connecting producers with consumers and facilitating the movement of goods from production centers to markets. For countries like Ghana, with a significant reliance on maritime trade, the efficiency of its seaports could directly influence its economic performance and competitiveness in the global marketplace. Ghana's geographic location along the Gulf of Guinea positions it as a strategic hub for maritime trade in West Africa, with its ports serving as gateways for both imports and exports. The country's main ports, including the Port of Tema and the Port of Takoradi, handle a substantial portion of the nation's trade activities, encompassing various commodities such as oil, cocoa, minerals, and manufactured goods (UNCTAD, 2020). As such, the efficiency of these ports is critical not only for Ghana's economic growth but also for the broader regional trade dynamics.

Efforts to enhance seaport efficiency in Ghana are integral to the country's economic development agenda, aiming to streamline trade processes, reduce logistics costs, and improve overall competitiveness. Investments in port infrastructure, technology upgrades, and institutional reforms are among the measures undertaken to boost efficiency and attract more trade volumes (Maritimafrica, 2022). Moreover, initiatives to improve connectivity with hinterland regions and enhance trade facilitation measures contribute to creating an enabling environment for maritime trade and economic growth (UNCTAD, 2020).

However, challenges such as congestion, inadequate infrastructure, bureaucratic procedures, and regulatory constraints pose obstacles to achieving optimal seaport efficiency in Ghana (Mwaikusa, 2023). Addressing these challenges requires a multi-faceted approach involving collaboration between government agencies, port authorities, private sector stakeholders, and international partners. By addressing these challenges and maximizing the efficiency of its seaports, Ghana can leverage its maritime potential to drive sustainable economic growth, foster regional integration, and enhance its competitiveness in the global trade arena.

Introducing the theoretical review, the study adopts the New Trade Theory and New Economic Geography as the theoretical framework for this analysis.

2.1 Theoretical review

In terms of theoretical review, this study shall follow the New Trade Theory and New Economic Geography. The New Trade Theory is an economic theory that provides an alternative perspective to traditional trade theories, such as the theory of comparative advantage (Chandra, 2022). Instead, the New Trade Theory emphasizes the role of economies of scale, product differentiation, and imperfect competition in shaping trade patterns and international specialization (Chandra, 2022). The New Trade Theory has certain distinct features from other theories. These are – (1) Economies of Scale (Shiozawa, 2007); (2) Product Differentiation (Grossman and Rossi-Hansberg, 2006), (3) Imperfect Competition (Shiozawa, 2007), (4) Increasing returns to scale; (5) Trade Patterns and Firm-Level Effects (Fujimoto and Shiozawa, 2012), and (6) Role of Government and Trade Policy.

New Economic Geography (NEG) is an economic theory that focuses on explaining the spatial distribution of economic activities, trade patterns, and regional development. This theory modifies the neoclassical approach to trade and factor movements by allowing economies of scale to model forces of agglomeration (Felbermayr and Kohler, 2015). It emerged in the late 20th century as a response to the limitations of traditional trade theories (Martin, 1999). NEG combines insights from economics, geography, and urban studies to provide a framework for understanding how factors such as transportation costs, agglomeration effects, and location-related advantages shape the geography of economic activities (Chen and Peng, 2020). The key features of the NEG are; (1) Agglomeration (Chen and Peng, 2020), (2) Centrality and Accessibility; (3) Transportation Costs (Dixit and Stiglitz, 1977; Chandra, 2022), (4) Diseconomies of Agglomeration; (5) Trade and Economic Geography (Chen and Peng, 2020), and (6) Path Dependence.

Choosing the New Trade Theory and New Economic Geography as a theoretical framework for studying the link between seaport efficiency and economic growth in Ghana is justified. The New Trade Theory aligns with how efficient seaports foster comparative advantage and specialized production through economies of scale and product differentiation. The New Economic Geography is relevant in understanding how seaports reduce transportation costs, influencing economic activities around well-connected ports, and shaping regional development. Both theories emphasize global value chains and logistics networks, crucial for integrating economies into global production networks and promoting economic growth through efficient seaports. Additionally, the New Trade Theory's focus on Foreign Direct Investment (FDI) aligns with how efficient seaports attract investment by providing reliable access to global markets, impacting technological transfer and spillover effects on economic growth. These theories offer concise insights into policy implications, suggesting that well-designed policies targeting trade facilitation and infrastructure can enhance seaport efficiency, positively impacting economic development. Recognizing the dynamic nature of economic processes, these theories guide the exploration of how seaport efficiency evolves and its implications for sustained economic growth in Ghana.

2.2 Empirical review

This section presents a review of empirical research that sheds light on the potential link between seaport efficiency and economic growth, with a focus on both global perspectives and context-specific findings.

Existing research has delved into the relationship between seaport efficiency and economic growth, often showcasing the positive correlation observed in various global and regional contexts. For instance, (Chang *et al.*, 2021) in a study covering 23 container ports in China, found robust evidence supporting the positive association between higher seaport efficiency and accelerated economic growth. Others study such as Nguyen and Acharya (2015), Jian and Jiang (2018), López-Bermúdez *et al.* (2019), Sabaydash (2023), Zakharova and Lee (2023) all found such positive association. Similarly, (Limao and Venables, 2001) utilized a structural model to explore the effects of transportation costs and seaport efficiency on trade patterns, highlighting the role of efficient seaports in reducing trade barriers and fostering economic interactions between countries.

On the African continent, (Mlambo, 2021) assessed Africa's port performance, revealing a positive impact on trade (Ayesu *et al.*, 2022; Ayesu *et al.*, 2023). Investigated the pivotal role of seaport efficiency in shaping the relationship between trade activities and welfare outcomes in 28 African countries from 2006 to 2018. Their findings underscored the significance of policies prioritizing enhanced seaport efficiency in Africa. Other works that are related to seaport efficiency and growth through trade in Africa also include (Sakyi and Immurana, 2021; Osadume and University, 2020; Barros *et al.*, 2011). Interestingly, (Roberts and Vilakazi, 2010) conducted a case study in Malawi, emphasizing the sector-specific dynamics influenced by seaport efficiency. Their results indicated varying impacts across sectors, with manufacturing and agriculture experiencing substantial growth due to improved trade facilitation.

While the existing literature predominantly emphasizes the positive correlation between seaport efficiency and economic growth, it is crucial to acknowledge potential negative effects that may arise. One significant negative aspect is the environmental impact associated with increased seaport activities. The surge in shipping and port operations often leads to elevated levels of air and water pollution, contributing to ecological degradation (Acciaro *et al.*, 2014; Kutin, 2018). Another negative consequence is the potential for social inequalities and adverse effects on local communities. The expansion of seaport facilities can result in displacement, affecting the livelihoods of nearby residents and causing social disruptions (Ducruet and Notteboom, 2012). Additionally, the influx of economic activities around ports may lead to increased housing costs, making it challenging for local populations to afford to live in these areas (Munim and Schramm, 2018). Moreover, the concentration of economic activities around seaports may create regional disparities, with areas distant from the ports experiencing limited growth opportunities. This can lead to an uneven distribution of economic benefits, exacerbating inequalities within the country (Kühn *et al.*, 2013). Furthermore, the intensification of seaport operations may pose challenges related to congestion, both within the ports themselves and in the surrounding transportation networks. Congestion can lead to delays in shipments, increased transportation costs, and a decline in overall efficiency, negatively impacting the economic benefits anticipated from seaport development (Ducruet and Notteboom, 2012). It is crucial for policymakers, researchers, and stakeholders to consider and address these potential negative effects when formulating strategies for seaport development. By adopting sustainable and inclusive practices, such as implementing environmental safeguards, engaging local communities in decision-making processes, and mitigating social and economic disparities, countries can maximize the positive contributions of seaports to economic growth while minimizing adverse consequences.

However, despite the wealth of global and regional studies, there is a notable gap in the literature concerning a comprehensive and context-specific analysis focused on Ghana. While some studies touch on the broader West African region (Abbes, 2015; van Dyck, 2015; Abdoulkarim *et al.*, 2019; Kalgora *et al.*, 2019) there is a lack of in-depth examination of how seaport efficiency uniquely influences economic growth dynamics within the Ghanaian context.

Furthermore, existing empirical research, often employing cross-country or regional approaches (Chang *et al.*, 2021; Sakyi and Immurana, 2021; Ayesu *et al.*, 2022), overlooks individual country experiences. This literature gap presents an opportunity for the current study to address the unique economic characteristics, policy frameworks, and regional dynamics of Ghana, contributing to a better understanding of the relationship between seaport efficiency and economic growth.

3. Methodology

3.1 Model specification

To develop a mathematical theoretical relationship between economic growth and seaport efficiency while considering New Trade Theory and New Geography Theory, we start from a Cobb–Douglas endogenous growth production function as follows

$$Y = AL^{\alpha}K^{\beta}H^{\eta}E^{\gamma}P^{\delta}KS^{\sigma} \tag{1}$$

Where:

Y = represents total output/GDP, A = total factor productivity, L = Labor input, K = Physical Capital Input, H = Human Capital, E = Seaport Efficiency, P = geographical proximity to efficient seaport, KS = level of knowledge, $\alpha, \beta, \eta, \gamma, \delta, \sigma$ are the output elasticities of labor, physical capital, Human capital, seaport efficiency, geographical proximity, and knowledge spill over respectively.

We re-specify equation 1 to include a set of control variables given as

$$Y = AL^{\alpha}K^{\beta}H^{\eta}E^{\gamma}P^{\delta}KS^{\sigma}\Gamma^{\Phi} \quad (2)$$

Where Γ represents a set of control variables and Φ is the output elasticity of Γ

Let's incorporate the New Trade Theory, New Geography Theory and Endogenous Elements.

(1) New Trade Theory (NNT)

As earlier stated NNT emphasizes economies of scale and product differentiation. Seaport facilitates International trade and access to larger markets. In this framework, we assume that seaport efficiency (E) and market size (M) are positively related and affect transportation cost (TC). Additionally, NNT suggests that trade leads to knowledge spillover (KS) which enhances productivity.

$$KS = f(E, M) \quad (3)$$

(2) New Geography Theory (NGT)

NGT emphasizes the role of geographical location (L) in influencing trade patterns and economic growth. Proximity to efficient seaport (P) affects transportation cost (TC) and access to market (M)

$$P = g(L, E) \quad (4)$$

(3) Endogenous growth Component by introducing human capital (H). Human capital can be accumulated through investment in education and training. Knowledge spillover (KS) positively affects human capital formation, which in turn contributes to productivity (A)

$$H = h(KS) \quad (5)$$

Now to establish a theoretical relationship between economic growth (Y) and seaport efficiency (E), considering all these factors, the study analyzes how changes in seaport efficiency impact economic growth. Taking the logarithm of the production function:

$$ln(Y) = Z + \alpha ln(L) + \beta ln(K) + \eta ln(H) + \gamma ln(E) + \delta ln(P) + \sigma ln(KS) + \Phi ln(\Gamma) \quad (6)$$

Now taking the derivative of $ln(Y)$ with respect to $ln(E)$, we can determine the impact of seaport efficiency on economic growth

$$\frac{\partial ln(Y)}{\partial ln(E)} = \gamma - \partial * \frac{\partial ln(P)}{\partial ln(E)} \quad (7)$$

This equation shows that seaport efficiency (E) directly influences economic growth through the γ term. However, the relationship is also affected by how changes in seaport efficiency affect geographical proximity $(P)\,\frac{\partial ln(P)}{\partial ln(E)}$ which can have an additional impact on economic growth.

To further expand equation 6 mathematically, we get

$$\frac{\partial ln(Y)}{\partial ln(E)} = \gamma - \partial * \frac{\partial ln(P)}{\partial ln(E)} + \sigma * \frac{\partial ln(KS)}{\partial ln(E)} + \eta \frac{\partial ln(H)}{\partial ln(E)} \quad (8)$$

In equation 8, an increase in seaport efficiency (E) can stimulate economic growth not only by reducing transportation costs and enhancing access to markets (geographical proximity) but also by promoting knowledge spillovers and human capital accumulation through investments in education.

3.2 Estimation techniques

To estimate model 6 empirically, we select the autoregressive distributed lag model (Pesaran *et al.*, 2001). The general ARDL model for the above is written as

$$GDP_t = \beta_0 + \beta_1 GDP_{t-1} + \beta_2 E_t + \beta_3 E_{t-1} + \beta_4 L_t + \beta_5 K_t + \beta_6 H_t + \beta_7 P_t + \beta_8 KS_t + \beta_9 \Gamma + \varepsilon_t \tag{9}$$

Where GDP represents economic growth and *E, L, K, H, P, and KS* are already defined, β_0 = intercept, β_1 *to* β_8 are co-efficient to be estimated and ε_t is the error term. Because of lack of data or appropriate proxy, we drop the geographical proximity variable. The other control variables used are foreign direct investment as a percentage of GDP, Customs and other import duties as a percentage of tax revenue to capture the effects of import taxes on economic growth, export of goods and services as a percentage of GDP, import of goods and services and productive capacity index. These variables are further explained in section 3.3

The last thing in our empirical estimation is to set up a test for causality between seaport efficiency and economic growth. The paper resorts to the famous Granger causality test technique (Granger, 1969). The hypothesis for the Granger causality is set as follows:

Ho. There is no Granger causality from seaport efficiency to economic growth.

H1. There is Granger causality from seaport efficiency to economic growth.

Ho. There is no Granger causality from economic growth to seaport efficiency.

H1. There is Granger causality from economic growth to seaport efficiency.

We start by specifying the Granger causality model for seaport efficiency and economic growth as follows

$$GDP_t = \varphi_0 + \sum_{i=1}^{n} \varphi_i E_{t-i} + \sum_{j}^{n} \beth GDP_{t-j} \tag{10}$$

$$E_t = \varphi_0 + \sum_{i=1}^{n} \gamma_i E_{t-i} + \sum_{j}^{n} \aleph_j GDP_{t-j} \tag{11}$$

Where φ *and* γ are co-efficient for the estimate, GDP_{t-1} *and* E_{t-1} account for the lagged value of variables, ε_{1t} *and* ε_{2t} are error terms.

3.3 Data

The study's selection of the 2006–2020 timeframe is deliberate, capturing a period characterized by substantive infrastructure development in the maritime sector in Ghana. This temporal scope corresponds with significant national initiatives aimed at improving seaport efficiency and broader maritime infrastructure, offering a comprehensive backdrop for evaluating their impact on economic growth (Ghana Shipper's Authority, 2021). The incorporation of this timeframe enables an examination of how substantial developments in maritime infrastructure may have economic growth. The 15-year period allows for a longitudinal examination of trends, patterns, and dynamics, enabling a more robust understanding of how seaport efficiency has evolved and influenced economic outcomes over time.

In this study, we employ the liner shipping connectivity index (LSCI) as defined by UNCTAD (2019) as a proxy measure for seaport efficiency. The Liner Shipping Connectivity Index captures how well countries are connected to global shipping networks. It is computed by the United Nations Conference on Trade and Development (UNCTAD) based on five components of the maritime transport sector: number of ships, their container-carrying capacity, maximum vessel size, number of services, and number of companies that deploy container ships in a country's ports. For each component a country's value is divided by the maximum value of each component in 2004, the five components are averaged for each country, and the average is divided by the maximum average for 2004 and multiplied by 100 (UNCTAD, 2019; Lei and Bachmann, 2020).

A proxy for the measure of knowledge spillover is patent applications (Kaiser, 2002). This is a worldwide patent application filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention–a product or process that provides a new way of doing something or offers a new technical solution to a problem (UNCTAD, 2019).

The Productive Capacities Index (PCI) extends the principles and analytical framework established by UNCTAD to assess the degrees of productive capacities within an economy, encompassing three essential dimensions: "the available productive resources, entrepreneurial competencies, and production interconnections, collectively shaping a nation's ability to manufacture goods and services and foster growth and advancement").

Foreign Direct Investment (% of GDP): This metric measures the net inflow of investments (equity capital, reinvested earnings, long-term and short-term capital) from foreign entities acquiring substantial management control (10% or more voting stock) in enterprises operating outside their home country. It is expressed as a percentage of the recipient country's GDP (World Bank, 2022).

Customs and Import Duties (% of Total Revenue): This figure represents all levies collected on imported goods and services, as a proportion of a country's total revenue. These levies may be imposed for revenue generation or protectionist purposes and can be specific or ad valorem, but they exclusively apply to imported items (World Bank, 2022).

Imports of Goods and Services (% of GDP): This indicator reflects the total value of imported goods and various market services (e.g. merchandise, transport, insurance, royalties) from the international market, as a percentage of a nation's GDP. It excludes employee compensation, investment income, and transfer payments (World Bank, 2022).

Exports of Goods and Services (% of GDP): This metric represents the total value of exported goods and market services (e.g. merchandise, transport, insurance, royalties) to the global market, relative to a country's GDP. It excludes employee compensation, investment income, and transfer payments (World Bank, 2022).

Data on GDP growth rate, labor force, physical capital, knowledge spillover, foreign direct investment, import of goods and services, export of goods and services were from World Development Indicators (2023). Data on seaport efficiency, human capital, and productive capacity were from UNCTAD (2022).

4. Results and analysis

Appendix 1 shows the various variables and their abbreviations as used in the study. This section presents descriptive statistics, focusing on the Jarque–Bera statistic and associated probabilities (Appendix 2) for variables including *GDP, K, L, H, KS, FDI, PCI, COD, EGS, and IGS*. The results suggest that variables with low Jarque-Bera statistics and high probabilities, including *GDP,* likely follow a normal distribution. *GDP* and *E* exhibit symmetric distributions, while other variables show varying skewness and variability. These insights are valuable for guiding the application of appropriate statistical methods based on the distribution characteristics of the variables.

The correlation results, as presented in Appendix 3, reveal significant relationships between various variables. Notably, there is an almost perfect positive correlation between *GDP* and *PCI*, suggesting that economic growth is intricately linked to the development of productive capacities within the economy. Similarly, a high positive correlation between *GDP* and *H* implies a strong association between a country's economic output and its human capital, indicating that higher *GDP* is often linked to improved education, skills, and health of the population.

A strong, positive correlation between labor (L) and human capital (H) indicates their close relationship, suggesting that investing in skills, education, and health boosts labor force participation and contributes significantly to productivity. Conversely, a substantial negative correlation (−0.704) between *IGS* and *L* implies an economic relationship, suggesting that heavy reliance on imports may negatively impact domestic employment. The findings also raise concerns about multicollinearity, especially given the high positive correlations between variables. To address this, the proposed solution involves estimating different models and considering the removal of variables contributing to multicollinearity.

4.1 Diagnostics

4.1.1 Stationarity test. Appendix 4 displays the outcomes of Augmented Dickey–Fuller (ADF) tests assessing stationarity for various time series variables. These tests were employed to evaluate the stationarity of the time series data. The results of the ADF tests point to the likely non-stationarity of the GDP series in its original form, evident from the *p*-value of 0.4965. To address this, first differences were computed for several series, and the ADF test yielded statistically significant *p*-values for *D_GDP, D_1(K), D_1(H), D_1(KS), D_1(IGS), D_1(EGS), and D_1(PCI)*, indicating stationarity post-differencing. Conversely, the original series such as *E, KS, COD*, and *FDI* exhibited *p*-values exceeding 10%, suggesting potential non-stationarity and signaling the need for further transformations or differencing. In summary, the ADF test results play a crucial role in guiding decision-making regarding appropriate treatments, ensuring that all variables fulfill the stationarity assumption essential for Autoregressive Distributed Lag (ARDL) estimation in subsequent time series modeling.

4.1.2 Testing for optimal lag for each variable. In this section, we conducted tests to determine the optimal lag order for each variable in the time series dataset. This step is critical in preparing for the construction of an Autoregressive Distributed Lag (ARDL) model. The results are shown in Appendix 5. The optimal lag lengths for various variables are crucial for constructing the ARDL model and subsequent analyses. For GDP, the optimal lag is 1, supported by log-likelihood, likelihood ratio test statistic, and Akaike Information Criterion (AIC) values. Seaport efficiency (E) has an optimal lag of 0, with significant log-likelihood and AIC values. Capital (K) exhibits an optimal lag of 2, while Labor (L) has an optimal lag of 1. Human capital (H) suggests an optimal lag of 2. Knowledge spillover (KS), Customs and Import Duties (COD), and other variables each have optimal lag lengths of 1. These findings provide a solid foundation for time series modeling and forecasting, aiding in the development of the ARDL model and ensuring the accuracy of subsequent analyses.

4.2 ARDL estimation

We present the results of the ARDL estimation for the dependent variable GDP, incorporating various independent variables. The estimated coefficients, standard errors (in parentheses), and their significance levels are shown in Table 1.

The author acknowledges the presence of potential multicollinearity, as indicated by the correlation matrix, and, in response, strategic decisions were made to drop certain variables

Table 1. ARDL estimation results

Dependent variable: GDP

Variables	Coefficients Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	−14.7882** (3.0630)	−10.8823* (3.6030)	13.6247** (3.4341)	0.5783 (0.4212)	−0.5975 (3.0132)	7.9670 (3.7193)	6.1097** (1.230)	27.9638* (9.0284)
LagGDP	0.5489* (0.1726)	0.0011** (0.0002)	0.1457 (0.3437)	0.9417*** (0.0246)	1.0306*** (0.1164)	1.0539** (0.2433)	0.9794** (0.2233)	0.5243 (0.3965)
	ES: 0.9944	ES: 0.6000	ES: 0.8852	ES: 0.9986		ES: 0.9055	ES: 0.9959	
E	0.0016** (0.0003)	0.0140** (0.0020)	0.0231* (0.0074)	0.0020 (0.0024)	0.0081 (0.0134)	0.0021*** (0.0003)	0.0026*** (0.0004)	0.0027 (0.0052)
	ES: 0.9704	ES: 0.7245	ES: 0.8960			ES: 0.7789	ES: 0.5691	
lagE	0.0097* (0.0026)		0.3405*** (0.0054)	0.1452 (0.1042)		0.0058** (0.0012)	0.0088* (0.0023)	0.0275* (0.0073)
	ES: 0.97048		ES: 0.8969			ES: 0.7789	ES: 0.5691	ES: 0.9532
K	0.1061** (0.0231)							
	ES: 0.9820							
L		−4.4402** (1.0546)						
		ES: 0.7100						
H			0.0455** (0.0097)					
			ES: 0.8878					
KS				0.5376*** (0.0074)				
				ES: 0.9843				
COD					−0.5975** (0.1132)			
					ES: 0.7178			
IGS						−0.0011 (0.0022)		
						ES: 0.0804		
EGS							0.0082*** (0.0013)	
							ES: 0.9563	
PCI								0.0499** (0.0125)
								ES: 0.9516

Note(s): ES: Effects Size, ***, **, * indicate significance at 1, 5, and 10% respectively, ( ) indicates standard error
Source(s): Table created by the author

across all eight models. This precautionary measure was taken to enhance the robustness and reliability of the models. By excluding variables exhibiting high correlation, the author aimed to mitigate issues associated with multicollinearity, ensuring that the estimated coefficients remain interpretable and the statistical inferences derived from the models are more dependable. This careful consideration of multicollinearity aligns with best practices in regression analysis, where the presence of highly correlated independent variables can introduce instability in parameter estimates and compromise the validity of statistical tests. Thus, the deliberate choice to exclude specific variables contributes to the methodological rigor of the analysis and reinforces the credibility of the study's findings. While each model provides insights into the relationship between the specified variables, it is essential to note that there is no explicit indication of the interrelationship or dependencies between the models. The information presented here focuses on the individual analyses conducted in each model.

The primary model selected for examining the linkages between seaport efficiency and economic growth in Ghana is Model 1. This model, under the ARDL framework, centers on the dynamic relationships among key variables - GDP, LagGDP, E, and lagE. Notably, LagGDP serves as a crucial indicator, reflecting the persistence of past GDP values on current economic conditions, with a statistically significant positive coefficient of 0.5489*. This result is in line with (Ausloos *et al.*, 2019). From a root cause perspective, this suggests that the economic conditions and policies in the past continue to shape present outcomes. Persistent positive relationships highlight that certain historical factors, possibly related to sustained economic development or stability, have a lasting impact on current GDP.

The variable E, demonstrates a positive and statistically significant relationship with GDP, with a coefficient of 0.0016** and an effect size (ES) of 0.9704. This result is consistent with (Munim and Schramm, 2018; Chang *et al.*, 2021; Chen *et al.*, 2022; Johansson, 2022; Onikosi-Alliyu, 2022). This signifies that improvements in seaport efficiency contribute positively to the current GDP, highlighting the pivotal role of efficient seaports in fostering economic growth. Additionally, the inclusion of lagE reveals a positive and statistically significant relationship with a coefficient of 0.0097*, indicating that past seaport efficiency positively impacts current GDP, emphasizing the lasting effects of efficiency improvements over time. From a root cause standpoint, this could be attributed to the facilitation of trade, reduced transportation costs, and enhanced overall economic activity resulting from efficient seaport operations. The lag effect suggests that efficiency improvements have lasting positive effects over time.

Model 1 intentionally excludes control variables, providing a focused examination of the interplay between past GDP, current seaport efficiency, and lagged seaport efficiency in shaping Ghana's economic landscape (Ducruet and Notteboom, 2012). The absence of control variables underscores the model's emphasis on the core relationships of interest. The positive relationship between seaport efficiency and GDP aligns with the findings from previous studies, emphasizing the importance of efficient seaports in enhancing economic growth.

Moreover, the model includes capital (K) as a significant contributor to GDP at the 5% level, supporting the notion that increased capital investment positively impacts economic output. This finding contrasts with some studies, such as that of Olusola (2016) suggesting variations in the relationship between physical capital and economic growth based on different growth determinants. Root causes for this could include the creation of job opportunities, technological advancements, and increased production capacity. It reflects the importance of sustained investment in capital-intensive industries for economic growth.

Analyzing LagGDP across the eight ARDL models reveals variations in the persistence of past GDP values in explaining current economic conditions. While Models 4 and 5 exhibit a robust positive relationship, indicating substantial persistence, Models 1, 2, 6, and 7 show varying degrees of significance, suggesting weak to moderate persistence. Notably, Models 3 and 8 lack statistical significance, highlighting diverse economic dynamics influencing the relationship (Imandojemu and Toyosi, 2018).

The coefficient of E is found to be positive and statistically significant at the 5% level in Models 1, 2, and 3, signifying a strong relationship with GDP. Models 6 and 7 also show significance at the 10% level. However, in Models 4, 5, and 8, the relationship is not statistically significant, underscoring the importance of context-specific analysis. In models where the relationship is significant, enhancing seaport efficiency correlates with higher economic growth, emphasizing the importance of efficient seaports in economic development (Ducruet *et al.*, 2016; Munim and Schramm, 2018).

Examining lagE, representing the influence of past seaport efficiency on current GDP across Models 1, 3, 6, 7, and 8, consistently reveals a positive and significant connection. This emphasizes the enduring impact of historical improvements in seaport efficiency on current economic output, reinforcing the role of efficient seaports in driving economic growth.

Model 2 reveals a significant negative relationship between labor (L) and GDP, suggesting that an excessive labor force without proportional capital or technological advancements may negatively impact economic output. From the root cause perspective, this could signal challenges related to labor productivity, skill mismatches or insufficient technological integration in labor-intensive sectors. This insight prompts considerations for optimizing the balance between labor and capital, as well as improving labor productivity through training, education, and technological innovation. Policymakers and businesses should consider optimizing the balance between labor and capital, as well as improving labor productivity through training, education, and technological innovation, to enhance economic growth. This result agrees with (Shahid, 2014), while it disagrees with (Jajri and Ismail, 2010). The contradiction between these empirical results and those of Shahid (2014) and Jajri and Ismail (2010) can be attributed to various factors, including differences in the specific economic contexts or periods analyzed, as well as variations in the models and methodologies employed.

Model 3 indicates a positive relationship between human capital (H) and GDP, emphasizing the role of investments in education and skills in driving economic growth. This positive association reinforces the idea that a knowledgeable and skilled workforce contributes significantly to a country's economic expansion. The results align with studies by Mohamed Arabi and Suliman Abdalla (2013) and Pelinescu (2015). From a root cause perspective, this may be indicative of a knowledge-driven economy, where the diffusion of information and innovation positively influences economic growth.

Model 4 shows a strong positive relationship between knowledge spillover (KS) and GDP, underlining the positive impact of knowledge diffusion on economic growth. This suggests that the sharing of knowledge across sectors and industries significantly contributes to economic development. This result has been found in other works including (Kuo and Yang, 2008; Kaneva and Untura, 2019). The real-world implications may vary depending on factors such as the efficiency of knowledge transfer mechanisms and the level of technological development.

Model 5 highlights a negative relationship between customs and import duties (COD) and GDP. Overreliance on import-related taxes may hamper economic growth, emphasizing the need for diversified tax revenue sources. This finding echoes the importance of a balanced taxation approach to foster economic development. Some studies (Ogwuru and Agbaraevoh, 2017; Owino, 2019) however, found positive relationships.

Model 7 signifies the positive impact of exports (EGS) on GDP, emphasizing the role of international trade in driving economic growth. The significant positive coefficient suggests that a higher percentage of GDP coming from exports is associated with increased GDP. This insight underscores the potential benefits of pro-export policies, such as trade agreements and incentives for exporters. Even though in theory and empirics, export has a positive impact on growth (Begum and Shamsuddin, 1998) some studies still found negative effects (Gabriele, 2006).

Model 8 indicates a positive relationship between Productive Capacities Index (PCI) and GDP, emphasizing the importance of efficient resource utilization in economic expansion. A higher PCI suggests efficient and effective utilization of resources, including human capital, physical capital, and technology, contributing to economic growth. This finding aligns with the idea that investments in technology, education, and infrastructure are associated with improved productivity.

4.2.1 Relationship among seaport efficiency, other variables, and growth. In the analysis of the relationship between seaport efficiency (E) and other variables in the eight models, the influence of E on economic growth manifests in diverse ways.

In Model 1, where seaport efficiency significantly impacts GDP, the interaction with the variable K (capital) demonstrates a noteworthy positive connection with a coefficient of 0.1061**. This implies that the positive effect of capital on GDP is amplified when seaport efficiency is high, emphasizing the complementary role of efficient seaports in enhancing the impact of capital investment on economic growth.

For Model 2, which considers the variable L (labor), the non-significant coefficient of seaport efficiency suggests that, within this specific model framework, the relationship between seaport efficiency and GDP is not pronounced when labor is considered. This could imply that, in this economic context, the influence of seaport efficiency on GDP is not significantly dependent on the amount of labor, challenging the conventional notion of labor as a direct driver of economic output.

In Model 3, the interaction between seaport efficiency and H (human capital) yields a positive and statistically significant coefficient of 0.0455**. This suggests that the positive impact of human capital on GDP is strengthened when seaport efficiency is high. Investments in human capital, coupled with efficient seaports, contribute synergistically to economic growth, reflecting the importance of a skilled workforce and well-functioning seaports in tandem.

For Model 4, which includes the variable KS (knowledge spillover), the significant and positive coefficient of 0.5376*** emphasizes the pivotal role of knowledge transfer in contributing to economic growth when seaport efficiency is high. This implies that, in this context, efficient seaports facilitate the effective dissemination and application of knowledge across sectors, enhancing overall economic output.

In Model 5, where COD (customs and import duties) is considered, the negative and significant coefficient of −0.5975** indicates that an overreliance on customs and import duties as a source of tax revenue is associated with a reduction in GDP. This implies that seaport efficiency, by influencing the dynamics of customs and import duties, can impact the overall economic growth positively.

For Model 6, which includes the variable IGS (percentage of GDP attributed to imports of goods and services), the non-significant coefficient for seaport efficiency suggests that the relationship between seaport efficiency and GDP is not statistically significant when considering the percentage of GDP from imports. This might indicate that, in this specific model, the level of imports does not significantly affect economic growth, or the economy may be relatively self-reliant.

In Model 7, the interaction between seaport efficiency and EGS (percentage of GDP attributed to exports of goods and services) yields a significant positive coefficient of 0.0082***. This implies that seaport efficiency enhances the positive impact of exports on GDP, underscoring the crucial role of efficient seaports in fostering international trade and economic growth.

In Model 8, the interaction between seaport efficiency and PCI (Productive Capacities Index) results in a positive and significant coefficient of 0.0499**. This suggests that seaport efficiency contributes positively to economic growth, particularly in the context of efficient utilization of resources, including human and physical capital, and technology. The positive coefficient indicates that as a country's productive capacities increase, its GDP tends to grow, emphasizing the pivotal role of efficient seaports in this relationship.

Overall, the interactions between seaport efficiency and other variables highlight the complex and multifaceted nature of the relationship between seaport efficiency and economic growth. The variations across models underscore the importance of considering specific contextual factors and the interconnectedness of various economic determinants. These findings contribute to a nuanced understanding of how seaport efficiency interacts with diverse variables to shape economic outcomes.

4.3 Bounce test of GDP and seaport efficiency

Table 2 presents the Bounce Test, which analyzes the relationship between Gross Domestic Product (GDP) and seaport efficiency (E) and was conducted to assess both short-run and long-run effects.

For the variable lagGDP, the test showed a significant long-run impact (0.2792***), suggesting that past values of GDP have a lasting influence on changes in GDP. This indicates that historical GDP figures significantly impact future GDP dynamics, providing evidence of a persistent relationship between past and current GDP values.

Similarly, the variable E demonstrated a statistically significant short-run impact (0.0771*) on changes in GDP. This result indicates that fluctuations in seaport efficiency (E) can exert an immediate influence on GDP. The short-run effect suggests that improvements or deteriorations in seaport efficiency may lead to temporary changes in GDP, but these effects may not be as long-lasting as those observed in the long run.

For the variable LagDiffGDP, it displayed a short-run impact (0.3221) on changes in GDP. This suggests that past changes in GDP have a relatively immediate influence on the current GDP dynamics. Such a short-run effect highlights that temporary variations in GDP might be explained by recent fluctuations in GDP itself. The variable DiffE demonstrated a short-run impact (0.0242) on changes in GDP. This indicates that short-term variations in seaport efficiency can lead to short-run fluctuations in GDP. However, the effect size is relatively small, suggesting that the immediate impact of changes in E on GDP might not be as substantial as other factors.

Lastly, LagDiffE showed a statistically significant short-run impact (0.03173*) on changes in GDP. This suggests that past changes in seaport efficiency (E) can influence short-run fluctuations in GDP. Similar to DiffE, the effect size indicates a relatively modest short-run influence of past changes in E on GDP. In summary, the Bounce Test results reveal both short-run and long-run relationships between GDP and seaport efficiency, underlining the importance of both historical GDP values and short-term fluctuations in E in explaining changes in GDP.

Dependent variable: DiffGDP

Variable	Adj.	Long run	Short run
lagGDP	0.2792*** (0.0213)		
E		0.0771* (0.0267)	
LagDiffGDP			0.3221 (0.1959)
DiffE			0.0242 (0.0102)
LagDiffE			0.03173* (0.0091)
Constant			6.4402* (2.0087)

Note(s): ***, * indicate significance at 1 and 10% respectively
Source(s): Table created by the author

Table 2.
Bounce test results

4.4 Granger Causality test

This section presents the results of Granger Causality test. The Granger Causality Test was employed to assess the causal relationship between two key variables, Gross Domestic Product (GDP) and seaport efficiency (E), as well as to examine the influence of including all relevant variables. The results of the test in shown in Table 3 below. The test produced significant results that shed light on the interactions between these factors.

First, the test indicated that past values of GDP do not Granger cause changes in seaport efficiency (E). This outcome suggests that historical GDP figures do not significantly help predict future values of E. In essence, fluctuations in GDP may not be a substantial driving force behind changes in seaport efficiency. This finding implies that E might be influenced by other factors or variables outside the scope of GDP.

Conversely, the Granger Causality Test revealed a noteworthy result: E Granger causes GDP. This indicates that past values of seaport efficiency significantly help predict future GDP figures. In practical terms, improvements or deteriorations in seaport efficiency may act as a predictive factor for changes in GDP. Therefore, seaport efficiency can be considered a driver of economic growth. This finding holds essential implications for policymakers and stakeholders in the maritime and trade sectors, emphasizing the potential for strategic investments and enhancements in seaport efficiency to positively impact overall economic growth.

Moreover, when both GDP and E were included in the Granger Causality Test alongside all other relevant variables, the results remained consistent with the individual tests. This reaffirmed the causal relationship between E to GDP, highlighting its predictive role in forecasting economic changes. In short, these test outcomes support the notion that optimizing seaport efficiency can contribute significantly to GDP growth and underscores the relevance of efficient port operations in the broader context of economic development.

5. Policy implication

The comprehensive analysis of seaport efficiency and its impact on economic growth in Ghana reveals crucial policy implications. Policymakers should prioritize strategic investments in seaport infrastructure, focusing on modernization and expansion to enhance overall operational efficiency and hence growth. Simultaneously, recognizing the positive interaction between seaport efficiency and human capital, there is a need for policies promoting skill development in the maritime sector through training programs and educational initiatives. Moreover, the positive relationship between knowledge spillover and economic growth calls for policies encouraging knowledge transfer mechanisms within the seaport industry, fostering innovation and efficiency.

Diversifying revenue sources becomes imperative due to the negative relationship between customs and import duties (COD) and GDP. Policymakers should explore alternative revenue streams to create a sustainable economic environment. Additionally, promoting export-oriented policies, including trade agreements and incentives, can capitalize on the

Variable	Excluded	F	Prob
GDP	E	0.5915	0.4615
GDP	ALL	0.5915	0.4615
E	GDP	5.4718	0.0436
E	ALL	5.4718	0.0436

Source(s): Table created by the author

Table 3.
Granger causality test results

positive impact of exports (EGS) on GDP. Balancing the labor force is crucial, as indicated by the negative relationship between an excessive labor force (L) and GDP. Policymakers should focus on improving labor productivity through training, education, and technological innovation.

Efficient resource utilization is key, supported by the positive interaction between seaport efficiency and the Productive Capacities Index (PCI). Policies should encourage investments in technology, education, and infrastructure to enhance overall productivity. In conclusion, the policy implications suggest a holistic approach, combining investments in infrastructure, human capital, innovation, and trade facilitation. By addressing these aspects, policymakers can create an environment conducive to seaport efficiency, catalyzing economic growth and ensuring the long-term sustainability of Ghana's maritime sector.

6. Conclusion

In wrapping up, our exploration into the nexus of seaport efficiency and economic growth in Ghana yields crucial insights. Over the 2006–2020 period, the study underscores the pivotal role of streamlined port operations in steering national economic prosperity. The positive correlation between seaport efficiency and economic growth highlights the strategic significance of well-functioning ports in Ghana's developmental trajectory. Practical implications emerge, emphasizing that bolstering seaport efficiency is not just a consequence but a driver of economic growth. The findings spotlight key intersections with variables like capital, human capital, knowledge spillover, and exports. This interconnectedness underscores the need for targeted, context-specific strategies to optimize the impact of seaport operations. Our policy recommendations echo this context specificity. From digital infrastructure upgrades to workforce capacity building, the proposed interventions aim at creating an environment where seaport efficiency acts as a catalyst for sustainable economic growth. By accentuating knowledge exchange, maintaining a balanced labor-capital equation, and tailoring policies to Ghana's maritime landscape, these recommendations align with the unique dynamics of the nation. As Ghana steers its economic course, the maritime sector emerges as a linchpin for global competitiveness. Implementation of these policies, coupled with continuous evaluation, promises to navigate challenges and seize opportunities. Ghana's maritime prowess, if harnessed effectively, not only enhances regional standing but also contributes significantly to the global discourse on the symbiotic relationship between seaport efficiency and sustainable economic development. In essence, this study transcends conventional analyses, offering a roadmap for policymakers and industry leaders. It envisions a future where Ghana's maritime excellence becomes the driving force behind economic resilience and prosperity.

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Appendix 1

Variable	Description
GDP	Gross Domestic Product
E	Seaport Efficiency
K	Capital
L	Labourforce
H	Human capital
KS	Knowledge Spillover
COD	Customs and other import duties (% of tax revenue)
IGS	Imports of goods and services (% of GDP)
EGS	Exports of goods and services (% of GDP)
FDI	Foreign direct investment, net inflows (% of GDP)
PCI	Productive Capacities Index

Source(s): Table created by the author

Table A1. Variables and their abbreviation as used in the study

Appendix 2

Table A2. Descriptive of the variables

	GDP	E	K	L	H	KS	FDI	PCI	COD	EGS	IGS
Mean	24.49008	20.18101	2.911989	16.24746	27.24642	13.83333	7.172065	35.54240	19.61696	31.36123	42.02577
Median	24.55299	20.14546	2.870658	16.25132	27.81165	14.00000	7.027542	36.43425	17.50072	30.33498	40.58426
Maximum	24.73468	21.71428	3.274230	16.34323	29.01560	15.00000	9.466664	38.11150	27.54315	40.35922	52.80882
Minimum	24.15998	18.87242	2.465052	16.13499	24.05810	12.00000	5.388487	31.35820	15.52847	25.02946	35.60466
Std. Dev	0.224516	0.969607	0.300364	0.079544	1.837556	1.169045	1.520714	2.811996	4.770752	5.305769	6.866949
Skewness	−0.467441	0.295497	−0.148583	−0.180438	−0.880866	−0.487567	0.326902	−0.572667	0.851004	0.664817	0.511622
Kurtosis	1.719731	2.342877	1.936078	1.706719	2.477919	1.989887	1.817232	1.714589	2.127297	2.516932	1.847603
Jarque-Bera	0.628274	0.195271	0.305059	0.450702	0.844067	0.492804	0.456600	0.741018	0.914611	0.500320	0.593762
Probability	0.730419	0.906979	0.858533	0.798236	0.655712	0.781608	0.795885	0.690383	0.632987	0.778676	0.743132

Source(s): Table created by the author

Appendix 3

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) GDP	1.000								
(2) E	0.764	1.000							
(3) H	0.955	0.886	1.000						
(4) KS	0.519	0.159	0.380	1.000					
(5) L	0.987	0.731	0.941	0.532	1.000				
(6) K	0.455	0.263	0.287	0.417	0.402	1.000			
(7) IGS	−0.377	−0.223	−0.284	−0.352	−0.403	−0.704	1.000		
(8) EGS	0.548	0.329	0.530	0.361	0.539	−0.158	0.479	1.000	
(9) PCI	0.992	0.746	0.942	0.539	0.980	0.470	−0.343	0.597	1.000

Source(s): Table created by the author

Table A3.
Matrix of correlations

Appendix 4

Series	ADF (probability)	Series	ADF (probability)
GDP	0.4965	D_GDP	0.0122**
E	0.0462*		
K	0.3132	D_1(K)	0.053*
L	0.008***		
H	0.8351	D_1(H)	0.059*
KS	0.5584	D_1(KS)	0.055*
COD	0.053*		
IGS	0.4110	D_1(IGS)	0.0081**
EGS	0.019**		
FDI	0.203	D_1(FDI)	0.0006***
PCI	0.107	D_1(PCI)	0.010**

Note(s): D_1 indicates first difference. ***, **, * indicate significance at 1, 5 and 10% respectively
Source(s): Table created by the author

Table A4.
ADF stationary test

Appendix 5

Series	Lag	Log-likelihood value for the model	Likelihood ratio test statistic	AIC
GDP	1	26.9051	47.258*	−4.15085*
E	0	−11.1201		3.03003*
K	2	5.52585	4.0213*	−0.420974*
L	1	54.1204	81.154*	−8.68673*
H	2	3.1385	−20.6683*	2.78451*
KS	1	−2.05744	8.9588*	1.62297*
COD	1	−22.8647	5.4624*	4.97294*
IGS	1	−42.0101	2.6344*	7.33502*
EGS	0	−36.8752		6.31253*
FDI	1	−16.6326	2.8615*	3.56956*
PCI	1	−20.3742	52.422*	2.48602*

Source(s): Table created by the author

Table A5.
Optimal lags

Appendix 6

	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]
	L_1	L_1	L_05	L_05	L_025	L_025	L_01	L_01
k_1	4.040	4.780	4.940	5.730	5.770	6.680	6.840	7.840
	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]
	L_1	L_1	L_05	L_05	L_025	L_025	L_01	L_01
k_1	−2.570	−2.910	−2.860	−3.220	−3.130	−3.500	−3.430	−3.820

Note(s): Pesaran *et al.* (2001) ARDL Bounds Test
H0: no levels relationship $F = 7.460$, $t = -3.044$
Source(s): Table created by the author

Table A6.
ARDL bounds test results

Corresponding author
Joseph Antwi Baafi can be contacted at: jobash5@hotmail.com, jbantwi@aamusted.edu.gh