An endogenous growth approach on the role of energy, human capital, finance and technology in explaining manufacturing value-added: A multi-country analysis

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ARTICLE INFO

Keywords:
Endogenous growth model
Human capital
Energy-led growth
Finance-led growth
Technology-led growth
Human capital-led growth
Economics
International trade
Economic growth
Macroeconomics
Energy economics

ABSTRACT

The multi-dimensional benefits offered by the manufacturing sector in economic growth and development make academicians and policymakers to consider this sector still as an *engine of growth*. The unique qualities of this sector occupy a predominant place in the development policies around the world. Against these insights gained from economic literature, the study empirically investigates the role of energy, human capital, finance and technology in influencing manufacturing value-added in an endogenous growth framework by assessing short-run and long-run relation through ARDL bounds test approach followed by VECM causality test. The results testify the existence of energy-led, finance-led (supply leading), technology-led, and human capital-led growth hypotheses. These results give important insights and directions to have long term well-framed policy perspectives to develop financial institutions, the uninterrupted energy flow to the manufacturing sector, a blend of education and skill intensive programs and, an import strategy specially designed to obtain the spillover benefit of foreign technology.

1. Introduction

What makes the researchers and policymakers to consider the manufacturing sector still an *engine of growth* is not only because of its direct bearing on the overall socio-economic development of a nation but also, how the vertical and horizontal expansion of this sector affects other sectors, capital accumulation, forward and backward linkages, structural transformation bonus, technological transformation, and utilizing the labour market at the optimum level, etc. The above-mentioned argument gains support even from the celebrated works of Lewis (1954) and Kaldor (1966). They also argue that the development of manufacturing sector observes not only the growing amount of raw materials, goods and even excess labour force from primary sectors, but also facilitates the service sector to grow by creating demand for services like banks, insurance and professional services. The findings of the seminal research works (Amar, 2000; Fagerberg, 2000; Peneder, 2003; Rodrik, 2009; Szermai, 2012; Szermai and Verspagen, 2011) are the testimonies for the arguments of Lewis (1954) and Kaldor (1966).

The existing contemporary evidence says that in many developed and developing countries, the progress of the manufacturing spectrum is the principal agenda for many reasons. The Asian Development Bank (2014) has rightly pointed out that channelling productive resources towards manufacturing sector has multi-fold benefits as it has high-income elasticity for its demand due to economies of scale being inherent in the production process. It is globally recognized that capital stockpiling is one of the important sources of growth; a higher degree of capital accumulation can be attained in the manufacturing sector than that of other major sectors. This sector is more or less a single most breeding ground for both embodied and disembodied technological advancement (Cornwall, 1977). Growth of manufacturing output plays a substantial role in attaining and sustaining a sustainable socio-economic development as it has a strong association with domestic, global trade and developments (Kaldor, 1966 and Chenery et al., 1986). Moreover, the manufacturing sector acts as the epic centre of the linkage and spillover effects which are trickling down to all the walks of economic activities. The linkage effect creates a conducive environment for positive externalities for investment, while the spillover effect produces the embodied as well as disembodied knowledge flowing across the sectors (Szermai, 2012). The available empirical evidence elucidates that there is a strong correlation between industrialization and per capita income. Further, the
dynamic variety of the structural transformation advantage is described by some renowned scholars (Fei and Ranis, 1964; Lewis, 1954; Chenery et al., 1986; Fagerberg, 2000; Timmer and Adam, 2000; Temple and Jonathan, 2006; Timmer and De Vries, 2009 and Rodrik, 2009) as the higher productivity growth percolates from manufacturing sector than that of other major sectors.

The classical predisposition of stationarity state refurbished by Solow (1956) implies the per capita output growth for industry or a nation as the whole will become zero in the long run. But many countries experienced the opposite of what has been proposed by Solow (1956). The long-run per capita growth is positive and this has been defined by Solow as an outcome of exogenous technological progress. Later, endogenous growth paradigms evolved modelling the technological progress, which so far is considered exogenous, a precarious position indeed. In this context, if we borrow theoretical solutions from new growth theories to this growth conundrum, we can see that they have added human capital as one of the factors of production. The dual role of human capital in terms of skill up-gradation through learning and creating new ideas through R&D has been established. As time elapsed, people start recognising the role of energy and finance as other vital inputs of production, which act as part of the endogenous process in influencing the future output and long-run growth.

In the dynamic economic environment, human capital, finance, technology, and energy are tightly interlinked around the world. In the globalized regime, mobility of human resource, finance, energy and technology from one economic region to the rest of the world (mostly from the West to the East) is a stylized fact. The recent paradigm shift from traditional Solow type analysis to new growth theories has resulted in the factors such as energy, technology, human capital, and finance, in the limelight, playing decisive roles in fixing production and productivity rather than the conventional factors of production. This situation calls for a scientific study to measure the effect of energy, technology, human capital, and finance on the manufacturing output. But, full-fledged research in the endogenous theoretical frame, encompassing the dynamics of the interaction of all these significant variables with that of manufacturing output is a new venture. This has a value-added effect that too in a multi-country framework.

Even before breaking the perfect competitive framework, human capital as one among the broad range of capital goods which would incur constant returns to scale. The prototype is the AK model (Romer, 1986, Lucas, 1988 and Grilliches, 1980). Schumpeter (1911) has recognized the importance of trade, human capital, energy, and finance as other vital inputs of production. The estimation technique employed is the ARDL model for cointegration. The estimated result components as vital inputs of production. The estimation technique important. The study thus doesn’t deviate from the recognition of these components as vital inputs of production. The estimation technique employed is the ARDL model for cointegration. The estimated result offered some interesting insights and based on this a few valuable suggestions are provided for the betterment of those nations. The definite purposes of the extant study are:

(i) to analyse the long-run and short-run dynamics of manufacturing output with that of energy, technology, financial advancement and human capital in an endogenous growth spectrum, and (ii) to establish the path of causality and thereby seeking evidence for energy-led growth, finance-led (supply leading/demand following), human capital led and technology-led growth hypotheses. This study, to our knowledge, is the first attempt to capture the causation among the variables under the endogenous environment in the industrial arena of the economy. There are works, which trod on the path of analysing the influence of such multiple variables in the context of growth. But, this is a new venture in the context of the industrial arena and that too in the late industrialised context. This is important as industrialisation is the soul of achieving technological progress and transforming lives.

2. Literature review

The individual-specific importance of trade, human capital, energy, technology, and finance on economic output and its growth has been studied by noted academicians, right from the beginning of 20th century or even before and well documented in the literature. As these factors are observed to be the vital components of production and recently been met with importance, which is either equal to or outweighs the conventional components of production such as labour and capital (Jones et al., 1998). Among the existing body of literature, Eliasson (1991) argues growth as a microeconomic phenomenon where ideas contribute to a non-linear relationship among inputs, outputs, and economic growth.

2.1. Energy and output

Exploring the causality between energy and output has been an attractive area of investigation right from the global oil shocks of the early 1970s (Paul and Uddin, 2011). Using a group of additional determinants, Erol and Yu (1988) for Japan, Ghali & El Sakka (2004) for Canada, and, Masih and Masih (1996), in the case of Pakistan, found bi-directional causality escalating between these two variables. Tahvonen and Salo (2001) studied the historical context of energy-income nexus and found that both renewable and non-renewable energy forms are simultaneously used. Also, they observed the existence of an inverted U-shaped hypothesis working without specific environmental policy. Hondroyiannis et al. (2002) experimented the interrelationship between economic growth, energy consumption and the price level in Greece during the period 1960–1996 and testing of cointegration using Johansen maximum likelihood approach revealed that cointegration exists and the causality test confirmed long-run causality escalating from energy intake to GNP. Zon and Yetkiner (2003), by extending Romer’s model (1986) of endogenous growth, including energy and intermediate products relationships, concluded in their study that the need for energy efficiency growth under rising real energy prices warrants a blend of
R&D and energy price policy. Ayres and Van den Bergh (2005) based on a demand feed mechanism integrated into a scale-cum learning cycle approach proposed that the economic growth should be coupled with structural change in terms of new products and production functions, change in efficiency and dematerialization and observed that environmental Kuznets curve was found to be working in low growth rates. The augmented production function estimation of Tugcu et al. (2012) to study the nexus between growth and energy consumption for G-7 countries found a mixed form of result. Further, the ARDL approach for cointegration and causality test revealed results in terms of the presence of growth, neutrality, feedback, and conservation hypothesis. In empirical work, Patrick (1966) detected the positive consequence of electricity feeding in manufacturing production and later the same was recommended by Mawejje and Maweje (2016).

The academic conversation on the partaking of energy in output creation was initiated after the oil sector blows were felt by the international economy in the 1970s. Alam (2006) for the first time considered energy as one of the primary inputs in determining output. The growing recognition of energy as a major input and the realization of energy efficiency, supply and R&D in the energy sector along with the growing academic literature discussing the role of energy. But energy has got certain relationships with some other important components of production, which has not so far been subjected to critical analysis based on any theoretical prism. The countries endowed with oil and others that import oil are confronted with different macroeconomic issues and the same has not been well explored.

2.2. Human capital and output

Klenow (1998) using data of 1951–1991 computed growth rates for 449 (4-digit level) US manufacturing industries, tested the rival endogenous models of idea-based and that of human capital based and concluded that capital intensive industries grew faster than that of labour-intensive testifying the upper hand of idea-oriented approach in human capital-based models. The International Monetary Fund (2008) portrayed that both in high income and low-income nations, accumulation of human capital has a significant impact on economic growth. The endogenous growth model (Romer, 1986 and Lucas, 1988) recognized human capital as one of the key determinants of paramount development in a nation. In a seminal work, Li and Liu (2005) found that human capital acts as an interacting force along with FDI in promoting economic growth by using panel data of 84 countries during the period of the 1970s. Likewise, a similar observation has been made by Hong (2014). He took a sample of 284 prefecture-level cities from China for the period 1994–2010 and ran GMM estimation and figured out that human capital, economies of scale, infrastructure, wage level, regional difference, etc interact with FDI influencing growth in China. Pelinescu (2015) found human capital has a dual positive impact on economic growth in terms of expansion of ideas as well as improvement in the quality of employees underpinned by education. Sulaiman et al. (2015) explained the Nigerian growth regime using the ARDL bounds method and opined technology and human capital are important variables to mould growth. Squicciarini & Voigtlander (2016) scanned the backing aspects of the Mid 18th century manufacturing renaissance relying on a panel study of France. They detected that the existence of superior tal knowledge led to nurturing yield and innovation in manufacturing spectrum rather than human skill indicated by literacy rate. Khan (2018) based on the study of a prodigious inventors’ example set of 434 men and a woman in Britain pronounced that rather than expert training, the accrual of luxurious human wealth and the role of elite-level people, it is encouragement for resourcefulness, flexibility and talent to make extra modifications which can amend the prevalent technology into innovation under the fundamental internal environments. Ma et al., (2019) did a panel work on 13 economies using data for 304 manufacturing companies and established that profession related inculation and employee involvement advance innovation activity at the firm level.

The human capital endowment among countries is different in terms of quality and quantity. In comparison to that of the developed countries, the human capital in developing countries is relatively unskilled. Also the agility of human capital in terms of creativity, productivity and endurance are reflected by the youthfulness of labour force which is ultimately determined by the demographic dividend of the labour force. A study which is directed upon the future viability and persistence of human capital and agility aspects is missing in the literature in vogue. The ability to create ideas and the interaction of human capital with research and development in the country is yet to be studied in developing country context.

2.3. Finance and growth nexus

Schumpeter (1911) was among the pioneers in arguing the positive relationship between the financial system and economic growth, followed by Goldsmith (1969), Shaw (1973) McKinnon (1973) and Levine (1997). In comprehensive research, Buerwa et al. (2011) relying upon a qualitative framework examined the association between sector wise total factor productivity and financial expansion in several countries and found that financial friction is responsible for inefficient allocation of entrepreneurial and financial capital across productive sectors resulting in adverse consequence on productivity. Koo and Kim (1999) employed stochastic frontier production function to panel data for Korean manufacturing industries and showed that an increase in financial services is associated with a reducing impact on technical efficiency. Rajan and Zingales (1998) measured the dependency of young companies on external financial flow. Similarly, Furstenberg (2004) attempted to measure the magnitude of the degree of young companies' dependence on external finance, concluded that the latter has no explanatory power on the structure of industrial growth in Poland. Asaleye et al. (2018) established the presence of causality, both in short-run and long-run between manufacturing output and financial indicators in Nigerian economic sector suggesting that the policy formulation is favourable to long-run industrial output enhancement through the development of the financial sector.

The Johansen cointegration technique applied by Ekor and Adeniyi (2012) on Nigeria’s data for the period 1970–2010 found magnitudes insignificant for credit flow to the manufacturing sector, banking efficacy and trade balance (non-oil) on manufacturing output and thus collected evidence for the dichotomy between real and financial sector. In another study, Olanrewaju et al. (2015) focused on the same nation - Nigeria, empirically checked the consequence on manufacturing sector due to banking sector reforms for the period 1970–2011 using cointegration mechanism and found a weak positive long-run relationship escalating from lending rate, exchange rate, bank assets, and the real rate of interest to manufacturing output. Similar to the earlier study of Levine in 1997, Pradhan (2013) has come up with a study interrogating the direct relation between financial advancement and economic progress. The former study of Pradhan underscores the long-run relation between the two variables using the ARDL bounds technique and underscores bidirectional causality among them using the VECM causality test. The realisation of financial inputs as one of the vital components of the production and its role in producing and creating a spillover of the technology has resulted in various theoretical underpinnings. This is basically from Schumpeter’s theory of finance-led innovation, finance-led growth hypothesis. The full-fledged role of finance should be analysed in the industrial sector context along with other factors which are so far held outside in the academic analyses as vital factors of production. In line with Schumpeterian philosophy Pradhan et al. (2018a) & (2018b) examined the empirical validity of various formulations depicting association of innovation & economic growth, finance & innovation. In the seminal studies, recently Asaleye et al. (2018) inspected the nexus between finance and output. Pradhan et al. (2020) along with ICT and innovation, explored the role of venture capital in long-lasting growth prospects in the premises of European union.
2.4. Technology & other supply shocks and output

Duan et al. (2010) using a monthly time series data set ranging from 1995-2008 of China employing multivariate vector autoregression (VAR) model established that there is a non-linear relation in vogue among world oil price, economic growth, and inflation. Positive supply shock in price has proved to have a trivial impact on economic growth, while negative shocks in price have shown a substantial effect on growth by reducing it. Lee and Ni (2002) using a structural VAR approach for 14 industries in the US economy found that both demand and supply shocks are found in the industries. Oil intensive industries are subjected to supply-side issues, while many industries like automobiles are prone to demand-side issues.

Greenan and Guellec (1994) examined through theoretical as well as empirical assessment and found that the technology changes and knowledge sharing between firms take place in a hierarchical and horizontal coordination model. Raut (1995) employed Cobb-Douglas production technique in the instance of Indian private manufacturing firms of light Petrochemicals and heavy industries over the period 1976–1986 and observed that R&D spillover acts as a relevant factor explaining manufacturing growth except in petrochemicals. Further, external R&D capital, in liaison with material capital and labour time, adds to the cause of augmenting the productivity in private firms. Also, the industry-wise model shows evidence for R&D spillover-led growth argument to prevail upon an extended sample of private manufacturing sectors. Kandil (1991) examined the relationship between industrial output and aggregate demand shocks in the US economy and found that the relationship is more or less defined by changes in the price of industrial output and the variability of demand. In wide-ranging research, Hulten and Schwab (1993) covering a period from 1970–86 explained growth in US regional manufacturing sectors as a function of factor accumulation in terms of capital and labour flows rather than multi-factor productivity shift firms. In another instance, Pradhan et al., (2016) captured the probable alli-

2.5. Existing hypotheses in the literature tested in the study

From 1990, many research scholars were involved in establishing the causality path between economic growth and financial progress, especially in the instance of Sub-Saharan Africa (see Spears, 1992; Akinboade, 1998; Aghetsiifa, 2003 and Odhiambo, 2004). Also, the supply-led and demand following proposition is met with academic interest. The theoretical arguments evolved in this regard is a transition from financial development as a major factor influencing growth (supply leading phenomenon) to the stage of higher-level, where economic growth leading financial development is termed as demand following effect. The view of Patrick (1966) has been termed as Patrick hypothesis. Connected to this, there is another theory, which is in vogue in academic discourse, is that the cause & effect relationship between financial development and economic growth is time-dependent and thus changes over time till a take-off to sustained growth trend happens. The financial development gives impetus to real innovation percolating economic progress. Pradhan et al. (2016, 2017, 2018a & 2018b) empirically ponder on the possibility of various propositions on financial development and economic growth to be in vogue.

In the theoretical discussion of economic growth and energy nexus, there are four academic theories in vogue such as (1) growth (2) neutrality (3) conservation and (4) feedback hypotheses/propositions.

The growth hypothesis describes that energy consumption Granger causes economic growth. The conservation hypothesis portrays that there is a uni-directional causal relation flowing from economic growth to energy use. This clarifies that any policy outcome to reduce energy consumption won’t conclude into partaking any influence on economic prosperity. Bi-directional causality between energy and growth is the feature of feedback hypothesis. Whereas, any relation amid energy and growth is negated through the argument denoted as neutrality hypothesis implying that no energy policy outcome would have any impact on output growth (Belke et al., 2011). Similarly export-led, human capital led and technology-led growth via import has been explored in line with the studies of Romer (1990) and Lucas (1988) etc.,

H1A, B. Financial advancement Granger causes manufacturing output growth and vice versa

H2A, B. Energy input Granger causes manufacturing output growth and vice versa

H3A, B. Human capital Granger causes manufacturing output growth and vice versa

H4A, B. Export Granger causes manufacturing output growth and vice versa

H5A, B. Technology Granger causes manufacturing output growth and vice versa

3. Materials and methods

The manufacturing arena has largely been subjected to supply shocks such as energy, financial flow, human endowment in terms of quality defined by human capital, and technology. The energy resource has highly been supported by international fossil fuel-based sources, fund flow especially credit from various sources and financial institutions. The fund flow is supposed to be rationed-out based on structural and institutional rigidity and viability, which the manufacturing sector is prone to and entrepreneurs frame their expectation models following that. The human quality & skill are defined by the coverage and quality of health and education system. The technology involves embodied and disembodied technical knowledge, which is observed to spillover from the developed countries to developing rather than emanating as a result of domestic R&D expenditure.

The theoretical explanations linking these premises are already well integrated into the economic literature, which have been reviewed so far in this study. Hence, based on these aspects, the relevant variables are taken into consideration and the functional form is specified. The endogenous model talks about increasing returns to scale by augmenting the normal production function by factors such as human and knowledge capitals. So, authors have a view from theory as well as existing literature
variable and electricity utilisation (LELEC), import (LIMP), export (as a stimulus to market expansion) as human capital, energy, the existing theory, we measured the dynamic interactions of factors such as innovation through investment intangible assets, Pradhan et al., (2018a, b) argue that in the present context, finance stimulates investment in intangible assets like human capital, knowledge and patents. Here the question arises about the technological strength of the model. That is whether the variables taken together actually have such distinctive individual contributions when taken at a time and not being overlapped by the other one. In this regard we point Pradhan (2013) and Pradhan et al. (2017, 2018a; 2018b) who argue apart from creating innovation, it has an important influence on economic growth that has to be captured. As innovation is a function of human capital invested in R&D, finance has to be treated as a separate variable along with human capital in examining output. This argument is further intensified by the notion of the indigenous financial system as an endogenous component in determining growth which is implicit in the above studies. There are pure R&D based endogenous models, which has been applied in the Indian context by Madsen et al. (2010). Energy input is already internalised by the works of Alam (2006). Hence it is acceptable as a separate variable. Hence, to test the existing theory, we measured the dynamic interactions of factors such as human capital, energy, finance, import (as a proxy for the foreign technology spillover) and export (as a stimulus to market expansion) with manufacturing output for the period from 1980 to 2015 in a multi-country framework.

The countries (India, Kenya, Peru, Morocco, and Sri Lanka) are selected deliberately as they are in the genre of late industrialized nations as per theUNCTAD 2019 classification belong to emerging markets across Asia, Africa and South America. The countries share a commonality in terms of structural mechanism which they follow. In addition to this, they have a demographic dividend in terms of youthfulness in the labour force. Further, these countries can act as the model of development for other countries having similar economic premises to follow their policy paradigm so that they can catch up and converge.

The relation among the variables has been made in the light of analyzing the scenario in 5 late industrialized nations using annual data series for the reference period 1980–2016. The criteria of data availability led to choose nations and periods of the study. In this empirical investigation, the manufacturing value-added (LMVA) is the regressee variable and electricity utilisation (LELEC), import (LIMP), export (LEXP), lending to private investment as a portion of GDP (LCRED), (financial development indicator), gross enrolment ratio in the primary sector (LGTER), a measure of human capital are the regressor variables of the manufacturing output in terms of value-added. Except for the energy variable, all the data are elicited from the globally acceptable domain of World Development Indicators while The International Energy Statistics is the source for energy-related data.

The variables such as the measure of manufacturing output, exports and imports are expressed in Million USD with the base period as 2010. Goodness of fit ratio is in index form while credit to private investment is denoted as a segment of GDP in percentage terms and units of electricity utilized is expressed in terms of Billion Kwh. In between, some values were found missing for the gross enrolment ratio which was rectified by interpolating the missing values. Ewing et al. (2007), as well as Friedl and Getzner (2003), expressed the idea that converting variables into per unit term only minimizes the magnitude of the variable and it thus permits the researchers to use the variables in the absolute term in place of per capita term. Therefore, the variables are not scaled down. To assure consistency and reliability in empirical results, the natural logarithm form of variables has been produced (Shahbaz et al., 2013). The equation describing the functional relationships among the variables is as follows.

\[
\text{LMVA} = f(\text{LELEC}, \text{LIMP}, \text{LEXP}, \text{LCRED}, \text{LGTER})
\]

Before determining the time series model, the data has been subjected to stationarity checking (Ewing et al., 2007). This has been done with the help of Augmented Dickey-Fuller (Dickey & Fuller, 1979), and Phillips-Perron (PP, 1988) tests¹. The variables revealed to be of I (1) genre, and for further detailed analysis, the ARDL bound test technique was adopted (Pesaran et al., 2001).

### 3.1. ARDL bounds technique of estimation

This experiment made use of the technique concerned with the ARDL bounds estimation system of cointegration propounded by Pesaran et al. (2001). The model involves the double benefit of explaining the dynamics of the association among variables in short and long durations. This has emanated as a replacement for Engle & Granger (1987) which is grounded on a residual test of cointegration. The major problem faced by Engle and Granger (1987) cointegration test is that if residuals are subjected to non-normal distribution, it leads to long-run inefficient results. This issue has been overcome by Engle and Yoo (1990) through developing a cointegration technique which gives more efficacy in results than the earlier one as a result of its strength and size.

However, as per the Johansen & Juselius (1990), this approach of examining cointegration is built on the structure of equations. The results obtained from Johansen and Juselius (1990) become null and void if any of the variables are stationary at the level or any mixed order I(0) & I(1). In this context, Pesaran et al. (2001) came up with an innovative approach called ARDL bounds, which takes care of the long-run co-integrating associations as well as accommodating structural break(s) incurring in the data generation process. From an econometric perspective, the ARDL bounds testing approach is viewed as convenient and much better than the other methods in accommodating data of small sample size as well as its ability to incorporate both short and long duration coefficients (Islam et al., 2013). Further, Pradhan (2013) underscores the long-run relation between the financial advancement and economic progression using ARDL Bounds technique and underscores bidirectional causality among them using the VECM causality test. In line with him, we also have employed the same technique.

This cointegration system of estimation applies to both series integrated at I(0) or a mix of I(0) and I(1). Apart from simultaneously providing scientifically valid short and long span associations among the variables, the ARDL approach has other benefits of returning steady estimates of the long duration coefficients that are asymptotically normal (Pesaran and Pesaran, 1997). As per Ahmad et al. (2017), the process of calculating long-run association amid the variables in ARDL bounds is two-pronged. First, we need to procure the F-statistics to detect the presence of a long-run association. The F-statistics has a non-standard distribution which is subjected to: (a) whether variables involved in the ARDL system are stationary or not; (b) the number of explanatory variables, (c) whether the function contains an intercept and/or a trend; and also, at last, depends on (d) the sample size. There are two critical values (CV) which form the higher and lower constraints in Pesaran and Pesaran (1997) as well as in Pesaran et al. (2001). If the computed F-statistics outweighs the upper bound, then the null hypothesis-no cointegration-is subjected to rejection, implying that the cointegration relation is confirmed. Then the result becomes inconclusive provided the value lies between the upper and lower critical value. we can’t reject the null of no cointegration if calculated F-stats is below the lower bound. If F

¹ Results for unit root test are reported in Appendix. A (Table No. A.2).
statistics is above the upper bound, the estimation procedure can be initiated and here comes the necessary condition that the error correction coefficient obtained should be significant and negative. The mathematical expression of the ARDL model of cointegration is as follows:

\[
LMVA_i = \beta_0 + \sum_{i=1}^{n} \beta_i LMVA_{i-1} + \sum_{i=0}^{m} \beta_i LELE_{i-1} + \sum_{i=0}^{m} \beta_i LIMP_{i-1}
\]

\[
+ \sum_{i=0}^{m} \beta_i \Delta LEPE_{i-1} + \sum_{i=0}^{m} \beta_i LCRE_{i-1} + \sum_{i=0}^{m} \beta_i LGER_{i-1} + \epsilon_i
\]

(1)

where, \( \epsilon_i \) is the white noise error term. The optimal lag length has been chosen based on the Akaike Information Criterion (AIC) grounded in a VAR based approach.

After stabilizing the long run connection among the variables, we need to obtain short-run estimates. The short-run model can be captured by translating equation no. (1) into Error Correction Condition (ECM) as:

\[
\Delta LMVA_i = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta LMVA_{i-1} + \sum_{i=0}^{m} \beta_i \Delta LELE_{i-1} + \sum_{i=0}^{m} \beta_i \Delta LIMP_{i-1}
\]

\[
+ \sum_{i=0}^{m} \beta_i \Delta \Delta LEPE_{i-1} + \sum_{i=0}^{m} \beta_i \Delta LCRE_{i-1} + \sum_{i=0}^{m} \beta_i \Delta LGER_{i-1} + \delta ECT_{i-1} + \epsilon_i
\]

(2)

where \( \delta \) capture speed of adjustment, \( \Delta \) denotes first difference and \( ECT_{i-1} \) represents disequilibrium. The long-run causal association is depicted by the value of error correction term coefficient \( \delta \) which is significant with a negative sign (Shahbaz et al., 2013).

4. Results and discussions

The endogenous theory from development economics and real business cycle model from macroeconomics highlight the factors which influence the long-run growth. These are supply-side factors. The factors representing supply-side involve energy, human capital, financial development and technology spillover. These are empirically verified to be largely influencing production and productivity in general to the economy and in particular to the manufacturing sector. Drawing idea from these realisations, the present study has opted the variables such as electricity consumption, credit to the private sector as a percentage of GDP, gross enrolment ratio and import as measures for energy consumption, human capital, financial development and technology spillover respectively. Also, export has been included as a measure of foreign demand for our products.

4.1. Descriptive statistics

The summary statistics confirm the fact that the variables are all normally distributed with their (Supplementary File 1. Table No A.1) mean and median sharing values which are very close to each other. Jarque-Bera probability value confirms normal distribution in general for all variables across the values. The normal distribution of variables is a prior requirement to generalise behavior into a measurable magnitude.

4.2. Correlation matrix

The correlation matrix reveals (Supplementary File 2. Table No A.2) higher degrees of correlation among the variables in all countries except in the case of gross enrolment ratio in the case of Kenya where the correlation is low and negative. It should be noted that in the analysis, we are interested in the correlation coefficient between manufacturing output and its determining variables.

4.3. Unit root test

The unit root tests such as Augmented Dickey-Fuller test (ADF) and Phillips-Perron test (PP) (Supplementary File 3. Table no A.3.) to detect the behaviour of the data. ADF is a parametric test while the Phillips-Perron test is non-parametric. The unit root tests authorize that all variables, considered in the study, are stationary at first difference confirming that they have a trend/long-run behaviour which indicates the possibility that there is a cointegration relation existing among them.

4.3.1. Structural break unit root test for checking exogenous shocks

The outcome of the Zivot-Andrews unit root approach, in general, supports the use of ARDL bounds test results. The conservative unit root testing techniques are impaired with the lack of information on exogenous shocks and they are likely to suffer from unfair results. This basic inability inherited in the elementary unit root test measures is guided to the evolvement of Zivot and Andrews (1992) approach. The analysis part has been added more empirically sound by incorporating the Zivot and Andrews structural break unit root test and the results are given in Supplementary File 4. Table No A.4. The interesting feature of the Zivot and Andrews method is that it spots the existence of one foremost perceptible break in the data set (Malliek et al., 2018). Added scientific strength is that the erstwhile structural break techniques such as Chow (1960) confirm breaks externally, while the technique used here is to decide it through an internal process. Further, the methods used in the conservative tests may have a consequence in terms of an over-rejection of unit root presupposition. In this milieu, the Zivot and Andrews (1992) submitted the strong scientific reasoning that the dates of the break should be deduced internally as it is allied with data set (Narayan, 2005).

Its procedure encompasses a testing technique where the date of the interruption is confirmed internally even though shocks are external events. The breaks are found to be of varying in occurrence and impact over the nations and the period under analysis. These breaks may be ascribed to internal and external shocks which are commonly observed as the financial meltdown in Asia in 1997 (Haque and Kim, 2002), world financial predicament in 2007–2008 (Kotz, 2009), neo-liberal policies (Panagariya, 2006) initiated by most of the economies around the world in 2007–08, supply and demand shocks such as spillovers of technology and business cycles (IMF, 2008) borne by the global trade sector around 2007 and demographic structural metamorphosis around 2004 which had economic repercussions.

The entire econometric analysis involving time series regression and causality test is carried out based on ADF and PP test only. Zivot-Andrews serves only the purpose of checking the exogenous shocks which have any influence. As it doesn’t influence the result, the remaining steps, including the application of causality test, are carried based on conventional unit root tests.

4.4. Bounds test result

The bound test result (presented in Table 1) confirms that all the countries comply with the necessary condition for the existence of cointegration that the F-statistic should be above the upper bound critical value. Except for Morocco, all other countries have their F-value significant at one per cent level, while for Morocco it confirms the notion of 5 per cent significance.

4.5. Short-run elasticity coefficients

The short-run elasticity coefficients result are presented in Supplementary File 5. Table No A. 5 shows that the determining variables like energy, import, export, financial development, and human capital have lagged impact and even the past values of the manufacturing output affect the present system.

In India, the past affirmative shocks are carried over. Electricity supply has an instantaneous positive impact and lagged responses which are favourable as well as adverse supply shocks of energy are critical and the economy has a memory of keeping such shocks. The variables like the financial system, export and import have a trivial impression on industrial output. The short-run is too small for technology to change. Also,
export penetration of India is poor. Further finance flow turns out to have a desirable significant consequence expected in the long-run. At the same time, human capital measured by gross enrolment ratio has a significant lagged affirmative imprint on manufacturing value-added. The marginal returns to education, health and skill development are positive.

In the case of Kenya, energy input incurs a negative return. The electricity supply is not backed by proper industrialisation and a supposedly negative marginal return is the outcome. Import carries negative and positive memories of the past. Import shocks probably influence raw materials and technological development. Human capital has a lagged positive carving on manufacturing value-added. Again returns on human resource development can have a dynamic impact. But its suspected that the production of quality human skill is too low.

In the instance of Peru, apart from past shocks of output gets transferred, the sudden imprint of energy and export is positive. Energy input has desirable returns and export penetration of manufacturing goods is supposedly successful in the short run. Finance system has a negative repercussion in the short-run probably because the financial system takes its course to incur a positive response on the dependent variable. Peru has its human capital incurring insignificant returns. The snags in human resource development has to be corrected.

Morocco has its past values influencing the industrial output. Energy has negative returns on output. Export has both positive and negative returns including lagged effects while imports have negative shades on output, lagged as well as instantaneous. Human capital also has negative returns.

In the example of Sri Lanka, all variables have lagged and instantaneous stamp on the manufacturing value-added. Both favourable and adverse events in the production process from the past get carried over. Energy has an affirmative outcome on the regressor both sudden and lagged. The same follows in the case of imports without lag. Exports and credit have an unfavourable consequence with a laggard response while human capital has a damaging instantaneous implication on output.

For the studied nations, the error correction is both negative and significant thereby confirming the necessary condition for cointegration. The short-run dynamics represent the kind of disequilibrium from the long-run path and these deviations are assumed to get corrected over time and ultimately converging to long-run equilibrium. So, the complete picture of the interaction among the variables are only possible in the long-run and thus seeking evidence for the absence or presence for the applicability of any theory in the premises of a particular economy is possible to a limited extent in the short-run. This is because the short-run scenario is often marred by disequilibrium situations and lagged responses, which most often the interaction of any variables may lead to. This trend can be explained in this way that the countries which we have considered here are undergoing a structural transformation and apart from the common identity of the late industrialized nations, these nations have different macroeconomic psyche (resource endowment, investment, the structure of the labour market, trade openness, price stability etc) and political system, which act as converging and diverging forces in influencing (weakening or strengthening/slowing or speeding up) the interaction among the variables.

4.6. Long-run elasticity coefficients

It can be seen from the computed result presented in the Table 2 that in the case of India, the electricity, import, and export proved to be of high significant influence on manufacturing value-added. Financial development influences manufacturing output at 10 per cent significance level. The influence of energy and import on manufacturing output in the long run for India has already been proved to be relevant (Sankaran et al., 2019). For the case of Kenya, electricity, and import proved highly significant, while export and human capital are significant at 10 per cent level in influencing manufacturing value-added. For Peru, energy, export and human capital have statistically as well as significantly influenced manufacturing output even at the level below 5 per cent. For Peru, the trend coefficient is significant indicating that the cointegration has a particular long-run behaviour.

For Morocco, all the variables are highly significant in influencing manufacturing output. In the case of Sri Lanka, the import is the only variable which is significantly influencing the manufacturing output at 5 per cent level. Again, export is a significant influence for all countries except Sri Lanka thereby confirming that export stimulates growth. Import is significant for all countries except Peru, which shows that import acts as a channel through which technology flows into the manufacturing sector and improving its productivity. This can be attributed to the liberalization policy persuaded by the countries in general.

India is the leading nation concerning its pace of growth, and the rest of the nations are also moving towards sustainable growth. Hence, there is a huge demand for unprecedented energy requirements and the lead is taken by capital intensive industrial units such as petrochemicals, petroleum products, and iron & steel. India is in an attempt to shift its reliance from fossil fuel grounded production technique to electricity oriented as this is globally recognised as a pollution-free energy source.

The key component of India's merchandise exports is the manufacturing items such as gems and jewellery, chemicals and textiles. But compared to India's pears in Asia, India's manufacturing exports are lower. India's share in global manufacturing exports is a negligible level of 1.4 per cent while China has a share of 14.8 per cent. The reasons attributed are poor infrastructure, low FDI inflows, low R&D spending, unfavourable governmental policies, rising input costs. etc (IBEF, 2019). Traditional exports such as textiles and leather and to some extent food products, which is fueling the slide in performance of manufactures and therefore they have been termed as ‘Laggards’. It should be mentioned here is that the export has a negative association with manufacturing output in the case of India testing our manufacturing products are not able to penetrate the foreign market, which is dominated by technologically sophisticated products from early industrialized nations. Abala's (2012) findings suggest that policy measures to improve export performance of Kenyan firms should focus on improving total factor productivity, encouraging foreign direct investment and stimulating modernization of manufacturing capital. The World Bank report in 2012 observes the role of manufacturing. At the same time exports in Africa have increased from 34% to 43%, while exports to low-income countries have increased from 32% to 38%. The share of exports to BRIC countries is still low at 3%. Major export destinations of Kenya are Uganda and Tanzania.

But in the context of India, the export destinations are highly industrialized countries. This requires a high amount of competitiveness unlike what Kenya face in the home market. Also, Kenya's manufacturing output is roughly around 10 per cent and its responsiveness in terms of export elasticity can be higher. But in India, this comes around 30 per cent of GDP. The strong foreign competition combined with the comparatively lower distance of current manufacturing export from the steady-state level would have inflicted a negative outcome of export on

\begin{table}
\centering
\begin{tabular}{|l|c|c|c|c|}
\hline
Country & India & Kenya & Peru & Morocco & Sri Lanka \\
\hline
5.21*** & 6.09*** & 16.21*** & 4.34** & 5.91*** \\
\hline
\end{tabular}
\caption{Bounds test results.}
\end{table}

Note: ** and *** respectively denotes rejecting of the null hypothesis at 5% and 1% level.
manufacturing output in India. While in Kenya, the competition they face in a foreign market is weak and the current manufacturing export of Kenya compared to the steady-state level is very low and thus the elasticity of exports on manufacturing can be very high and positive. Moreover, the author’s focus is more on the role of human capital, finance, technology and energy in explaining manufacturing sector in these 5 late industrialized countries selected and export, rather than acting as a mere control variable doesn’t have much relevance in our analysis. The coefficient of exports doesn’t have any influence in determining the direction of the research.

Countries like Kenya are agricultural oriented and still left with a lot of the structural adjustment measures to be undertaken, their energy utilization for manufacturing spectrum is very meagre. The results obtained by the extant analysis also support this argument. Electricity which is supposed to be used for industrial production is possibly reallocated for some other purposes in those nations. Financial development is found to be a strong component, which influences the manufacturing sector through fund flow. In the case of Kenya, import has a negative association with the manufacturing output, probably attributed to inappropriate import policies and underperformance of industrial sectors. The estimated results illustrate that import is the major source of technology transfer to countries such as India, Morocco, and Sri Lanka as the coefficients of import are statistically significant. At the same time, energy is one common vital factor for all countries for more or less all economic activities confirming that it is an inevitable part of the production function. Human capital stimulating production is found in Kenya and Morocco and this is supposed to be a potential factor which can reshape the economic structure there. Added along with, the negative association of human capital with that of manufacturing output in the case of Peru is proved statistically significant, posing a question on the quality of the education system. This has been mentioned by Carpio (2019) affiliated to the World Bank.

In general, we can see that electricity is a significant determining variable for manufacturing output in India, Kenya, Peru and Morocco indicating that energy is again proved to be one of the significant factors of production which augments production and productivity (Alam, 2006).

4.7. The diagnostic check

The diagnostic check result (see Table 3) depicts that the results for all countries are free from model specification issues as confirmed by the result of the Ramsey test. Further, the LM test confirms that there is no serial correlation issue as such for the model. While the Jarque-Bera test and ARCH test substantiate the normality of the distribution of the error terms and absence of heteroscedasticity problem respectively.

4.8. The stability check

The examination of the stability of parameters in the estimation entails cumulative sum of recursive residuals (CUSUM) followed by the application of cumulative sum of recursive residuals squares (CUSUMSQ) techniques of inspection promulgated by Pesaran and Pesaran (1997). These are structural stability test of the parameter. According to the rule, if the plots adhere to the mandate of lying within the critical bound of the 95 per cent, then it ensures that the parameters are free from issues regarding stability and consistency. Our model plots (presented in

Table 2. Long run coefficients. Dependent variable: LMVA.

| Country | Variables | Coefficient | Std. Error | t-Statistic | Prob. |
|---------|-----------|-------------|------------|-------------|-------|
| India   | LELE      | 0.88***     | 0.18       | 4.85        | 0.00  |
|         | LIMP      | 0.49***     | 0.14       | 3.50        | 0.01  |
|         | LEXP      | -0.49***    | 0.20       | -2.42       | 0.04  |
|         | LCRED     | 0.40*       | 0.23       | 1.78        | 0.10  |
|         | LGER      | 0.17        | 1.20       | 0.15        | 0.89  |
|         | C         | 18.18***    | 3.94       | 4.61        | 0.00  |
| Kenya   | LELE      | 1.01***     | 0.30       | 3.41        | 0.01  |
|         | LIMP      | 0.80**      | 0.18       | -2.74       | 0.02  |
|         | LEXP      | 0.39**      | 0.21       | 1.86        | 0.10  |
|         | LCRED     | 0.22        | 0.15       | 1.43        | 0.19  |
|         | LGER      | 0.36*       | 0.21       | 1.68        | 0.10  |
|         | C         | 20.83***    | 4.76       | 4.38        | 0.00  |
| Peru    | LELE      | 0.76***     | 0.08       | 9.42        | 0.00  |
|         | LIMP      | 0.66        | 0.05       | 1.29        | 0.21  |
|         | LEXP      | 0.21***     | 0.05       | 4.04        | 0.00  |
|         | LCRED     | -0.02       | 0.02       | -0.92       | 0.37  |
|         | LGER      | -0.50**     | 0.20       | -2.47       | 0.02  |
|         | C         | 17.79***    | 1.56       | 11.43       | 0.00  |
| Morocco | LELE      | 0.12***     | 0.04       | 3.18        | 0.01  |
|         | LIMP      | 0.14***     | 0.05       | 2.85        | 0.01  |
|         | LEXP      | 0.35***     | 0.11       | 3.13        | 0.01  |
|         | LCRED     | 0.22***     | 0.03       | 8.22        | 0.00  |
|         | LGER      | 0.71***     | 0.12       | 5.98        | 0.00  |
|         | C         | 6.85***     | 1.91       | 3.59        | 0.00  |
| Sri Lanka| LELE     | 0.09        | 0.33       | 0.28        | 0.78  |
|         | LIMP      | 1.51**      | 0.68       | 2.23        | 0.05  |
|         | LEXP      | -0.83       | 0.62       | -1.34       | 0.21  |
|         | LCRED     | -0.02       | 0.09       | -0.19       | 0.85  |
|         | LGER      | -1.22       | 1.58       | -0.77       | 0.46  |
|         | C         | 10.20       | 9.15       | 1.11        | 0.29  |

Note: *, ** and *** respectively denotes rejecting of null hypothesis at 10%, 5% and 1% level.
sophisticated technology embedded products, which might have shifted the growth through foreign technology spillover. This has to go in tandem with the historical scenario where the liberalization regimes initiated in 1980s have largely culminated in the export-led, and manufacturing output giving evidence for the presence of bi-directional causal relation with manufacturing output pinpointing the feedback hypothesis. Export is in the occasion of Kenya, the causality results reveal that credit influencing export indicates finance-led export growth in Kenya. In the case of Peru, there is evidence for long-run unidirectional causality escalating from energy, export, and credit to manufacturing output giving evidence for the presence of energy-led, export-led, and finance-led (supply leading) hypotheses. Import is having a bi-directional causal relation with manufacturing output pinpointing the fact that both reinforce each other. Energy, export and import influence human capital in the long run.

In the context of Morocco, energy, import, and human capital are found to be causatively influencing the manufacturing output giving testimony for the existence of energy-led, import-led and human capital-led growth hypotheses. The causality is viewed to be flowing from export to manufacturing output giving evidence for export-led growth in the instance of Sri Lanka.

5. Discussion and conclusion

The entire analytics of study focused on the dynamic association of energy, human capital, financial development and technology with that manufacturing output in an endogenous growth framework. Thus, it seeks evidence and triggers discussion for the existence of energy, and finance-led growth hypotheses, and arguments for the existence of human capital and technology-led growth in a multi-country scenario. The result has been procured by employing the ARDL bounds system of cointegration technique of ARDL bounds in the case of Peru. The VECM causality results pinpoint the presence of energy-led growth hypothesis, import-led growth and evidence for supply-led growth in the occasion of the relationship between financial development and manufacturing output as evidenced from Patrick (1966) hypothesis. It is important to note here, that there exists a negative relation of human capital with manufacturing output, which invites human development-oriented approaches thrust upon social intervention in the education sector and health care. Carpio (2019) observes how low quality of human skill has implications on limiting productivity. They have to increase their investment in capital and wage goods. At the same time, invest in education, health and energy also needed to be stressed. This may not be possible by their effort alone but by the efforts of the World Bank, African development institutions etc. But this leaves a door ajar for these variables to positively tinker with manufacturing output by framing policy prescriptions which takes insights from this study. This situation calls for a strategic long-run approach and policy reformulation.

The economy of Peru is ahead compared to a few of the countries under consideration concerning the structural transformation that the economy has undergone in a Kaldorian way. There is a decent contribution of the industrial sector to GDP which is 32.7 per cent as per 2017 estimate (CIA, 2019) but low in its contribution in terms of labour force absorption. The long-run relationship of manufacturing output with that of energy, import, export and human capital is established through cointegration technique of ARDL bounds in the case of Peru. The VECM causality results pinpoint the presence of export-led growth hypothesis, import-led growth and evidence for supply-led growth in the occasion of the relationship between financial development and manufacturing output as evidenced from Patrick (1966) hypothesis. It is important to note here, that there exists a negative relation of human capital with manufacturing output, which invites human development-oriented approaches thrust upon social intervention in the education sector and health care. Carpio (2019) observes how low quality of human skill has implications on limiting productivity. They have to increase their expenditure on education and give thrust on quality and agility of the workforce. Both savings and investment are low in their magnitude and improving in-vestor’s confidence and facilitating capital flow internally and externally is a requirement. There is a bilateral causal pathway established between energy and manufacturing output pinpointing that feedback hypothesis
is pertinent in the instance of Peru. Any policy, which destabilizes the equilibrium relation between energy usage and manufacturing output, will prove fatal in the long-run production and productivity of the manufacturing sector. The supply leading argument in Patrick hypothesis (1966) proved to be relevant in the circumstances of Peru which pose the argument that the financial development has the potential to make innovation, which has a favourable influence on manufacturing output and productivity. So, uninterrupted credit flow to the much-needed manufacturing sector should be the major agenda of policymakers.

**Note:** All are significant at 5% level.

*Figure 1. CUSUM & CUSUMSQ test. Note: All are significant at 5% level.*
In the case of Morocco, it has undergone a lot of structural transitions, has a decent contribution from the industrial sector to GDP and workforce absorption (CIA 2019). Moreover, the gross national savings and gross capital formation are in a stable and safe magnitude (CIA, 2019). The macro-dynamics are strong and this ought to be reflected in the empirical analysis. The long-run influence of energy, imports, and human capital has been captured using the cointegration test undertaken in the case of Morocco. The long-run causality result testifies the direction of causal relation flowing from energy, import and human capital to manufacturing output. This warrants the existence of relevant hypothesis such as energy-led growth hypothesis, technology-led growth hypothesis and also the argument of human capital-led growth. The policy recommendation at this juncture is to frame a forward-looking framework which integrates the flow of energy and technology-oriented import flow. Further, a strategic long-run human capital generation model should also be taken deliberately into consideration.

In the instance of Sri Lanka, the macroeconomic fundamentals are very strong. The industrial contribution to GDP is around 30 per cent and it contributes to the employment of the 26 per cent of the workforce. The nation is endowed with low unemployment rate and inflation. Further, gross national savings and gross capital formation are above the 30 per cent of the GDP signifying that the economy is well maintained. On the positive side, there is an impressive record of achievement in terms of access to primary and secondary education. The quality of achievement is mediocre with only one-third of primary school children becoming skilled at language and mathematics. Moreover, while the share of Sri Lankans with secondary education is as good as to that of East Asian countries, the tertiary education numbers are much lower than in East Asian countries (International Monetary Fund, 2008). If we take the case of Sri Lanka, there is a long-run connection between manufacturing output and imports, which has been identified, but the long-run causality is found to be missing in this regard. Hence, Sri Lanka may target for strengthening import channel of technology flow.

In a nutshell, the study confronts evidence for the existence of energy-led, finance-led (supply leading), technology-led, human capital-led growth hypotheses, and arguments. The insights from the study render important revelations and directions to have perspective planning to develop financial institutions and the efficient energy flow to the manufacturing sector. Followed by this, the call also goes for a hybrid system nurturing diversified education and skill intensive programs, and import strategy specially designed to make benefit of the spillover of foreign technology. Most importantly, improving the horizon of the market by tracking the global consumers and designing export strategies driven by labour skill, energy and technology is the need of the hour because this can take countries to converge their growth and development to a steady-state.

5.1. Future research

The human capital apart from acting as an agent of spillover of technology and bringing productivity shift, its role lies in engaging R&D and bringing new technology to benefit the economy. The interaction of human capital and knowledge capital is not explored. This can be investigated bringing an interaction variable which is a future area of research to be pursued. Further, the interaction of the governance with R&D and Human capital in bringing industrial progress is a key aspect.

Declarations

Author contribution statement

Arjun. K.: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Arunugam Sankaran: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Sanjay Kumar: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mousumi Das: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2020.e04308.
