Energy Policy 133 (2019) 110916

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

How do industrialization and trade openness influence energy intensity? Evidence from a path model in case of Bangladesh

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ARTICLE INFO

Keywords:
Industrialization
Trade openness
Economic growth
Energy intensity
Path model
Bangladesh

ABSTRACT

Nowadays, multifaceted interdependence between macroeconomic variables results in an extended list of factors that have diverse impacts on energy intensity. Thus, sustaining energy intensity at a desired level demands advanced studies to investigate the multifarious influences of its factors and ensure proactive measures to deal with them. This paper aims to set up a path model to analyze the direct and indirect impacts of industrialization and trade openness on energy intensity in Bangladesh. The results corroborate that industrialization has a direct positive influence on energy intensity where trade openness shows a direct negative effect on it; and both industrialization and trade openness have negative indirect impact on energy intensity through technological innovation and economic growth respectively. In case of individual total impacts, only industrialization affects energy intensity positively, where trade openness, technological innovation and economic growth negatively do. Based on the empirical results, some policy implications regarding energy intensity and effects of its factors on it are also presented.

1. Introduction

Bangladesh, a small South Asian country with 160 million populations, has been making impressive economic growth for more than two decades after re-establishment of democracy in early 1990s and following immense policy reforms (Rahman and Kashem, 2017). In recent times, the country has been experiencing speedy industrialization, increased population and major changes in patterns of trade and financial sector development (Shahbaz et al., 2014). More precisely, Bangladesh is going to be a focal point of economic progress in South Asia showing an average economic growth of more than 6% per year over the last decade with industry and services accounting for the most of the growth. With the expansion of trendy economic growth shaped by accelerated process of industrialization and major changes in trade pattern, the demand for energy is also increasing day by day. Though 78% of the total population has access to electricity (Mujeri et al., 2014), approximately 58% of rural households in Bangladesh are energy poor compared to the income poverty of 45% (Barnes et al., 2011). In this situation, government of Bangladesh devised Power System Master Plan (PSMP), by setting a milestone to increase installed electricity generation capacity to 24,000, 40,000 and 60,000 Megawatt (MW) by 2021, 2030 and 2041 respectively (Bangladesh Economic Review, 2017). However, Mondal et al. (2010) anticipated that the final electricity demand of the country will be 107.3 and 192.7 Terawatt hours (TWh) in 2025 and 2035 respectively with the largest share coming from industries e.g., 48.64 and 101.50 TWh respectively. On the other hand, natural gas accounts for 68% of the commercial energy of the country and the demand for natural gas in industrial sector is 191 billion cubic feet (Bcf); which is expected to reach 390 Bcf in 2021 (Bangladesh Economic Review, 2017). Islam and Khan (2017) pointed out that government is trying to fulfill the growing demand of energy with various projects such as setting up nuclear power plants, harnessing renewable energy sources and establishing regional cooperation on power trade, among others. Conversely, government of Bangladesh also set up a plan to improve energy intensity in 2030 by 20% compared to the 2013 level. In this situation, it has become a dilemma that how does the country keep its economy at the current momentum of progress by fulfilling the rising demand of energy, and improve energy intensity as it is targeted at the same time. Thus, it requires more and more in-depth researches regarding energy intensity, its influential factors, and its relationships with other macroeconomic variables in case of Bangladesh. In this study, we explore the impacts of industrialization and trade openness on energy intensity in Bangladesh either direct, or indirect through technological innovation and economic growth respectively.

Due to the large-scale significance of energy intensity to ensure both

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https://doi.org/10.1016/j.enpol.2019.110916
Received 18 January 2019; Received in revised form 10 June 2019; Accepted 1 August 2019
Available online 13 August 2019

sustainable economic development and environmental conservation, it has become a hot topic of research among the intellectuals round the globe. Since the pioneering study of Kraft and Kraft (1978), that exposed causality from output to energy consumption, a plethora of researches has been conducted by academia to study the dynamic relationships of energy intensity with other important variables like economic growth, carbon emissions, industrialization, trade openness, foreign direct investment and so on. And, the matter is also true for Bangladesh as some studies dealt with energy, economic growth, emissions and others in case of this country. For example- Asaduzzaman and Billah (2006) stated that the level of energy use is positively related to the level of growth and higher level of development entails higher level of energy use in Bangladesh. Ghosh et al. (2014) uncovered that energy has a significant positive effect on economic growth and economic growth is not energy dependent rather growth ensures energy consumptions in case of Bangladesh. Islam and Khan (2017) studied the energy sector of Bangladesh as a whole and revealed that Bangladesh has achieved economic progress with a relatively lower per capita energy usage compared to various other countries. It has one of the lowest per capita energy consumption, only 371 kWh (World Bank, 2016), for the same per capita GDP of different developed nations. Thus, Bangladesh has the potential to perform better economically and can attain economic growth higher than that of now if smooth energy supply can be ensured. A list of the major energy literatures in case of Bangladesh is given in Table-1, where researchers used different research methods, took different variables with energy consumption, focused on different time span and found diverse results.

If we focus on the studies on energy intensity and its influencing factors worldwide, we notice that numerous academics and experts mainly emphasized on decomposing energy intensity into its forcing factors using different decomposition techniques i.e., index decomposition analysis (IDA) and structural decomposition analysis (SDA), as decomposition analysis has become a widely used tool to study energy and environment (Ang and Choi, 1997; Ang et al., 2004; Zhou and Ang, 2008; Xu et al., 2014; Chen et al., 2018; Chen et al., 2019; among others). Ma and Stern (2008) and Nie and Kamp (2013) decomposed energy intensity of China and claimed that the main factor behind energy intensity decline is technological changes, where Wu (2012) found energy efficiency as the main contributing factor to reduce energy intensity in that country. In case of Latin American countries, Jimenez and Mercado (2014) opined that structural changes in economic activities do not lead to a reasonable change in energy intensity, where Shahiduzzaman and Alam (2013) found the factors behind energy intensity turn down are both efficiency in energy use and structural changes in the economy in case of Australia. Adetutu (2014) estimated substitute elasticity among the inputs in case of the Organization of the Petroleum Exporting Countries (OPEC) and stated that energy and capital are substitutes in Algeria and Saudi Arabia, and complements in Iran and Venezuela. He also argued that negative energy efficiency creates no motivation for productivity and efficient energy choices. Voigt et al. (2014) found changes in the composition of industries help decreasing energy intensity in some countries when they studied a total 40 major economies together. Parker and Liddle (2016) decomposed energy intensity of manufacturing sector of OECD countries and revealed that energy efficiency improvement is the key factor of declining energy intensity. Kerimray et al. (2018) revealed that both sectoral and inter-sectoral structural changes play important roles in changing energy intensity when they decomposed energy intensity of Kazakhstan. Dargahi and Khameneh (2018) came across that both structural changes in economic activities and inefficiency of energy consumption lead to energy intensity in case of Iran. They also found a positive linear relationship between per capita income and energy intensity in that country. Tan and Lin (2018) found seven factors that are related to the decline in the energy intensity and technology improvement effect is the most significant one in China's energy intensive industries, where Chen et al. (2019a) found total population as the greatest influencing factor when they studied the driving factors, disparities and trends of global non-fossil fuel consumption.

To analyze the changes in energy intensity, Mielnik and Goldemberg (2002) studied the data for 20 developing countries and noticed a clear decline in energy intensity due to the increase in foreign direct investment that possibly induces the uses of modern technologies. Li et al. (2013) found that technological changes are the key influential factor of energy intensity changes in three regions of China. They opined that the improvement of technologies will have a considerable share in energy efficiency enhancement in China, while Li and Lin (2014) found a negative impact of technology improvement on energy intensity in case of this country. Stern (2012) opined that movement to technological progress as well as human capital development would facilitate the development of energy intensity and environmental contamination after conducting a study on 85 countries. In a study on 76 developing countries, Sadorsky (2013) found that energy intensity is positively associated with urbanization and industrialization where negatively correlated with income. Adom (2015a) found a positive correlation between per capita income and industry's share of production with energy intensity; and a negative correlation between energy intensity with foreign direct investments, trade openness and TFP (total factor productivity used as a proxy for technology) in Algeria. In another

Table 1
Energy related studies in case of Bangladesh.

Authors	Period	Methodology	Results
Mozumder and Marathe (2007)	1971-1999	Cointegration and VECM	Per capita GDP → per capita electricity consumption
Ruhul et al. (2008)	1980-2005	Cointegration and VECM	No causal relationship between GDP and EC
Ahamad and Islam (2011)	1971-2008	VECM and Granger causality	Electricity consumption ↔ EG
Paul and Uddin (2011)	1971-2010	Cointegration and Granger causality	GDP inversely affect movements in energy use
Alam et al. (2012)	1972-2006	Cointegration and dynamic causality	EC → EG and electricity consumption ↔ EG
Islam et al. (2013)	1971-2010	ARDL Bounds Testing Approach	Income, trade openness and urbanization Granger cause EC
Das et al. (2013)	1980-2010	Cointegration test	GDP → natural gas consumption
Ahmed et al. (2015)	1980-2010	Cointegration and augmented Granger causality	EG, FD, urbanization and ISG have positive effects on EC in short-run; ISG has no impact in long-run.
Rahman and Kashem (2017)	1972-2011	ARDL cointegration and Granger causality	Long-run cointegration among CE, EC and Industrial growth
Wahid et al. (2017)	1985-2013	ARDL Bounds Testing Approach	Long run relationships of EG with both power consumption and fossil fuel consumption
Pan et al. (2019)	1976-2014	Directed acyclic graphs (DAG) and structural vector autoregression	FD, EG, trade openness and TI influence EI where FD, trade openness and TI influence EG

EC = Energy consumption, EI = Energy intensity, EG = Economic growth, CE = Carbon emission, FD = Financial development, ISG = Industrialization, TI = Technological innovation, VECM = Vector error correction model, ARDL = Autoregressive Distributed Lag, → Unidirectional causality, ↔ Bi-directional causality.

study, he (Adom, 2015b) found that higher imports and de-industrialization have contribution to turn down energy intensity in South Africa. Yan (2015) revealed that the ratio of energy price to capital price and foreign direct investment derived technology contribute to decrease in energy intensity in the provinces of China, while urbanization, industry, and exports take part in increasing it. In case of Saudi Arabia, Belloumi and Alshehry (2016) found that industrialization, urbanization and services share in GDP have positive impacts on energy intensity. Rafiq et al. (2016) employed both linear and nonlinear panel models on 22 emerging economies in their sample and established that trade openness significantly reduces both pollutants emissions and energy intensity. Bilgili et al. (2017) researched on 10 Asian countries and stated that the impact of ruralization, urbanization, per capita GDP on energy intensity is different in different country. Yang and Shi (2018) studied 40 economies to examine the role of some intangible capital; like research and development investment, organizational capital, staff training, brand equity, technology licenses, patents and copyrights; in influencing energy intensity and found that these factors have reduction effect on sectoral energy intensity.

Though decomposition analysis is widely used in analysing energy intensity, a strand of researchers also shows interests to explore the determinants of energy intensity using different types of regression analysis, cointegration analysis, error correction models, ARDL methods and even some trans-log cost functions. For example, Kaufmann (2004) analyzed the mechanism of autonomous energy efficiency improvement (AEEI) for America considering the decrease in energy intensity and found that fossil fuels, household energy expenditure, and energy prices influence the changes on energy intensity, and technical or structural changes cause AEEI. Karl and Chen (2010) explored the impacts of government expenditure, ratio of the tertiary sector to GDP, productivity, and energy prices on energy intensity in China and found that government expenditure positively impacts energy intensity in different economic situations. Zheng et al. (2011) reported that the greater the exports, the greater the industrial energy intensity and the impact of exports on energy intensity is different in different industrial sector. Herrerias et al. (2013) confirmed that both foreign and non-state investments in China's different regions play an important role in declining energy intensity, while state investment has no positive contribution in declining it. In case of 28 European Union (EU) member countries, Filipovic et al. (2015) estimated that energy prices, energy taxes and GDP per capita negatively influence energy intensity, where the growth of gross domestic usage and final energy consumption per capita positively influence it. Akal (2016) modeled energy intensity of Turkey and concluded that energy efficiency of Turkey would improve with increasing per capita income, rising global energy prices and shrink with the energy gap or import growth. By developing a green growth model for Italy, Calcagnini et al. (2016) concluded that oil price, technology, and environmental regulations (supply side shocks) play roles in energy intensity changes and have permanent effects on it, whereas changes in real interest rate and unemployment rate (demand shocks) influence energy intensity only in the short run. In a study in EU, Petrovic et al. (2018) found a significant positive influence of industrial gross value added and a significant negative effect of real per capita GDP on energy intensity, while the effect of trade openness on energy intensity is unspecified. Using symbolic regression in case of Chinese provinces, Yang et al. (2016) found that the total population is the main factor of energy intensity followed by GDP, industrial share of GDP, energy consumption and energy prices. Choi et al. (2017) used panel regression in case of six countries to study energy intensity and firm's growth, and found that energy intensity and relative energy intensity might have different impacts on firm growth in different countries. In case of Iran's industry, Barkhordari and Fattahi (2017) found out long run relationship between energy prices and energy intensity. They also claimed that technology change has a constructive impact on energy intensity, while Farajzadeh and Nematollahi (2018) found a non-linear relationship between energy intensity indices and per capita GDP in the same country. Aydin and Esen (2018) revealed that energy consumption has a significant positive impact on economic growth, but after a threshold level, energy consumption impedes economic growth in case of 12 independent commonwealth countries. By estimating a penalized panel quantile regression model, Guang et al. (2019) found that the effects of economic growth and foreign direct investments on energy intensity are negative while the effects of urbanization and industrialization on energy intensity are positive. They also showed that economic growth is the most prominent factor that contributes to energy intensity differences across different regions in China, followed by industrialization, foreign direct investment and energy structure.

To be specific, most of the scholars, who conducted researches on energy intensity, were mainly interested in either to identify the causal relationships between energy intensity and other variables; or to explore only the direct impacts of different factors on energy intensity. To do so, they mainly used different types of decomposition technique and to some extent, several types of regression, cointegration, vector autoregression, error correction and other methods. But none of them aimed to explore both of the direct and indirect impacts of the influencing factors such as industrialization, trade openness, technological innovation, economic growth and others, on energy intensity. However, multifaceted interdependence between macroeconomic variables results in a list of determinants which have direct, indirect or both impacts on energy intensity. And for this reason, our study is an attempt to empirically investigate the direct and indirect impacts of industrialization and trade openness on energy intensity in Bangladesh using a simple path model. The study contributes to the existing literatures in the following two ways. First, we use industrialization and trade openness as two important independent factors and analyze their impacts on energy intensity either direct or mediated by technological innovation and economic growth respectively, where previous studies only examine the direct effects. Second, we use a path model to examine and estimate the size, direction and significance of the direct and indirect effects of each variable on energy intensity, while other researchers commonly used decomposition techniques and other frequently used methods. As per authors' knowledge, it is the first study that uses a path model to examine both the direct and indirect effects of industrialization and trade openness on energy intensity in case of Bangladesh.

The remaining of the paper is ordered as follows. Section 2 briefly describes the research background and hypothesis development. In section 3, we discuss the research method in a very simple way with a short description of data. Section 4 exhibits the empirical findings and section 5 concludes the paper with some policy implications.

2. Research background and hypothesis development

Industrialization is a prerequisite for economic development of a developing country like Bangladesh. According to Bangladesh Bureau of Statistics (BBS), the contribution of the broad industry sector to GDP was 32.42% in fiscal year 2016-17 in Bangladesh with the highest contribution from manufacturing sector. The largest consumer of energy e.g., electricity and natural gas, is industrial sector in that country. This sector devours about 43% of the total electricity demand and at the same time, the growth rate of industrial sector in recent years was about 8% (Mondal et al., 2010). Ahmed et al. (2015) emphasized on giving priority to industrialization because consumption of energy in industrial sector of Bangladesh will be greater than any other sector in future. On the other hand, according to the Daily Star, a leading Bangladeshi English newspaper, “Bangladesh has made significant improvements in trade liberalization in recent times due to numerous policy reforms. In terms of total trade as percentage of gross domestic product, the country is now the second most open economy, after Sri Lanka, among the four major economies of South Asia. The country's trade-GDP ratio reached 47.1 percent in fiscal 2012-13, up from 30 percent in fiscal 1999–2000 (The Daily Star, 2014)." According to WTO (World Trade Organization) statistics, Bangladesh ranked 39th and 31st positions in merchandise exports and imports respectively (excluding intra-EU trade) in 2017. The country experienced a 9% growth in merchandise exports and a 10% growth in merchandise imports over the period 2010–2017 (WTO, 2018). Till June 2018, Bangladesh has signed three Preferential Trade Agreements (PTAs) and two Free Trade Agreements (FTAs) to boost up its trade with other nations (Bangladesh Economic Review, 2018). Practically, trade liberalization has resulted in the increase of the size of the economy and Nath and Mamun (2004) stated that trade openness promotes investment in the economy of Bangladesh. In this case, how do industrialization and trade openness impact energy intensity in Bangladesh need to be studied; and for this reason, we choose both of these variables as the independent factors in our study along with technological innovation and economic growth as two mediating factors to analyze their impacts on energy intensity.

Generally, industrialization arises when industry is initiated to a country or a region at a greater extent, i.e., it is the journey of an agriculture based economy to a manufacturing based one. Availability of natural resources, political stability, available workforces help a country being industrialized. When the process of industrialization starts, the economy goes through some notable changes which are linked to each other. For example, agrarian village people migrate to town to seek work in industries that enhances urbanization; industrial workers' income rises that increases the demand for goods and services which stimulates further investment in industries and finally economic growth. But, energy supply is a must to keep the industrialization process going. As products are produced with the help of machineries in manufacturing and other industries, it needs continuous supply of energy. And, it is obvious that the industrial sector is the main consumer of energy of a country. The more production in industries, the more energy it consumes. A number of empirical studies found that the level of industrialization enhance energy intensity like Ye and Ye (2010), Ali et al. (2016) among others. Thus, our first hypothesis can be proposed as follows.

Hypothesis-1 (H1). Industrialization has positive direct impact on energy intensity.

If we look back into the history of industrialization, it is undoubtedly true that industrialization occurred due to technological innovations. At the same time, industrialization brings new technologies is not also a lie. As industrialization occurs, large investors, like financial institutions, start to invest in industrial sectors largely and with the help of available funds, business organizations invest in research and development to a greater extent and bring new technologies in market. Industrialization also attracts foreign direct investments that facilitate host countries to bring in sophisticated technologies from developed nations. The adoption of highly developed technologies lessens energy intensity and produces more output simultaneously. Welsch and Ochsen (2005) found that technological change acts as an energy saving factor while trade openness acts as an energy using factor in case of West Germany. Ma et al. (2009) concluded that budget effect and adoption of energy-intensive technologies are the two major drivers of changes in energy intensity of China. After employing different models, Tan and Zhang (2010), Xing (2014), Cagno et al. (2015) and Wei et al. (2016) found that technical progress or technological innovation has a positive impact on energy efficiency in different countries. Sohag et al. (2015) studied the data for Malaysia and concluded that technological innovation increases energy efficiency and correspondingly it reduces energy consumption at a given level of output. Hence, we can devise our second hypothesis as follows.

Hypothesis-2 (H2). Industrialization has negative indirect impact on energy intensity through technological innovation.

On the other hand, trade openness measures the extent of international trade of a country. It impacts energy usage through economies of scale, combined effects of production factors, and effects of technologies (Shahbaz et al., 2014a; Wan et al., 2015). When the amount of export increases, it boosts up the activities of economy, which therefore amplifies energy consumption in the home country (Cole, 2006). Kyophilavong et al. (2015) studied the associations between trade openness and energy demand and disclosed that trade openness and energy consumption are mutually dependent i. e., trade openness Granger causes energy consumption and energy consumption Granger causes trade openness. However, Ghani (2012) found no impact of trade liberalization on energy consumption in case of developing countries. Nasreen and Anwar (2014) found positive impact of trade openness on energy consumption in Asian countries. Sbia et al. (2014) came across that trade openness are negatively linked with energy consumption. Adom (2015c) disclosed that both foreign direct investment and trade significantly decrease energy intensity. Thus, based on the above discussion we can develop our third hypothesis as follows.

Hypothesis-3 (H3). Trade openness has negative direct impact on energy intensity.

In general, an open economy grows faster than a closed economy as trade openness affects per capita income positively through its static and dynamic gains stemming from reallocation of resources and efficiency gains respectively. Ali et al. (2016) examined the effects of trade openness and industrial value added on economic growth in Bangladesh and their econometric model indicates that imports have a negative relationship as exports positively influence economic growth. After studying the trade openness and output growth of 23 Asian economies, Trejos and Barboza (2015) concluded that countries which have a rising level of trade openness could experience faster growth in per capita output through gains in productivity connected with capital accumulation, rather than the presumed technological spillover effects coming from the trading sector. Ahmed (2017) pointed out that economic growth and trade openness increases energy intensity in BRICS countries. Tiba and Frikha (2018) found the presence of feedback causality between energy consumption and income and between trade openness and income. Their findings also revealed a unidirectional causality running from trade openness to energy consumption without any feedback effects. Mahmood and Ahmad (2018) found a negative relationship between energy-intensity and the growth rate of per capita GDP i.e., energy intensity is significantly declined in response to economic growth. Based on these references, the fourth hypothesis can be put forwarded as the following.

Hypothesis-4 (H4). Trade openness has negative indirect impact on energy intensity through economic growth.

The aforementioned hypotheses are illustrated in figure-1, which shows the hypothesized direct and indirect connections of industrialization and trade openness with energy intensity.

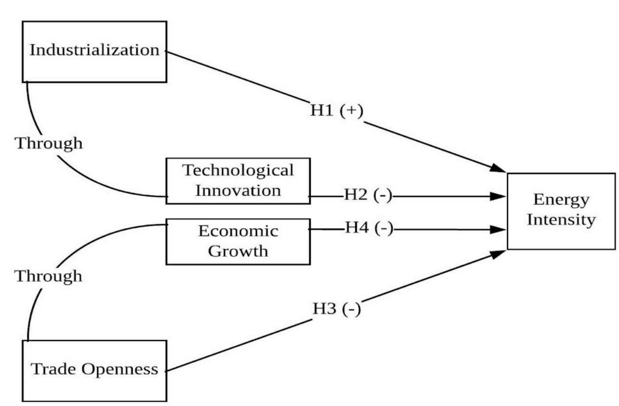

Fig. 1. Pictograph of proposed hypotheses.

Table 2
Description of the variables.

Variable's type	Variable's name	Definition	Unit
Dependent variable	Energy intensity (EI)	Total energy consumption/GDP	Kg[a]/US$
Independent variables	Industrial Share of Growth (ISG)	Industrial value added to GDP	%
	Trade Openness (TO)	(Exports + imports)/GDP	%
Mediating variables	Technological Innovation (TI)	Number of patents	Number
	Per capita GDP (P_GDP)	Total GDP/total population	US$

[a] Oil equivalent.

3. Materials and methods

3.1. Variables and data description

The two independent variables are industrialization, measured as the industrial share of GDP, and trade openness, measured as the ratio of international trade to GDP. Based on the contemporary literature on energy intensity and its influencing factors, we select two other variables that might have effect on our dependent variable energy intensity. These two factors are per capita GDP as a proxy for economic growth and number of patents as a proxy for technological innovation. These two variables also act as two mediating variables in our study. The details of the variables are presented in Table-2.

The study period is 1986–2015 and the time frame is chosen based on the availability of data related to each variable under question. Patents data are collected from the Department of Patents, Design and Trademarks, Ministry of Industries in Bangladesh. All other data are collected from the World Bank World Development Indicators database. A description of data is arranged in Table-3.

3.2. Path model

Path model, pioneered by Wright (1921, 1934), is considered as an extension of multiple linear regression which is generally used to evaluate the causal models by examining the relationships between dependent and independent variables. Sometimes, the model is viewed as a special case of structural equation model which combines both factor analysis and simultaneous equations models together. The model is admired in agriculture, biology, genetics, sociology, psychology, epidemiology and econometric researches as it can analyze the direct and indirect impacts of independent variables on dependent variable by estimating both the magnitude and significance. The model can be conceptualized as depicted in figure-2, where some independent and dependent variables i.e., x, u, z and EI are represented in rectangles or boxes. Variables that are exclusively independent and not dependent are called 'exogenous' variables like x and u. In general, these exogenous variables' boxes lie at the outer sides of the model and have single-headed arrows departed from them where no single-headed arrows ends at these variables. On the other hand, variables those are solely dependent (or which are both independent and dependent) and those have at least one single-headed arrow pointing at them are termed as 'endogenous' variables like z and EI. An endogenous variable may also be affected by variables and factors coming from outside the model like e_1 and e_2 in circles. Practically, the single-headed straight arrow from one variable to another variable denotes a direct path ($P_{z,x}$, $P_{EI,u}$, $P_{EI,x}$ *and* $P_{EI,z}$ in figure-2), the double-headed curvature arrow represents correlation between two variables ($r_{x,u} = r_{u,x}$ is correlation between x and u in figure-2) and $e1$ and $e2$ connote error or disturbance terms in the model.

Table 3
Descriptive statistics of the variables.

Variable	Minimum	Maximum	Mean	Std. Dev.	N
EI	0.20	0.49	0.35	0.07	30
ISG	20.05	28.15	24.06	2.28	30
TO	16.69	48.11	30.55	9.98	30
TI	93	354	240	92	30
P_GDP	227.42	1210.16	498.83	261.51	30

To analyze the impacts of the factors discussed above on energy intensity, we develop a model as follows.

$$EI_t = aISG_t^b TO_t^c TI_t^d P\_GDP_t^e \varepsilon_t \tag{1}$$

where a, b, c, d, e are regression coefficients, t signifies time and ϵ is disturbance term. After taking logarithm, the model looks like:

$$lnEI_t = lna + blnISG_t + clnTO_t + dlnTI_t + elnP\_GDP_t + ln\varepsilon_t \tag{2}$$

The direct path coefficient of an independent variable is the partial regression coefficient for this independent variable such as b, c, d, e in equation (2). For example, $P_{EI,x}$ in figure-2 represents the direct effect of independent variable x (factor) on dependent variable EI (energy intensity). The indirect path coefficient of an independent variable through another independent variable on dependent variable can be calculated using equation (3).

$$P_{EI,z,x} = P_{z,x} \times P_{EI,z} \tag{3}$$

Where, $P_{EI,z,x}$ represents the indirect path coefficient of x on EI through z (figure-2) that denotes the indirect effect of independent variable x through another independent variable z on dependent variable EI, $P_{z,x}$ represents the direct path coefficient of x on z; and $P_{EI,z}$ denotes the direct path coefficient of z on EI. Thus, the total path coefficient of independent variable x on the dependent variable EI can be written as:

$$TP_{EI,x} = P_{EI,x} + \sum_{i=1}^{n} P_{EI,z_i,x} \tag{4}$$

Here, $TP_{EI,x}$ stands for total path coefficient of x on EI which represents the total impact of x on EI, and $i = 1, 2, 3 \ldots \ldots n$.

4. Results and discussion

First of all, we tested the data for correlation. Because if no correlation test is carried out, the risk of unreliable and unstable data may influence the conclusion of the study. In our study, we found all the variables are correlated with each other and significant at 0.01 levels (2 tiled). The results of the correlation analysis is given in Table-4.

Path analysis is mainly based on the assumptions of regression analysis such as all causal relations are linear and additive, and all models are recursive (results in uncorrelated error terms, no two-way causal relations, no feedback loops). Based on these assumptions the model is formed and it calculates the coefficients through the standardized regression path coefficients. For this purpose, we use SPSS (Amos 23) to estimate and explain the relationships between variables and predictions regarding them via maximum likelihood method. In this statistical package (Amos 23), the model can be worked out as it is described in section 3.2. Our path model, consisting the dependent, mediating and independent variables, is depicted in figure-3, where all the *Ps* with 2 other variables' names subscripted with it represents the direct path coefficients of the path shown by the arrows and $r_{ISG,TO} = r_{TO,ISG}$ represents the correlation coefficients between

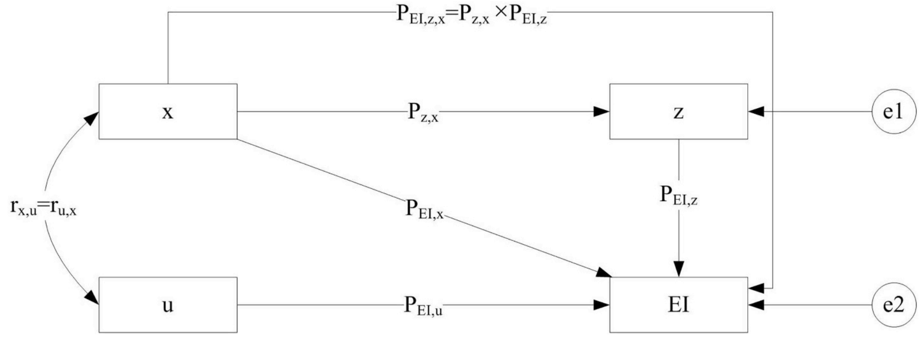

Fig. 2. A simple diagram to illustrate a path model.

Table 4
Correlations among variables (only lower triangle is depicted).

	ISG	TO	TI	P_GDP	EI
ISG	1				
TO	.933**	1			
TI	.801**	.842**	1		
P_GDP	.916**	.935**	.784**	1	
EI	-.870**	-.920**	-.790**	-.945**	1

**means correlations are significant at the 0.01 level (2- tiled).

industrialization and trade openness. Any path in a path model can be represented as a regression equation.

To examine the impacts of industrialization and trade openness on technological innovation and economic growth respectively as well as the impacts of these four variables on energy intensity we found a total of 3 regression equations. The regression path coefficients of the equations are given in Table- 5 and the label of the corresponding paths is depicted in figure-3. In our first equation, we see that if industrialization increases by 1 unit then technological innovation increases by 0.801 units. Our second equation which shows the impact of trade openness on economic growth expresses that a 1 unit increase in trade openness causes a 0.935 units increase in economic growth. The last equation which represents the impacts of all variables on energy intensity implies a 1 unit change in industrialization, trade openness, technological innovation and economic growth leads to a 0.149, -0.298, -0.064 and -0.670 unit changes in energy intensity respectively. All the path coefficients of variables in all models are significant at different

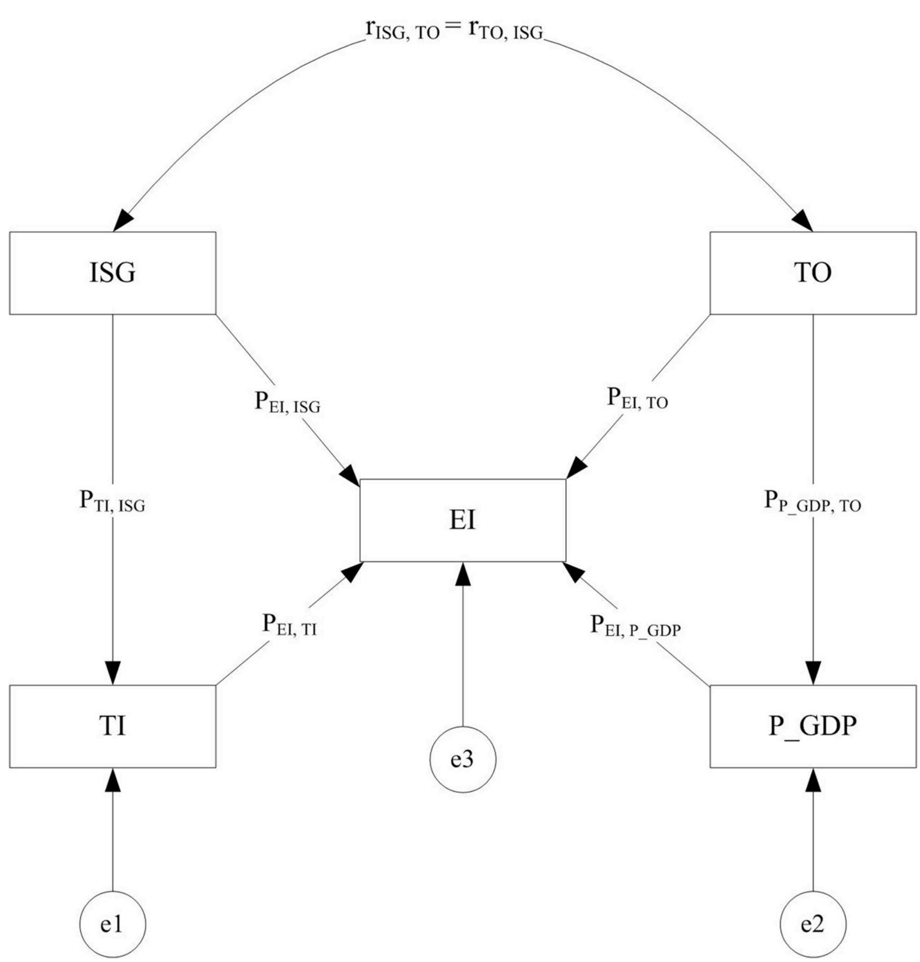

Fig. 3. Path model.

Table 5
Regression path coefficients of different models.

Equation	Dependent variable	Independent variable	Label	Estimate	P-value	R^2	F-statistic
1.	TI	ISG	$P_{TI,\ ISG}$	0.801	***	0.642	50.147***
2.	P_GDP	TO	$P_{P\_GDP,\ TO}$	0.935	***	0.873	193.152***
3.	EI	ISG	$P_{EI,\ ISG}$	0.149	0.082	0.923	61.577***
		TO	$P_{EI,\ TO}$	-0.298	0.039		
		TI	$P_{EI,\ TI}$	-0.064	0.045		
		P_GDP	$P_{EI,\ P\_GDP}$	-0.670	***		

*** means p-value is less than 0.001.

Table 6
Decomposition of the path coefficients of the model.

Casual variable	Outcome variable	Standardized direct effects	Standardized indirect effects	Standardized total effects
ISG	TI	0.801	0.000	0.801
	EI	0.149	-0.051	0.098
TO	P_GDP	0.935	0.000	0.935
	EI	-0.298	-0.627	-0.925
TI	EI	-0.064	0.000	-0.064
P_GDP	EI	-0.670	0.000	-0.670

levels. The R^2 value and the F-statistics also imply that the models fit the data well.

The standardized direct, indirect and total effects of independent variables on dependent variables are shown in Table-6. First, industrialization influences energy intensity positively in terms of direct effects. More specifically, a one percent increases in industrial share of GDP causes a 0.149 percent increase in energy intensity. It is due to the increasing consumption of energy with the increasing productions in industrial sector. This result is consistent with the results found by Ye and Ye (2010), Ali et al. (2016) and others. Thus, our first hypothesis is proved. Second, in terms of indirect effect, industrialization negatively influences energy intensity through technological innovation. The reason behind this is the negative direct impact of technological innovation on energy intensity. As technological innovation reduces energy intensity (Cagno et al., 2015; Sohag et al., 2015; Wei et al., 2016), the coefficient of indirect path from industrialization to energy intensity become negative (-0.051) as it is shown in figure-4. Hence, our second hypothesis proposed as industrialization has negative indirect effect (through technological innovation) on energy intensity is verified.

Third, the direct path coefficient from trade openness to energy intensity is -0.298, which implies that a one unit rise in trade openness causes a 0.298 unit fall in energy intensity. In other words, trade openness negatively influences energy intensity. This result can be conceptualized if we look into the recent imports and exports segments of Bangladesh. The country's import of capital machineries has risen by 138.72% over 2014–2018, followed by major primary commodities

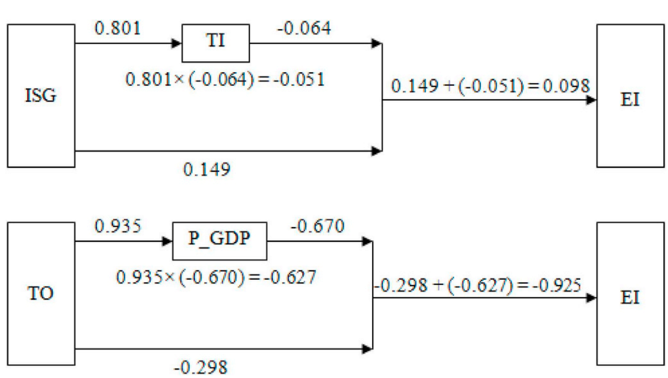

Figure-4. Paths from industrialization and trade openness toward energy intensity.

(35.91%) and major industrial commodities (14.17%) and so on. On the other hand, export earnings from agricultural product and ceramic products have increased by 38.55% and 32.70% respectively over 2017–2018, followed by handicraft products (15.26%), cotton and cotton products (14.03%) and others (Bangladesh Economic Review, 2018). Due to the import of modern energy saving machineries and use of these machineries in agricultures and different industries, the productions rise with a decline in energy consumption. Thus, our third hypothesis is established and it is due to the economy of scales and production factors' impacts brought by openness into the country. And, the result is consistent with other scholars like Sbia et al. (2014), Adom (2015c) among others. Fourth, trade openness has negative indirect impact on energy intensity through economic growth measured by per capita GDP. As trade openness has positive direct impact on per capita GDP (Trejos and Barboza, 2015) and per capita GDP has negative direct effect on energy intensity (Mahmood and Ahmad, 2018) the final outcome become negative as it is shown in figure-4. So, our fourth hypothesis is verified as trade openness has indirect negative impact on energy intensity through economic growth. A summary of the hypotheses testing results are given in Table- 7. In terms of total effect, industrialization has a positive total effect on energy intensity, where trade openness, technological innovation and per capita GDP have negative total impacts on it. Their standardized total effects on energy intensity are 0.098, -0.925, -0.064 and -0.670 respectively. In absolute value, their individual total effects can be written as in TO > P_GDP > ISG > TI order.

5. Conclusion and policy implications

The study is an attempt to find out the direct and indirect impacts of industrialization and trade openness on energy intensity using a path model. For this purpose, we use data from 1986 to 2015 for Bangladesh. We proposed a total of four hypotheses and analyze the data for proving these hypotheses. The results confirm that both industrialization and trade openness impact energy intensity in Bangladesh directly and indirectly, which are sufficient enough to prove the proposed hypotheses. The direct effect of industrialization on energy intensity is positive, where its indirect impact on energy intensity is negative through technological innovation. On the other hand, both the direct and indirect effects of trade openness on energy intensity are negative. In case of total effects, industrialization has positive influence and trade openness has negative influence on energy intensity. So, we can conclude by saying that industrialization positively influences energy intensity where trade openness negatively does.

Based on the aforementioned results and discussion, we propose the following policy implications. First, we found that industrialization has a direct positive and an indirect negative impact on energy intensity in Bangladesh. In other words, industrialization plays both the direct stimulating and indirect inhibiting roles (through technological innovation) in influencing energy intensity. But, the total effect of industrialization on energy intensity is positive. Thus, the stimulating effect of this factor is powerful than its inhibiting effect. At the same time, energy efficiency is a must for Bangladesh to hold back carbon emissions and introducing proper technology may work to mitigate

Table 7
Decisions regarding proposed hypotheses.

Hypothesis	Decision
Hypothesis-1: Industrialization has positive direct impact on energy intensity.	Proved
Hypothesis-2: Industrialization has negative indirect impact on energy intensity through technological innovation.	Proved
Hypothesis-3: Trade openness has negative direct impact on energy intensity.	Proved
Hypothesis-4: Trade openness has negative indirect impact on energy intensity through economic growth.	Proved

carbon emissions (Gunter and Rahman, 2012). At this situation, policy makers need to devise some industrial policies that enhance technological innovations through which industrialization plays its inhibiting role. More specifically, policy makers could take decisions to motivate innovations in industries to reduce energy intensity or improve energy efficiency. It can be done through supplying enough funds to the industrial sectors to invest in research and development as well as by attracting more and more foreign direct investments into the country. Second, our results suggest that trade openness inhibits energy intensity both directly and indirectly. And the indirect path is through economic growth, where trade openness stimulates it. Thus, Bangladesh has enough room to reduce its energy intensity through increasing trade openness as well as economic growth. Policy makers might introduce new trade policy which would be more open and friendly. If it could be ensured, economic growth would be increased and energy intensity might be lessen in Bangladesh to fulfill the government's target of improving energy intensity in 2030 by 20% compared to the 2013 level.

The study was mainly focused on analysing the direct and indirect impacts of industrialization and trade openness on energy intensity in case of Bangladesh. To do so, we used a simple and robust path model and obtain parameter values with regression analyses. The results are satisfactory which have practical policy implications. However, the study is not free from limitations. We take industrialization, trade openness, technological innovation and economic growth as explanatory variables in our model and use data from 1986 to 2015 for Bangladesh only. So, studies taking some additional variables, such as government expenditures, energy prices, urbanization and total population, and using data for other major economy even for a panel of countries for a longer period could be carried out to investigate their impacts on energy intensity.

Acknowledgement

The work is supported by the National Natural Science Foundation of China (Grant No. 71734001); the National Social Science Foundation Project (Grant No. 17BGL266); the Liaoning Provincial Economic and Social Development Project (Grant No. 2019lslktyb-011); the Fundamental Research Funds for the Central Universities (Grant No. DUT18RW210) and the Dalian Youth Science and Technology Star Cultivation Project (Grant No. 2016RQ004). The authors are thankful to these organizations for their supports. The authors are also grateful to the Editor and referees for their helpful comments and suggestions.

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