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Does capital efficiency influence economic growth in Bangladesh? Application of the Harrod-Domar model

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Abstract

Purpose – The main purpose of this paper is to analyse the influence of capital efficiency on the economic growth of Bangladesh using the Harrod-Domar (H-D) model.

Design/methodology/approach – We use annual data from 1980 to 2019 for this paper. Three steps are taken in the data analysis. First, to check the existence of a unit root, we use the augmented Dickey-Fuller (ADF) test and to determine co-integration among the variables, we use the Johansen-Juselius co-integration test. Next, for long-run estimation, we use the dynamic ordinary least square (DOLS) estimator. The sensitivity of the long-run estimations is further checked by the fully modified OLS (FMOLS) and autoregressive distributed lag (ARDL) estimators. Lastly, we use the Granger causality test to determine the long-run causality among the variables.

Findings – The long-run co-integration test validates the co-integrating relationship among the variables. DOLS estimations reveal that the economic growth of Bangladesh is negatively associated with the incremental capital output ratio (ICOR), validating the notion that capital efficiency matters for achieving higher economic growth. On average, an increase in ICOR by a unit tends to reduce economic growth in the long term by 0.75 percent. Our results also reveal no significant relationship between savings and economic growth when the model is extended. Finally, causality results indicate unidirectional causality between ICOR and economic growth.

Practical implications – Based on the results obtained, we argue that the enhancement of capital productivity could bring efficiency because ICOR is an inverse of capital productivity. Since Bangladesh's capital productivity is considerably low compared with other neighbouring countries, it is suggested that firms should gradually move towards technological advancement and enhance economies of scale, etc. in the long run. Moreover, policies in favour of continuous skill development programmes could be highly effective in increasing capital productivity given that capital follows a vintage structure.

Originality/value – This is the first paper to analyse the economic growth pattern of Bangladesh using the traditional H-D model by incorporating variables such as savings and ICOR and also by relaxing the assumption of time-invariant (i.e. fixed) data of the variables. Moreover, this paper extends the traditional H-D empirical model by introducing key indicators and time breaks for Bangladesh's economy through a stepwise regression process.

Keywords Harrod-Domar model, Bangladesh, ICOR, Savings, Capital, Economic growth

Paper type Research paper

JEL Classification — C5, E1, E21, E22, E23

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1. Introduction

Existing literature suggests that, over the years, many researchers have attempted to analyse the determinants of growth patterns of several nations worldwide for country and region-wise policy implications. Given this broad objective, the approach for determining effective growth factors has been relatively heterogeneous (Boianovsky, 2018; Coccia, 2019). Smith (1776) highlights a growth assumption claiming output to be a function of labour and capital, a more widely derived version of which – according to Rostow and Kennedy (1992) – included an institutional framework of the economy in terms of a competitive free-market economy, capital growth, population growth, and the division of labour concerning technological progress. The Harrod-Domar (H-D) model came into existence after Keynes (1936) developed a "demand-side" economic theory.

The H-D model is, in fact, an extended version of the Keynesian theory, which merged two independent studies: Harrod's theory of dynamic equilibrium (1939) and Domar's growth theory based on capital expansion, growth rate and employment (1946). Despite the differences between the two models, one significant notion regarding growth equilibrium was common in both models, resulting in a standard H-D model that we have today (Orlando and Rossa, 2021; Hochstein, 2020). The model suggests that the economic growth rate could be improved by increasing the gross national savings as a percentage of Gross Domestic Product (GDP) or by decreasing the incremental capital output ratio (ICOR). A lower ICOR indicates faster economic growth (i.e. GDP growth) (Leibenstein, 1966; Singer, 1952). At a later period, many other growth models were introduced to determine the economic growth pattern of nations, testing the effect of several variables (economic, environmental, institutional, social, etc.) from different perspectives (Ojo *et al.*, 2020; Gründler and Potrafke, 2019; Pan and Mishra, 2018).

However, the model faced criticism over the proposition that the slightest variation of the natural growth rate from its equilibrium (warranted) rate could lead to either massive unemployment or prolonged inflation. This shortcoming was later modified in Solow's neoclassical growth model in 1956 (Solow, 1956), which explained that such extreme instability in the long-run growth was not possible given that the factor proportion was made flexible rather than concentrating on the fixed-coefficient of technology (Hagemann, 2009). Although the recent growth trend of any nation can be effectively evaluated using various well-established factors, the significance of the H-D model persists (Figure 1). The scatter plots indicate a positive relationship between savings and economic growth, while a negative relationship prevails between ICOR and economic growth over the years, considering the world scenario and Bangladesh. This intuitively indicates that, even though the H-D model portrays the notion of a business cycle, ICOR and savings seem to be linkable with growth dynamics across nations (Singer, 1952; Kaldor, 1961; Boianovsky, 2018; Okoro *et al.*, 2019; Ojo *et al.*, 2020). Besides, growth empirics (i.e. empirical study of economic growth) have found support for conditional convergences; variations in capital use and savings augmented by population growth can explain half of the variation in long-run economic growth (Ray, 2003). Thus, the savings dynamics and ICOR may have their unique ways of portraying the development trajectory of a nation, which should not be ignored during policy formulation.

As Bangladesh – a well-known nation from the South Asian cohort due to recent world affairs – is advancing to the next development stage, the country will need optimal macroeconomic policies for the thrust industries to facilitate the projected development trend (statistics). Bangladesh's economy has experienced landmark success over the past 5 decades, as reflected in different socio-economic indicators (such as life expectancy, infant mortality and school enrolment).

Moreover, Bangladesh, which was once believed to be a "bottomless basket with no hope of survival," is now globally known as a "development miracle" because of the country's outstanding track record of growth and development, even in times of elevated global

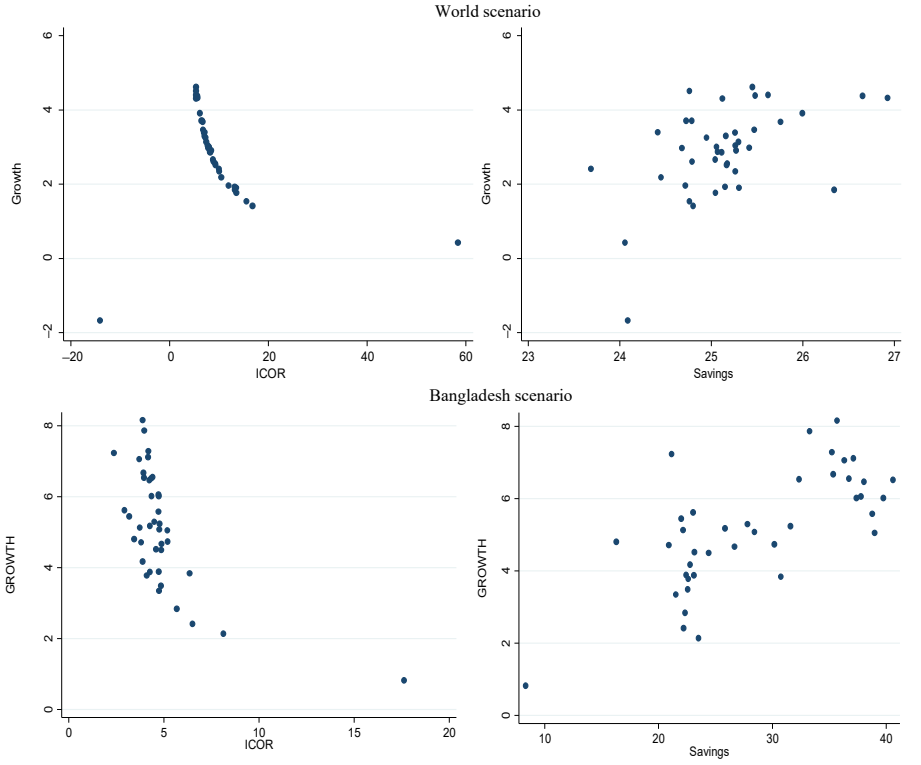


Figure 1.
GDP growth, savings and ICOR

Source(s): Authors' own figure from software-generated results

uncertainty. On average, the GDP growth rate of Bangladesh has increased from about 3% in the 1970s to 7% in the 2010s and traversed 8% just before the COVID-19 pandemic disruption. Moreover, according to the 2018 statistics of the Bangladesh Bureau of Statistics (BBS), extreme poverty was reduced to 10.50% in 2019 from around 80% in the early 1970s. The country has recently completed the implementation of its 7th five-year plan (FYP) of 2016–2020 and has set to implement the next five years' development strategies (i.e. 8th FYP). Previous FYPs indicate that the average ICOR of Bangladesh has been around 4.30 for the last 10 years, with a declining trend.

To analyse the impact of vicissitudes in ICOR on economic activities and what policies can be designed based on the impact, we scrutinise the growth trajectory of Bangladesh from the lens of the H-D model. Since Bangladesh's government is expecting to expedite the investment and economic growth rate for achieving Vision 2041, the results from the holistic analysis can also help us provide a long-run prediction of economic advancement from which we can draw a subsequent strategic conclusion.

The main research question of this paper is to examine whether there is an inverse long-run relationship between ICOR and economic growth in Bangladesh. Given the theoretical construction of the H-D model, it should be worth pointing out that the inverse relationship between ICOR and GDP growth indicates the degree of capital utilisation efficiency, and it is very different from capital fundamentalism (i.e. capital accumulation). The level of capital efficiency is also referred to as improved technical conditions in the existing literature (Ni *et al.*, 2023; Loayzna and Pennings, 2022; Robinson, 2017; Meier and Baldwin, 1957).

Without economic jargon, capital efficiency indicates how effectively capital is utilised by other factors of production. We argue that apart from the notion of capital fundamentalism – an assumed primary determinant of economic growth – ICOR should also be considered to analyse the dynamics of economic growth.

The novelty of this paper is manifold. First, this is the first paper where the economic growth pattern of Bangladesh is analysed through the lens of the variables examined in the H-D model, such as savings and ICOR. Earlier, Masuduzzaman and Biswas (2017) studied the growth pattern of Bangladesh in the light of a simplified version of the H-D model focussing on only the investment-GDP ratio. Therefore, highlighting the research gap, this paper brings about changes in the main model by relaxing the assumption of time-invariant (i.e. fixed) savings and ICOR, and assuming time relevancy in both of the variables.

Second, this paper extends the traditional H-D empirical model by introducing sectoral disaggregation and time breaks for Bangladesh's economy through a stepwise regression process to justify the underlying relationship of savings and ICOR with economic growth by using annual data from 1980 to 2019. Third, the paper applies a recent and robust time series econometric methods, which can reduce the unwanted effects of endogeneity and bias in the long-run estimation. Furthermore, post-estimation stability and robustness checks were carried out. Finally, this paper aims to provide a few policy suggestions for sustainable economic growth and development in Bangladesh.

For empirical analysis, we use the augmented Dickey-Fuller (ADF) unit root test to check the stationary properties of the variables. Johansen-Juselius co-integration is applied for checking the long-run co-integration among the variables. Next, dynamic Ordinary Least Square (DOLS) is applied to estimate the long-run coefficients of the concerned variables, and the Granger causality test checks long-run causality. Additionally, model stability tests were finally performed to confirm the stability of the results.

The rest of the paper is organised in the following structure: section 2 presents a review of the existing literature followed by a discussion on model formulation and econometric methodology in section 3. Section 4 presents the results, while the relevant discussion is presented in section 5. Finally, section 6 brings the paper to an end.

2. Literature review

Several studies have been conducted, either in terms of savings or in terms of capital-output ratio, to determine the relevance of the H-D model with the economic growth of various developed, developing or underdeveloped nations (Table 1). We briefly discuss some of the studies in the existing literature in this section. Given the paper's aim, we have selected these studies to gain comprehensive knowledge about the different variables, hypothesis formulation and econometric methods to setup our econometric models to derive some policy implications.

Soon after the contribution of Harrod (1939) and Domar (1946), the existing literature on growth empirics and development economics observed an increase in theoretical, analytical and empirical discussions on the H-D model's key aspects. A rigorous focus was given on the framework and intuitions of capital utilisation. Boianovsky (2018) explicitly highlighted that the essence of the H-D model was somewhat misjudged in the early 1950s by development economists due to the lack of textual evidence. It was believed that capital fundamentalism arose from the H-D model; however, it was not really a part of the growth model.

Even though development economists did not accept ICOR as a growth determinant, some scholars argued in favour of ICOR and the overall structure of the H-D model. Among others, Robinson (2017) – in her seminal work – strongly pointed out that the H-D model is a very simple model, yet the dynamics are not quite fully understood by many. Robinson (2017) further explained that the H-D model determines economic growth by the savings dynamics

Author(s)	Country/Place of study	Time frame	Methodology	Main findings
Adhikar (2018)	Nepal	1974–2017	ARDL	Savings has a positive effect, and ICOR has a negative impact on economic growth
Easterly (1999)	138 countries	1950s-1995	Panel regression analysis	No significant theoretical or empirical results were found to explain the relationship between growth, ICOR and investment requirements
Jagadeesh (2015)	Botswana	1980–2013	ARDL DOLS	Significant long-run correlation exists between savings and economic growth
Najarzadeh *et al.* (2014)	Iran	1972–2010	ARDL	Two-way positive, significant and long-run causality between the variables
Ohkawa and Rosovsky (1962)	Japan	1890–1931 (7 years moving average)	Graphical analysis of the collected variables	Inverse relationship between ICOR and growth rate
Osundina and Osundina (2014)	Nigeria	1980–2012	OLS	Increased savings leads to increased capital accumulation through investment, which causes economic growth and enhances production
Sekantsi and Kalebe (2015)	Lesotho	1970–2012	ARDL VECM-based Granger causality	Short-run and long-run Granger causality exists from savings towards investment, and both short-run and long-run causality from investment to economic growth exists
Siraj and Bengali (2007)	Pakistan	1973–2003	OLS	National savings was insignificant for the GDP of Pakistan Changes in per-capita income and interest rates changed private savings
Boianovsky (2018)	None	None	Literature-based argumentative discussion	Discussed the history of the H-D model
Robinson (2017)	None	None	Theoretical and literature-based argumentative discussion	Discussed the perceived notion regarding the H-D model and how it should be interpreted
Solow (1999)	None	None	Theoretical and literature-based argumentative discussion	Focused on the issues regarding mechanical description of the H-D model

Table 1.
Summary of the literature review

(*continued*)

Author(s)	Country/Place of study	Time frame	Methodology	Main findings
Singer (1952)	A group of 1,000 persons from under developed communities is assumed	None	Theoretical discussion and numerical illustration	It is showed that along with normal investment, productivity of capital helps to sustain economic development
Rumawir (2019)	Indonesia	2009–2010	SEM	Capital utilisation efficiency has direct effect on economic growth
Okoro *et al.* (2019)	Nigeria	1986–2016	OLS	There is a long-run positive effect of international capital inflow on economic growth
Ojo *et al.* (2020)	Nigeria	Micro data of 360 rice farmers	Stochastic Frontier Analysis	Farmers produce below the frontier level due to the technical inefficiencies

Note(s): See, Section 2: Literature review and references section for more details
Source(s): Authors' own elaboration

Table 1.

and prevailing technical conditions rather than by effective demand. Furthermore, Solow (1999) also highlighted how misleading mechanical descriptions used by the scholars undermined the actual essence of capital efficacy in determining economic growth. Singer (1952) first used the H-D model empirically by bringing some changes (Keynesian and Malthusian intuitions) so that the actual notion of demand, savings and capital utilisation efficiency can be statistically proven. Singer (1952) found that along with normal investment, the productivity of capital helps to sustain economic development through an increase in per capita income. However, the issue of time dynamics of exogenous ICOR (due to innovation and factor substitutions) was still missing (such as Bruton, 1955), which was intuitively discussed by Ray (2003) and incorporated in this paper.

Najarzadeh *et al.* (2014) studied the impact of savings on both the economic growth and non-oil based sectoral growth in Iran. The study analysed the impact of just two variables: GDP, calculated for both the total economy and non-oil sectors, and the gross domestic savings (GDS) using annual time series data from 1972 to 2010. The autoregressive distributed lag (ARDL) model was used to investigate the variables which suggested a positive and significant impact of savings on both the types of growth. The results also showed a long-run causality running from economic growth towards savings, implying a two-way relationship between the variables in the case of Iran.

Another study done by Osundina and Osundina (2014), using a data set from 1980 to 2012, examined the relationship between savings, capital accumulation and economic growth in Nigeria. A savings and investment model was primarily used to deduce the variables – gross national savings, savings deposit rate, gross fixed capital formation, inflation and lending rate – into a growth equation, which was then estimated using an OLS estimator. The results suggested a positive linkage between savings and economic growth, mentioning that a person's savings, channelled through investment policies, will form additional capital. This accumulated capital will be further used in the production process to expedite economic growth.

Sekantsi and Kalebe (2015) also conducted a study to analyse the effect of savings and capital accumulation on the economy of Lesotho. The variables used in the study were GDS, gross domestic investment and GDP. Using the ARDL bound testing framework and vector

error correction model (VECM) based on a Granger causality test, the authors analysed a data set from 1970 to 2012. The results showed a similar result as that of the study by Osundina and Osundina (2014), suggesting that capital accumulation through investment and savings drives sustainable economic growth.

Jagadeesh (2015) studied the 1980 to 2013 time series of Botswana's economy using the ARDL model to determine the possible existence of any long-run relationship between GDP and GDS. The study further tested the dynamic long-run co-integration of GDP and its other independent variables – gross capital formation, exports, inflation rate and labour force – using the DOLS model and established a significant relationship between the savings and economic growth in Botswana, which supports the H-D model.

Adikari (2018) investigated data over the period of 1974–2017 to inspect the relevance of the model to the Nepalese economy. By using a series of different tests such as the ADF unit root test, the Johansen system of co-integration test, the Granger causality test and the ARDL model, the author found that the increasing rate of savings positively impacted the growth of the Nepalese economy, whereas a negative impact of ICOR was found on growth, supporting the proposition of the H-D model.

On the other hand, the study on the relationship between ICOR and growth rate dates back to as far as 1962, when Ohkawa and Rosovsky (1962) graphically calculated the fluctuation of Japan's GDP, gross domestic investment, price level, exports and imports over the period of 1890–1931 (seven-year moving averages) to understand the impact of ICOR on the growth rate. The graphical analysis clearly depicted an inverse relationship between ICOR and Japan's growth rate, supporting the notion of the H-D model.

However, some cases depict the inefficiency of the H-D model in explaining GDP growth. For example, Easterly (1999) mentioned a new model, the "financing gap", which was widely used by International Financial Institutions. By definition, a financing gap is a gap between the required level of investment needed in an economy and the available resources. This gap is supposed to be filled up by foreign aid. However, based on the panel data analysis from as early as the 1950s until around 1995, the author rejected the prediction that there is a short-run proportional relationship between growth and investment requirements and that ICOR cannot be a significant derivative of growth with respect to investment.

The basic H-D model also fails to estimate the economic growth of Pakistan (Siraj and Bengali, 2007). When variables such as national savings, per capita income, capital-output ratio and interest rates for the period from 1973 to 2003 were analysed, using the OLS model, the results proved that savings was an insignificant determinant of GDP growth in Pakistan. Similarly, for the case of North Sulawesi, Indonesia, Rumawir (2019) investigated the pattern of economic growth in light of the H-D model. For the empirical analysis, the structural equation modelling (SEM) technique was used. Results indicated that capital efficiency did not have any impact on government stimulus policies. However, capital utilisation efficiency has a direct effect on economic growth. It was further observed that government stimulus policies tend to precisely achieve targeted goals, leading to higher economic growth.

Using the H-D modelling setup, Okoro *et al.* (2019) analysed the impact of international capital on economic growth in Nigeria. Based on the data covering the period from 1986 to 2016, Oroko *et al.* (2019) applied several unit root tests, the Johansen-Juselius co-integration test and the OLS model for the empirical analysis. According to the results, there is a long-run positive effect of international capital inflow on economic growth. However, without adequate market environment and productivity of capital, such an effect may not be sustainable. On the other hand, Ojo *et al.* (2020) used microdata from 360 rice farmers to analyse the financing gap and effect of technical efficiency from the H-D model perspective in South-western Nigeria. A stochastic frontier modelling framework was used where the production function followed Cobb–Douglas form. The results indicated that most of the

farmers produce below the frontier level due to the technical inefficiencies in production factors resulting from lack of credit and agricultural information.

Based on the literature, two key hypotheses can be formed as follows:

HA. ICOR (capital efficiency) influences the economic growth of Bangladesh.

HB. ICOR (capital efficiency) does not influence the economic growth of Bangladesh.

3. Method

We use a derived version of the H-D model to empirically analyse the relationship between capital efficiency and economic growth in Bangladesh, since the H-D model provides a meaningful discussion on capital efficiency through the linkage between capital-output ratio and economic growth. Indeed, other growth models could have been applied; however, obtaining precise econometric models would not be as desirable as using the H-D model, given the objective of the paper.

3.1 The model

We define GDP by equation (1) following the arguments of Harrod (1939) and Domar (1946).

$$Y_t = C_t + S_t \tag{1}$$

Here, Y_t = GDP of a particular period t. C_t and S_t are the aggregate consumption and savings in the economy, respectively, for period t. Since the volume of savings and investments is considered as the important determinant of economic growth (i.e. cyclical nature), savings and investment are equal in the H-D model. Therefore,

$$Y_t = C_t + I_t \tag{2}$$

The process of capital stock formulation for the next period can be written as

$$K_{t+1} = (1-\delta)K_t + \mathrm{I}_t$$

$$\geqslant K_{t+1} = (1-\delta)K_t + S_t$$

Assuming that a portion (s) of GDP is saved and capital stock is defined as $K = \vartheta Y$

$$\geqslant \vartheta Y_{t+1} = (1-\delta)\vartheta Y_t + sY_t$$

$$\geqslant \frac{\vartheta Y_{t+1}}{Y_t} = \frac{(1-\delta)\vartheta Y_t + sY_t}{Y_t}$$

$$\geqslant \frac{\vartheta Y_{t+1}}{Y_t} = \frac{\vartheta Y_t - \vartheta Y\delta + sY_t}{Y_t}$$

$$\geqslant \frac{Y_{t+1}}{Y_t} = s.\frac{1}{\vartheta} + \delta$$

$$\geqslant \frac{Y_{t+1}}{Y_t} = s.\frac{1}{\vartheta} \text{ [Depreciation adjusted]}$$

$$\geqslant \frac{Y_{t+1}}{Y_t} = s.\frac{1}{\vartheta} \tag{3}$$

Equation (3) represents a positive relationship between the growth rate of the economy and the speed of savings, and an inverse relationship between economic growth rate and ϑ. Since

$K = \vartheta Y, \vartheta = \frac{K}{Y}$, the ratio is known as the ICOR, and it is fixed in time. In general, ICOR tends to show the efficiency of capital used for the production process in the economy. In other words, it shows the magnitude of capital used to produce one unit of output. On the other hand, the saving rate can be seen as fixed in time. However, we relax these assumptions and allow both saving rate and ICOR to be time-variable for the empirical estimation, as discussed in Ray (2003).

$$\frac{Y_{t+1}}{Y_t} = s_t \cdot \frac{1}{\vartheta_t} \tag{4}$$

Let us assume a functional form of the model as shown in equation (5)

$$Y_{g,t} = f(s_t,\ ICOR_t) \tag{5}$$

We further aim to extend our analysis by incorporating other vital explanatory variables of economic growth such as growth in gross agricultural value-added and gross non-agricultural value-added while accounting for two incidents: the structural regime change in Bangladesh from the late 1990s and the world financial crisis in 2008. The influence of these incidents is captured by two-time dummies (TDUM1 and TDUM2). The econometric viability of these dummies was tested with the Chow breakpoint test before incorporating them into the model. After the 1990s, the non-agricultural sector (or industry) started to boom, with more and more people investing in the industrial sector. On the other hand, the financial meltdown also affected countries around the world through numerous channels. Since equation (5) is the basis of our empirical analysis, we add the variables mentioned above progressively and check whether the fundamental intuition of the H-D model persists in the long run.

$$Y_{g,t} = f(s_t) \tag{6}$$

$$Y_{g,t} = f\left(s_t, ICOR_t, Agri_{g,t},\ TDUM_1,\ TDUM_2\right) \tag{7}$$

$$Y_{g,t} = f(s_t, ICOR_t, IND_{g,t},\ TDUM_1,\ TDUM_2) \tag{8}$$

$$Y_{g,t} = f\left(s_t, ICOR_t, Agri_{g,t}, IND_{g,t},\ TDUM_1,\ TDUM_2\right) \tag{9}$$

In equations (6) - (9) $Agri_g$ and IND_g are the growth of agricultural gross value added and industrial gross value added, respectively. To estimate the long-run coefficient of the variables, the econometric arrangement of the functional forms is shown in equations (10) - (14).

$$Y_{g,t} = \alpha_0 + \tau s_t + \varepsilon_t \tag{10}$$

$$Y_{g,t} = \alpha_0 + \tau s_t + \mu ICOR_t + \varepsilon_t \tag{11}$$

$$Y_{g,t} = \alpha_0 + \tau s_t + \mu ICOR_t + \rho Agri_{g,t} + \Phi TDUM_1 + \Psi TDUM_2 + \varepsilon_t \tag{12}$$

$$Y_{g,t} = \alpha_0 + \tau s_t + \mu ICOR_t + \varphi IND_{g,t} + \Phi TDUM_1 + \Psi TDUM_2 + \varepsilon_t \tag{13}$$

$$Y_{g,t} = \alpha_0 + \tau s_t + \mu ICOR_t + \rho Agri_{g,t} + \varphi IND_{g,t} + \Phi TDUM_1 + \Psi TDUM_2 + \varepsilon_t \tag{14}$$

3.2 Econometric strategy

3.2.1 Unit root and co-integration analysis. To determine the existence of unit root in the time series analysis, we run the ADF test because, in time series analysis, a unit-root process can cause unpredictable and biased results (Amin *et al.*, 2020; Dey and Tareque, 2020). Next, to check the long-run association among the variables of interest, we use the Johansen

co-integration test proposed by Johansen and Juselius (1990). The test is based on the unrestricted vector autoregressive (UVA) approach and provides two statistics: the trace statistics and maximum eigenvalue statistics. Both tests can be written as follows:

$$\lambda_{Trace} = -T \sum_{i-r+1}^{n} ln(1-\lambda_i) \tag{15}$$

$$\lambda_{max}(r, r+1) = -Tln(1-\lambda_{r+1}) \tag{16}$$

The trace test assesses that there are at most r co-integrating vectors, the null hypothesis of the test; meanwhile the maximum eigenvalue estimates a null hypothesis suggesting that there are exactly r co-integrating vectors.

3.2.2 Long-run estimation of the cointegrating factors. For a long-run estimation of the variables of the proposed model, we use the DOLS estimator proposed by Stock and Watson (1993). One of the main advantages of this estimator is that it can deal with regressor's endogeneity by incorporating lags and leads on the first differenced regressor through a single robust equation approach. Furthermore, DOLS can run the test on even a small sample size and dynamic sources of bias. The general form of the DOLS equation can be expressed by equation (17).

$$Y_t = \beta_0 + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \ldots + \beta_K X_{k,t} + \sum \alpha_{i\Delta} X_{l,t-i} + \sum \gamma_{i\Delta} X_{2,t-i} + \ldots \sum \delta_{i\Delta} X_{k,t-I} + \varepsilon_t \tag{17}$$

3.2.3 Long-run causality. A long-run causal relationship can be obtained once the variables are co-integrated, given the stationarity criteria and long-run coefficients are estimated. For long-run causality, we have used the Granger causality test proposed by Granger (1988). The Granger causality test determines whether the previous values of Y rightfully explain the present condition of present values of X with regard to the previous values of X. If former values of Y cannot explain the present changes in the values of X, then Y does not Granger cause X.

$$x_t = \alpha_o + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \ldots + \alpha_i X_{t-i} + \beta_1 Y_{t-1} + \ldots + \beta_i Y_{t-i} + u_t \tag{18}$$

$$y_t = \alpha_o + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_i Y_{t-i} + \beta_1 X_{t-1} + \ldots \beta_i X_{t-i} + v_t \tag{19}$$

3.3 Data

We use time series data covering from 1980 to 2019 for our analysis. Data on GDP annual growth rate (Growth), savings as percentage of GDP (GS_G) (proxy of varying savings rate), gross capital formation as percentage of GDP, growth of gross agricultural value added (AGRI_G) and growth of gross industrial value added (IND_G) are obtained from the world development indicators (WDI, 2020). From the data received on gross capital formation as percentage of GDP and GDP annual growth rate, we calculate ICOR by taking the ratio as shown in the model formulation. An overview of the dataset can be seen in Table 2.

4. Results

4.1 Unit root test results

Table 3 represents the results of the ADF test. According to the results, all the concerned variables are found to be stationary at the first difference form [integrated after the first difference, I (1)], considering both intercept and intercept and trend.

Criteria	Growth	GS_G	ICOR	IND_G	AGRI_G
Mean	5.14	28.48	4.82	7.27	3.31
Median	5.15	27.23	4.38	7.18	3.33
Maximum	8.15	40.60	17.63	12.67	9.21
Minimum	0.82	8.33	2.37	−3.82	−0.44
Std. Dev	1.61	7.68	2.30	2.90	2.17
Skewness	−0.39	−0.16	4.51	−1.24	0.21
Kurtosis	3.00	2.38	25.57	6.64	3.27
Jarque-Bera	1.03	0.83	985.01	32.41	0.42
Probability	0.60	0.66	0.00	0.00	0.81
Sum	205.65	1139.02	192.60	290.87	129.06
Sum Sq. Dev	101.48	2302.94	206.08	328.88	178.68

Table 2.
Descriptive statistics

Note(s): Software generated results
Source(s): Authors' own elaboration

Variable	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Growth	0.64	−2.73	−3.32**	−3.55**
GS_G	−1.43	−2.75	−6.19***	−6.13***
ICOR	−2.80*	−2.75	−6.11***	−6.08***
AGRI_G	−1.41	−1.25	−5.53***	−5.53***
IND_G	0.30	−1.80	−3.88***	−3.97***

Table 3.
Unit root test results

Note(s): ***, ** and * refer to significance level at 1, 5, and 10 percent, respectively
Source(s): Authors' own elaboration from software-generated results

4.2 Co-integration test results

Table 4 shows the results of the long-run co-integration analysis. The table shows that both the trace test and the maximum eigenvalue test statistics indicate co-integrating relationships among the variables of the models. Such a result allows us to estimate the long-run coefficients and probable causality among the variables of interest.

4.3 Long-run estimation of cointegrating factors

DOLS estimation results can be seen in Table 5. We analyse the variables sequentially, creating a new model every time by introducing a new variable in the system and running a regression analysis each time. In this method, we determine the accuracy and interaction of the variables used in a particular model.

When the impact of just savings on the growth rate of GDP is estimated, a positive relationship between savings and GDP growth rate can be found, which is highly significant as well (at 1%). The value is relevant to the expected signs. The coefficient of savings is greater than 0, but less than 1, which indicates that a one percent change in the savings will lead to a 0.14% change in the GDP. Diagnostic tests show that the model does not suffer from autocorrelation and irregularity in the residuals. However, the model is not entirely justified as we have omitted another most essential parameter of the primary H-D model, ICOR. Hence, we now add ICOR to the existing model and re-estimate.

After adding ICOR in the model, the elasticity of savings is still lower than 1. However, the coefficient of ICOR is negative, but not in a proportionate manner. This means that a unit change in ICOR will negatively change the GDP growth by 0.77% in the long run. This

Hypothesis	Trace statistics	Max-eigen statistics
Model-1		
None	12.32	9.66
At Most 1	2.65*	2.65*
Model-2		
None	28.73*	18.22
At Most 1	10.51	14.26
At Most 2	0.80	0.77
Model-3		
None	134.07***	50.59***
At Most 1	83.47***	43.90***
At Most 2	39.57	20.16
At Most 3	19.41	12.64
At Most 4	6.76	6.55
At Most 5	0.21	0.21
Model 4		
None	102.65***	43.40***
At Most 1	59.24	28.35
At Most 2	30.89	15.78
At Most 3	15.11	8.56
At Most 4	6.55	6.55
At Most 5	0.0003	0.0003
Model-5		
None	179.55***	125.61***
At Most 1	109.87***	95.75***
At Most 2	64.17	69.81
At Most 3	38.63	47.85
At Most 4	19.87	29.79
At Most 5	6.89	15.49
At Most 6	0.02	3.84

Note(s): ***, ** and * refers to significance level at 1, 5 and 10 percent, respectively
Source(s): Authors' own elaboration from software-generated results

Table 4.
Co-integration test results

inverse relationship is one of the core hypotheses of the H-D model and our paper as well. The autocorrelation and residual diagnostics suggest that there is no autocorrelation in the year-to-year residuals and that it is normally distributed.

We extend the H-D model to check whether the relationship remains or not after introducing other known GDP growth indicators. To analyse the effect of sectorial growth on the GDP growth rate, we add the variables – agricultural value-added growth and industrial value-added growth – in the presence of time dummies. From the estimation results, we observe that the coefficient values of savings decreased and ICOR increased (in absolute terms). At this stage, the growth in the value added of the agricultural sector was found to be negative as well as weakly significant (at 10%). This explains that a 1% increase in the growth of agricultural value added has negatively related to the GDP growth rate, but the intensity of this negative impact is trivial. It is evident that the residual is normally distributed, and no autocorrelation is observed.

Next, we estimate the impact of the industrial value-added growth, in the presence of dummy variables, by dropping the agricultural value-added growth. In this model, we find that the coefficient of savings decreases, indicating that a 1% change in savings affects the GDP growth rate by only 0.04%. In this model, the ICOR coefficient is −0.48, which is weakly

Model	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
VAR	Y	Y	Y	Y	Y
GS_G	0.14***	0.14***	0.09***	0.04*	−0.002
	(0.02)	(0.01)	(0.03)	(0.03)	(0.00)
ICOR		−0.77***	−1.11***	−0.48*	−0.65***
		(0.34)	(0.18)	(0.28)	(0.14)
TDUM1 (1990)			1.05***	0.94***	0.90***
			(0.45)	(0.42)	(0.20)
TDUM2 (2008)			−1.64*	−0.72**	0.07
			(1.11)	(1.29)	(0.40)
AGRI_G			−0.07*		0.43***
			(0.10)		(0.06)
IND_G				0.33***	0.30***
				(0.10)	(0.05)
Adj-R^2	0.51	0.92	0.91	0.92	0.99
J-B	1.58	1.96	4.59	0.58	0.12
Q-Stat (AC)	0.55	0.27	0.10	0.09	−0.18

Table 5. DOLS estimation results

Note(s): ***, ** and * show significance at 1, 5 and 10 percent, respectively. Standard errors are in parenthesis. J-B and AC refer to Jarque-Bera and Autocorrelation tests
Source(s): Authors' own elaboration from software-generated results

significant at a 10% level. It is observed that the new explanatory variable is highly significant (at 1%) with a coefficient of 0.33, meaning that a growth of 1% in the industrial sector leads to a growth of 0.33% in the GDP growth of the country in the long run. Finally, the residual regularity and autocorrelation diagnostic test results show no issue of normality and year-to-year autocorrelation.

Finally, we incorporate all the variables to determine the effect of the key variables. The estimated coefficient of savings is insignificant and extremely close to zero. This insignificancy is consistent with the findings of Siraj and Bengali (2007). On the other hand, the coefficient of ICOR (−0.65) is highly significant and maintains the inverse relationship with GDP growth. The effect of agricultural growth in this final model is positive and significant (0.43 at 1% significance level) as opposed to the previous model, in which the use of agricultural growth resulted in negative and merely considerable outcomes. Even though the coefficient of industrial value added in this final model is 0.30, slightly lower than the previous model in which it was 0.33, it is still a strong contributing factor to economic growth. Lastly, model diagnostic tests show no issue with residual normality and autocorrelation.

4.4 Sensitivity analysis

We conduct a sensitivity analysis for checking the robustness of the estimated long-run coefficients of the variables of interest. Table 6 shows the results of the sensitivity analysis, where we use ARDL and fully modified OLS (FMOLS) estimation approaches. From the results, it is evident that coefficients (ICOR) do not portray any significant deviation from the DOLS estimation. However, we observe some ambiguity regarding the significance of the savings rate.

4.5 Causality test results

A Granger causality test was conducted to determine a long-run causality among the variables. The test was run at lag 4, but to assess the strength of the results, we took lag1, lag 2 and lag 3 as well. The results of the test are shown in Table 7.

Model	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
FMOLS					
VAR	Y	Y	Y	Y	Y
GS_G	0.14***	0.05*	0.07**	0.01	−0.06**
	(0.02)	(0.03)	(0.04)	(0.03)	(0.00)
ICOR		−0.40**	−0.40***	−0.62***	−0.85***
		(0.18)	(0.15)	(0.28)	(0.09)
TDUM1 (1990)			1.10**	1.16***	0.18
			(0.53)	(0.33)	(0.20)
TDUM2 (2008)			−0.02	0.96	1.10**
			(0.91)	(0.67)	(0.50)
AGRI_G			−0.05		0.43***
			(0.10)		(0.06)
IND_G				0.46***	0.30***
				(0.10)	(0.05)
Adj-R^2	0.39	0.70	0.70	0.60	0.80
J-B	1.00	3.96	4.59	1.58	2.56
Q-Stat (AC)	5.91**	3.00	0.10	0.09	1.01
ARDL					
GS_G	0.15***	0.23***	0.10***	0.04	−0.06
	(0.02)	(0.02)	(0.03)	(0.03)	(0.00)
ICOR		−0.40***	−1.38***	−0.62***	−0.60**
		(0.18)	(0.26)	(0.25)	(0.26)
TDUM1 (1990)			1.21**	1.06***	0.64*
			(0.51)	(0.37)	(0.20)
TDUM2 (2008)			−2.94**	−1.002	−1.45
			(0.91)	(0.77)	(0.96)
AGRI_G			−0.04		0.20**
			(0.06)		(0.07)
IND_G				0.42***	0.30***
				(0.10)	(0.08)
Adj-R^2	0.58	0.60	0.94	0.96	0.96
J-B	0.63	5.50	0.17	4.01	2.82
Q-Stat (AC)	0.45	0.001	2.47	1.28	0.52

Note(s): ***, ** and * show significance at 1, 5 and 10 percent, respectively. Standard errors are in parenthesis. J-B and AC refer to Jarque-Bera and autocorrelation tests
Source(s): Authors' own elaboration from software-generated results

Table 6.
Sensitivity analysis

From the table, we can see a bidirectional causality between savings growth and GDP growth since both of the null hypotheses can be rejected at 5%. This supports the hypothesis of the H-D model from the point of view that as the growth rate of savings of a nation rises, so does the GDP growth rate of that nation, keeping all other things constant. However, when a country's GDP increases, it affects savings as income may rise in the process, which subsequently may also boost people's propensity to save given that all other things are constant. We also observed a causality is running from ICOR towards GDP growth only, but not the opposite, in the long run, indicating a change in the ICOR can bring changes in the GDP growth rate, which is consistent with findings of the long-run estimation.

There is also bidirectional causality between industry growth and GDP growth. As Bangladesh is leaning towards industrial development, industry growth will further bring about productivity and increase the GDP. On the other hand, if GDP rises, more and more people will invest in the booming industrial sector to reap profit in the long run. From an agricultural point of view, a rise in the growth rate in the agriculture sector will surely add

Null hypothesis	*F*-statistic
GS_G → Growth	4.98***
Growth → GS_G	3.02**
ICOR → Growth	3.41***
Growth → ICOR	0.63
AGRI_G → Growth	4.92***
Growth → AGRI_G	1.20
IND_G → Growth	5.72***
Growth → IND_G	12.22***

Note(s): ***, ** and * show significance at 1, 5 and 10 percent, respectively
Source(s): Authors' own elaboration from software-generated results

Table 7.
Causality test results

value to the country's GDP growth. However, as mentioned earlier, with the flourishing industrial sector of Bangladesh, the increase in GDP will affect the agricultural sector very insignificantly. The underlying notion of such a causal direction correlates with the argument of Rostow's five stages of development (Rostow, 1959).

4.6 Model diagnostics

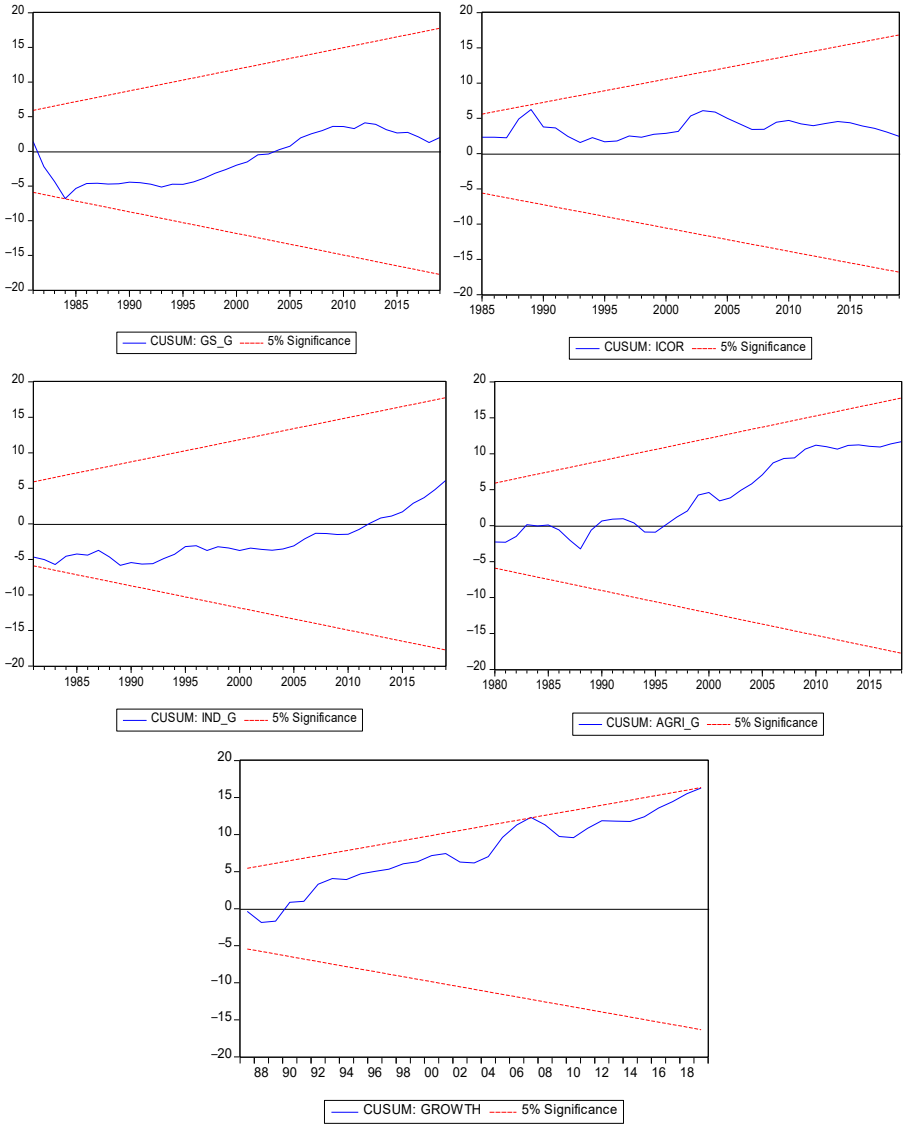
Figure 2 shows the Cumulative Sum (CUSUM) test results of the variables that were used in the analysis. The test result shows that the plots of the variables are in a range of 5% critical value, depicting the stability of the model in terms of both systematic and sudden movements.

5. Discussion

From the empirical analysis, we find that the long-run ICOR and GDP growth rate are negatively related. Long-run results indicate that an increase in ICOR leads to a reduction in GDP growth by 0.75%. Besides, the long-run causality test confirms one-way causality (i.e. ICOR to GDP growth rate). The overall result indicates that achieving capital efficiency (lowering ICOR) can increase long-run economic growth, highlighting the relevance of the H-D model's concept that capital efficiency influences economic growth under the assumption of time-variant variables. On the other hand, the savings-GDP nexus is not validated as the model is extended while relaxing the time-invariant assumption.

The concept of vintage capital utilisation can explain the underlying argument of such an inverse relationship. Díaz and Puch (2016) and Atkeson and Kehoe (1999) argue that capital utilisation in a particular economy follows the vintage structure. It means that over the period, efficiency in capital utilisation depends not only on factor prices and other macro-indicators, but also on other autonomous embodied factors. For instance, the use of both technology and knowledge. Therefore, to increase capital efficiency, it is necessary to scale up the effectiveness of the capital utilised in the production process, translating into higher GDP growth. It is also worth noting that the augmentation of autonomous embodied factors like technology adoption and the enhancement of technical knowledge in the production process can reduce the costs associated with capital utilisation by minimising the intake of several factors, one of which is the level of energy consumption. One might want to argue that fully replacing vintage capital with newer ones can solve this issue. However, the introduction of new capital has various drawbacks like production delay, training of users and new industry setup, etc., leading to negative pressure on GDP growth.

We argue that savings may not always allow economic growth for two broad reasons. First, a distortion in the transmission channel of savings. The H-D model assumes that investment equals savings. However, savings may not be fully translated into an investment



Source(s): Authors' own figure from software-generated results

Figure 2.
CUSUM test results

due to various distortions such as consumer behaviour, investment mechanism, asymmetric information between banking institutes and potential investors, risk of default, etc. Therefore, it is imperative to find out effective channels through which savings could be translated into effective investment. This would eventually lead to enhanced economic activities and increase economic growth. Second, institutional distortions, which arise from certain patterns prevailing in most South Asian economies. Amin *et al.* (2021) argue that the absence of administrative authority within a decentralised system prevents and slows the

formulation of the appropriate regulatory regime and execution framework in South Asian economies. This ultimately hinders the transmission channel of savings through different administrative loopholes (such as bureaucracy and regulatory sluggishness), leading to potential investment loss that could have increased GDP growth. Therefore, introducing regulatory efficacy is recommended for facilitating the saving effect.

Since the ongoing COVID-19 pandemic has affected our country's economy extensively, a scope for analysing this factor can also be considered. Our paper has incorporated the two economic shocks of industrial growth after the 1990s and the 2008 economic recession. In the future, researchers could analyse how the current pandemic situation has affected the economy regarding GDP, saving and investment behaviour and how capital was utilised during this period, etc. Moreover, in our paper, we have introduced the growth trends of agricultural and industrial value added; however, the influence of other variables on the performance of savings and ICOR could also be determined.

Future research might also be conducted based on sector-wise ICOR and saving rates from different income levels in Bangladesh. Another avenue of extension of this paper could be to analyse the impact of capital efficiency on economic growth for a group of Latin American countries.

6. Conclusion

The results of our analysis are relevant to the model's initial hypothesis. We have found that, in the long run, an increase in ICOR can negatively impact the economic growth rate of Bangladesh. On average, an increase in ICOR by a unit can reduce economic growth by 0.75% in the long run. We have also found a bidirectional causality between the growth rate of savings and economic growth, and a unidirectional Granger causality running from ICOR towards economic growth in the long run. Moreover, we have also revealed the insignificant impact of the saving rate on the growth rate when the estimation is carried out in the extended H-D model. Based on our findings, we propose the following explicit policy recommendations for Bangladesh.

Since the lack of statistical significance arises due to the lack of proper channelling of the savings amount in different sectors of the economy, we emphasise the need to strengthen targeted financing schemes currently operating in Bangladesh's banking sector through effective public and private collaboration and regulation. Such development could be effective for channelling savings into productive investments, leading to economic growth.

Another way for Bangladesh to increase its economic growth rate is by increasing its capital efficiency. This could be achieved in many ways. Among others, enhancement of capital productivity can bring efficiency because ICOR is the inverse of capital productivity. As per GED (2019) statistics, capital productivity (ratio) in Bangladesh is 4.54, which is considerably low compared with other neighbouring countries. Therefore, firms should gradually move towards technological advancement, increase economies of scale, etc.

Besides, firms operating for a long time could undergo specific technological changes to expedite productivity. In this way, the efficiency of capital could be gained. Apart from the advances in technology, we argue that offering training to the labour force will improve their efficiency and adaptability to shifting industry dynamics and traditional capital applications. According to BBS (2017) of Bangladesh, low-skilled and high-skilled labour shares are 57.90% and 42.10%, respectively. Therefore, policies in favour of continuous skill development programmes under various ministries focussing on different sectors would be very effective for Bangladesh given that regulatory and institutional legitimacy are ensured. It is worth noting that regulatory legitimacy discusses the structure of standard rules, policies and effectiveness in the process of bureaucracy (Amin *et al.*, 2021).

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