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Physical and Human Capital and Economic Growth in Indonesia: The ARDL Approach

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Abstract

This research paper investigates the relationship between physical and human capital accumulation and economic growth in Indonesia using the Autoregressive Distributed Lag (ARDL) approach. Inspired by Alam's (2023) study on India, the paper seeks to contribute to the understanding of economic dynamics in Southeast Asia, focusing on Indonesia as a significant regional economy. Methodologically, the paper employs the ARDL approach to analyze time series data on GDP, physical capital, and human capital in Indonesia. The data utilized in this research are sourced from Indonesian national statistics agencies and relevant government publications from 2010-2018. GDP, PMTB, and IPM are collected for the specified time period and transformed. The results indicate differing impacts of physical and human capital on GDP, both in the short and long run, underscoring the importance of investment priorities and policy considerations for sustainable economic development.

Keywords: *ARDL, GDP, Human Capital, Physical Capital*

Abstrak

Penelitian ini menyelidiki hubungan antara akumulasi modal fisik dan sumber daya manusia dengan pertumbuhan ekonomi di Indonesia dengan menggunakan pendekatan Autoregressive Distributed Lag (ARDL). Terinspirasi oleh studi Alam (2023) tentang India, penelitian ini berupaya memberikan kontribusi terhadap pemahaman dinamika ekonomi di Asia Tenggara, dengan fokus pada Indonesia sebagai perekonomian regional yang signifikan. Secara metodologis, penelitian ini menggunakan pendekatan ARDL untuk menganalisis data runtun waktu mengenai PDB, modal fisik, dan modal manusia di Indonesia. Data yang digunakan dalam penelitian ini bersumber dari badan statistik nasional Indonesia dan publikasi pemerintah terkait pada tahun 2010-2018. PDB, PMTB, dan IPM dikumpulkan untuk jangka waktu tertentu dan diubah. Hasilnya menunjukkan perbedaan dampak modal fisik dan sumber daya manusia terhadap PDB, baik dalam jangka pendek maupun jangka panjang, yang menggarisbawahi pentingnya prioritas investasi dan pertimbangan kebijakan untuk pembangunan ekonomi berkelanjutan.
Kata Kunci: *ARDL, Modal Fisik, Modal Sumber Daya Manusia, PDB*

INTRODUCTION

Human capital, a concept rooted in the Solow growth model and human capital theory, is widely recognized as a fundamental driver of economic growth and development. The Solow growth model posits that sustained economic growth is driven not only by traditional factors like physical capital accumulation but also by investments in human capital, which encompasses the skills, knowledge, and expertise of a country's workforce. Human capital theory further elucidates this relationship by emphasizing the role of education, training, and healthcare in enhancing human capital formation and, consequently, fostering economic prosperity.

The relationship between human capital accumulation and economic growth has been the subject of extensive empirical research, with studies exploring this dynamic across various countries and regions. One such study, conducted by Alam (2023), delved into the relationship between human capital and economic growth in India, employing the Autoregressive Distributed Lag (ARDL) approach.

This paper aims to replicate Alam's empirical work, albeit with a different dataset focusing on Indonesia. By replicating the study's methodology and adapting it to an Indonesian context, we seek to contribute to the existing literature on human capital and economic growth, particularly within the Southeast Asian region. The choice of Indonesia as the focus of our analysis is driven by its significance as one of the largest economies in the region and its ongoing efforts to promote economic development through investments in human capital.

In this research, we will first review the relevant literature on the relationship between human capital and economic growth, drawing upon theoretical frameworks and empirical findings from previous studies. Following the literature review, we will detail the methodologies employed in both the original study and our replication, highlighting any modifications made to accommodate the Indonesian context. Additionally, we will explain the proxies used for variables, ensuring transparency and comparability with the original study.

Subsequently, we will present the empirical findings of our replication, comparing them with the results obtained by Alam (2023) for India. Through this comparative analysis, this research aims to identify similarities, differences, and potential implications for policy and future research. Finally, we will conclude with a discussion of the implications of our findings and areas for further investigation in the field of human capital and economic growth in Indonesia.

RESEARCH METHODOLOGY

Relevant Literature

The Solow (1956) growth model stands as a foundational framework for understanding long-term economic growth and disparities in income levels among nations. According to this model, economic output (Yt) is determined by factors such as capital stock (Kt), labor force (Nt), and an exogenous productivity measure (At). The model posits a production function with diminishing marginal returns to each factor input but constant returns to scale, assuming perfect competition in input markets. A central implication of the Solow model is the positive relationship between capital accumulation and output per worker, as well as between technological change and output per worker. However, in this framework, sustained increases in output per worker are primarily driven by exogenously determined technological growth, with limited scope for government intervention or policy influence (Solow, 1956).

Expanding upon the Solow framework, Lucas (1988) and Loening (2004) introduced human capital as an independent factor of production in their endogenous growth models. Mankiw et al. (1992) further modified the Solow model to incorporate human capital directly into production functions, emphasizing the importance of adjusting the labor force for qualitative changes over time as individuals accumulate human capital through education, training, and experience.

Endogenous growth theories, including those proposed by Lucas (1988) and Romer (1990), depart from the neoclassical paradigm by positing mechanisms within the model that generate returns to scale, potentially offsetting diminishing marginal returns. These theories suggest that productivity growth may be endogenously determined, with investments in human capital, skills, and technological knowledge driving sustained long-term growth by fostering increasing returns to scale (Arrow, 1962; Romer, 1990).

Empirical studies have provided further insights into the relationship between education, human capital, and economic growth. Lucas (1988) emphasized the crucial role of human capital development in fostering economic growth, while Rebelo (1991) expanded on this concept by integrating physical capital as a complementary input to the accumulation of human capital. Romer (1990) proposed an endogenous growth model where new ideas, emanating from human capital in the form of knowledge, fuel economic growth through their impact on physical capital accumulation. Benhabib & Spiegel (1994) identified human capital development as a significant driver of economic progress.

In the context of empirical evidence, De Meulemeester & Rochat (1995) utilized Granger causality tests to explore the relationship between higher education enrollments and economic growth across several nations, discovering bidirectional causal links in some countries, including France, the United Kingdom, and Japan. Bils & Klenow (2000) and Pradham (2009) found evidence of a significant causal relationship between education and economic growth, with varying directions of causality across different countries and time periods.

Studies focusing on specific regions, such as Abbas (2000) in Pakistan and India, and Haldar & Mallik (2010) examining the influence of education on health investments and GNP per capita, further underscore the importance of human capital for economic development. Additionally, research by Tamura (2006) highlights the adverse correlation between mortality rates and education levels, indicating the potential impact of human capital on demographic outcomes.

Recent investigations by Hanushek (2013) and Zang & Lihuan (2011) underscore the critical role of education in driving long-term economic prosperity, with postsecondary education identified as particularly impactful for economic growth. Furthermore, Diebolt & Hippe (2019) demonstrate the historical significance of regional human capital in explaining contemporary disparities in innovation and economic development.

Methodologies

For this research, the Autoregressive Distributed Lag (ARDL) approach is employed to analyze the relationship between GDP, physical capital (PMTB), and human capital (IPM) in Indonesia. The ARDL methodology is chosen due to its suitability for analyzing both short-and long-run dynamics in a small-sample setting, making it particularly well-suited for the limited time series data available.

Variables and Transformation:

1. Gross Domestic Product (GDP): GDP data is utilized as the primary indicator of economic output, measured in trillion rupiah and converted to natural logarithm for analysis.
2. Physical Capital (PMTB): PMTB, representing investment in capital goods, is used as a proxy for physical capital accumulation. It is measured in trillion rupiah and transformed into natural logarithm for consistency with GDP.
3. Human Capital (IPM): IPM, capturing various dimensions of human development, including health, education, and living standards, is employed as a measure of human capital. IPM is transformed into natural logarithm to facilitate analysis.

Methodological Approach:

In contrast to Alam (2023), who employed a comprehensive set of tests including the Augmented Dickey-Fuller (ADF) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, Zivot-Andrew Unit Root Test, and Toda-Yamamoto Test of Causality, this study focuses solely on the ARDL approach. The decision to solely use ARDL is due to resource constraints and the limited availability of data. The ARDL approach is considered appropriate for capturing both short- and long-run relationships among variables, thus providing valuable insights into the dynamics between GDP, physical capital, and human capital in Indonesia.

Data Limitations:

It is important to acknowledge the limitations of the data in this study. The time period covered by the dataset is relatively short, spanning only 8 years (2010-2018) for the PMTB variable. This short time span may limit the robustness of the analysis and the ability to draw definitive conclusions. Additionally, the conversion of GDP, PMTB, and IPM to natural logarithms aims to stabilize the variance and linearize the relationships, yet it may not fully capture the underlying dynamics of the variables.

Data Source:

The data utilized in this research are sourced from Indonesian national statistics agencies and relevant government publications. GDP data at constant 2011 national prices, PMTB, and IPM are collected for the specified time period and transformed as described above.

RESULT AND DISCUSSION

Stationary Tests

```
Dickey-Fuller test for unit root                   Number of obs   =         8

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.415            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0105

. dfuller dgdp

Dickey-Fuller test for unit root                   Number of obs   =         7

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.952            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.3082

. dfuller dpmtb

Dickey-Fuller test for unit root                   Number of obs   =         7

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.299            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1723

. dfuller dipm

Dickey-Fuller test for unit root                   Number of obs   =         7

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.537            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1068
```

The interpretations of the Dickey-Fuller test results for each variable:

1. gdp:
   - Test Statistic (Z(t)): -3.415
   - Critical Values: The critical values at 1%, 5%, and 10% significance levels are -3.750, -3.000, and -2.630, respectively.
   - MacKinnon approximate p-value: 0.0105 Interpretation: Since the test statistic (-3.415) is less than the critical value at the 1% significance level (-3.750), we reject the null hypothesis of a unit root. This suggests that the GDP variable is stationary at the 1% significance level.
2. dgdp (first difference of GDP):
   - Test Statistic (Z(t)): -1.952
   - Critical Values: The critical values at 1%, 5%, and 10% significance levels are -3.750, -3.000, and -2.630, respectively.
   - MacKinnon approximate p-value: 0.3082 Interpretation: The test statistic (-1.952) is greater than the critical value at the 1% significance level (-3.750). Therefore, we

fail to reject the null hypothesis of a unit root. This suggests that the first difference of GDP variable is non-stationary.

3. dpmtb (physical capital):
   - Test Statistic (Z(t)): -2.299
   - Critical Values: The critical values at 1%, 5%, and 10% significance levels are -3.750, -3.000, and -2.630, respectively.
   - MacKinnon approximate p-value: 0.1723 Interpretation: The test statistic (-2.299) is greater than the critical value at the 1% significance level (-3.750). Therefore, we fail to reject the null hypothesis of a unit root. This suggests that the physical capital variable is non-stationary.
4. dipm (human capital):
   - Test Statistic (Z(t)): -2.537
   - Critical Values: The critical values at 1%, 5%, and 10% significance levels are -3.750, -3.000, and -2.630, respectively.
   - MacKinnon approximate p-value: 0.1068 Interpretation: The test statistic (-2.537) is greater than the critical value at the 1% significance level (-3.750). Therefore, we fail to reject the null hypothesis of a unit root. This suggests that the human capital variable is non-stationary.

Based on the Dickey-Fuller test results, it appears that only the GDP variable is stationary, while the first differences of the other variables (dgdp, dpmtb, and dipm) are non-stationary. This suggests that differencing may be necessary to achieve stationarity in these variables for time series analysis.

Regression Results, Interpretation and Discussion

Here is the regression without derivation first:

```
ARDL(1,0,0) regression

Sample:       2011 -      2018                 Number of obs     =          8
                                               R-squared         =     0.8944
                                               Adj R-squared     =     0.8153
Log likelihood =  41.045241                    Root MSE          =     0.0020

------------------------------------------------------------------------------
       D.gdp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ADJ          |
         gdp |
         L1. |  -.6195382   .2224471    -2.79   0.050     -1.23715   -.0019261
-------------+----------------------------------------------------------------
LR           |
        pmtb |   .0896757   .0492856     1.82   0.143    -.0471632    .2265145
         ipm |   4.622001   .4708997     9.82   0.001     3.314574    5.929428
-------------+----------------------------------------------------------------
SR           |
       _cons |   -1.57234   1.011823    -1.55   0.195    -4.381612    1.236933
------------------------------------------------------------------------------

note: estat btest has been superseded by estat ectest
      as the prime procedure to test for a levels relationship.
      (click to run)
 Pesaran/Shin/Smith (2001) ARDL Bounds Test
 H0: no levels relationship                   F =  11.298
                                              t = -2.785

 Critical Values (0.1-0.01), F-statistic, Case 3

       | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]
       |   L_1     L_1  |   L_05    L_05 |   L_025   L_025|   L_01    L_01
 ------+----------------+----------------+----------------+---------------
   k_2 |   3.17    4.14 |   3.79    4.85 |   4.41    5.52 |   5.15    6.36
 accept if F < critical value for I(0) regressors
 reject if F > critical value for I(1) regressors

 Critical Values (0.1-0.01), t-statistic, Case 3

       | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]
       |   L_1     L_1  |   L_05    L_05 |   L_025   L_025|   L_01    L_01
 ------+----------------+----------------+----------------+---------------
   k_2 |  -2.57   -3.21 |  -2.86   -3.53 |  -3.13   -3.80 |  -3.43   -4.10
 accept if t > critical value for I(0) regressors
 reject if t < critical value for I(1) regressors
 |
 k: # of non-deterministic regressors in long-run relationship
 Critical values from Pesaran/Shin/Smith (2001)
```

The ARDL (1,0,0) model's R-squared indicates a strong fit, explaining about 89.44% of the variance in the dependent variable (GDP). In the long run (ADJ), lagged GDP (gdp) has a negative coefficient, suggesting a negative relationship between past and current GDP. However, its significance is marginal (p = 0.050). In the short run (LR), physical capital (pmtb) does not significantly affect GDP, while human capital (ipm) has a highly significant positive impact on GDP. The ARDL Bounds Test indicates the presence of a levels relationship among the variables, suggesting that they are cointegrated.

Coefficients:

1. ADJ (Long-run relationship):
   - gdp (Lagged 1): The coefficient is -0.6195 with a standard error of 0.2224. It suggests that a one-unit increase in lagged GDP is associated with a decrease of approximately 0.6195 units in the current GDP, with a marginal significance (p-value = 0.050).
2. LR (Short-run relationship):
   - pmtb: The coefficient is 0.0897 with a standard error of 0.0493. It implies that a one-unit increase in PMTB is associated with an increase of approximately 0.0897 units in GDP in the short run, but this relationship is not statistically significant (p-value = 0.143).
   - ipm: The coefficient is 4.6220 with a standard error of 0.4709. It indicates that a one-unit increase in IPM is associated with a significant increase of approximately 4.6220 units in GDP in the short run (p-value < 0.001).

   Constant:
   - _cons: The constant term is -1.5723 with a standard error of 1.0118. It suggests the value of GDP when all independent variables are zero. However, it's not statistically significant at conventional levels (p-value = 0.195).
3. ARDL Bounds Test:
   - F-statistic: 11.298
   - t-statistic: -2.785

The results suggest that while physical capital might not have an immediate impact on GDP, human capital plays a significant role in driving short-term economic growth in Indonesia. However, it's essential to consider the marginal significance of lagged GDP in the long run and the non-significance of the constant term in the short run.

Here is the first derivatives regression:

```
ARDL(1,1,0) regression

Sample:       2012 -      2018                  Number of obs     =          7
                                                R-squared         =     0.8326
                                                Adj R-squared     =     0.4979
Log likelihood =  38.468802                     Root MSE          =     0.0019

------------------------------------------------------------------------------
      D.dgdp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ADJ          |
        dgdp |
         L1. |  -1.164956    .467161    -2.49   0.130    -3.174988    .8450756
-------------+----------------------------------------------------------------
LR           |
       dpmtb |   .1406892   .0278196     5.06   0.037     .0209914    .2603871
        dipm |  -1.679881   1.980293    -0.85   0.486    -10.20039    6.840634
-------------+----------------------------------------------------------------
SR           |
       dpmtb |
         D1. |  -.0808232   .0534979    -1.51   0.270    -.3110059    .1493595
             |
       _cons |   .0608877   .0348015     1.75   0.222    -.0888509    .2106263
------------------------------------------------------------------------------

note: estat btest has been superseded by estat ectest
      as the prime procedure to test for a levels relationship.
      (click to run)

Pesaran/Shin/Smith (2001) ARDL Bounds Test
H0: no levels relationship               F =   2.797
                                         t =  -2.494

Critical Values (0.1-0.01), F-statistic, Case 3

      | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]
      |   L_1     L_1  |  L_05    L_05  | L_025   L_025  |  L_01    L_01
------+----------------+----------------+----------------+---------------
  k_2 |   3.17    4.14 |   3.79    4.85 |   4.41    5.52 |   5.15    6.36
accept if F < critical value for I(0) regressors
reject if F > critical value for I(1) regressors

Critical Values (0.1-0.01), t-statistic, Case 3

      | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]
      |   L_1     L_1  |  L_05    L_05  | L_025   L_025  |  L_01    L_01
------+----------------+----------------+----------------+---------------
  k_2 |  -2.57   -3.21 |  -2.86   -3.53 |  -3.13   -3.80 |  -3.43   -4.10
accept if t > critical value for I(0) regressors
reject if t < critical value for I(1) regressors

k: # of non-deterministic regressors in long-run relationship
Critical values from Pesaran/Shin/Smith (2001)
```

This ARDL(1,1,0) regression model aims to analyze the relationship between GDP (dependent variable) and two independent variables: dpmtb and dipm, which represent physical capital and human capital, respectively.

1. Model Fit:
   - R-squared: 0.8326
   - Adjusted R-squared: 0.4979 These statistics indicate that the model explains approximately 83.26% of the variance in GDP, though the adjusted R-squared suggests that when considering the number of predictors in the model, the explanatory power decreases to 49.79%.
2. Coefficients:

- For the ADJ section (autoregressive distributed lag), the coefficient for the lagged dependent variable (dgdp at lag 1) is -1.164956. However, it is not statistically significant at conventional levels (p-value > 0.05).
- For the LR section (long-run), the coefficient for dpmtb (which represents physical capital) is 0.1406892 with a p-value of 0.037, indicating statistical significance at the 5% level. This suggests that a one-unit increase in physical capital leads to an increase in GDP.
- The coefficient for dipm (representing human capital) is -1.679881 with a p-value of 0.486, indicating it is not statistically significant at conventional levels.

3. Short-Run Dynamics:
   - In the short-run (SR section), the coefficient for the first difference of dpmtb is -0.0808232, indicating that an increase in physical capital in the previous period leads to a slight decrease in GDP in the current period. However, this coefficient is not statistically significant (p-value > 0.05).
4. Error Correction Term (ECT):
   - The constant term (_cons) in the SR section represents the error correction term (ECT). Its coefficient is 0.0608877, but it is not statistically significant (p-value > 0.05). The ECT captures the speed at which the system corrects for deviations from the long-run equilibrium relationship between the variables.
5. Pesaran/Shin/Smith Bounds Test:
   - This test is used to determine the presence of a long-run relationship between the variables. The test statistic (F = 2.797) is compared to critical values to decide whether to accept or reject the null hypothesis of no levels relationship. In this case, the F-statistic is smaller than the critical value, indicating that we fail to reject the null hypothesis.

The results suggest that physical capital (dpmtb) has a statistically significant positive relationship with GDP, at least in the long run, while human capital (dipm) does not show a statistically significant relationship.

Discussion

The difference in results between the ARDL (1,0,0) and ARDL (1,1,0) models can be attributed to the inclusion of the first difference of the physical capital variable (dpmtb) in the latter model. In the ARDL (1,0,0) model, human capital appears to have a significant positive impact on GDP in the short run, while physical capital does not. This implies that investments in human capital may lead to immediate economic growth. Conversely, in the

ARDL (1,1,0) model, physical capital shows a statistically significant positive relationship with GDP, while human capital does not exhibit a significant relationship. This suggests that investments in physical capital may have a more pronounced impact on GDP, at least in the long run. The discrepancy in results could also be due to the different specifications of the models and the nature of the data used.

The differences in the results obtained from the ARDL approach applied to datasets from India and Indonesia can be attributed to several factors, including structural, institutional, and policy differences between the two countries. India and Indonesia have different economic structures and levels of development. India is characterized by a more diversified economy with a significant services sector, while Indonesia's economy is more reliant on natural resources and manufacturing. The stage of economic development also varies between the two countries, with India being at a different stage of development compared to Indonesia. These differences can influence the relative importance of factors such as physical capital accumulation and human capital development in driving economic growth.

Differences in government policies and investment priorities can shape the patterns of physical and human capital accumulation in each country. For example, Indonesia may have different policies regarding infrastructure development, education, and healthcare compared to India, which can affect the magnitude and significance of the relationships between these variables and GDP. Variations in investment levels and efficiency in physical and human capital formation can also contribute to differences in the results obtained from the ARDL analysis.

Discrepancies in the quality and availability of data between India and Indonesia may also influence the results. Differences in data collection methods, accuracy, and coverage can affect the estimation of coefficients and the statistical significance of relationships in the ARDL model.

Institutional factors, including governance quality, regulatory environments, and institutional frameworks, can vary between India and Indonesia and influence the effectiveness of policies aimed at promoting physical and human capital accumulation. Differences in the efficiency of public institutions, investment climate, and ease of doing business can impact the translation of investments in physical and human capital into economic growth outcomes.

Cultural and social factors unique to each country can also play a role in shaping economic dynamics and influencing the relationships between physical and human capital accumulation and GDP growth.

Although our finding has potential to be true which means falsify the theoretical background, our finding can also be false because we use the index to measure the human capital, not money value as the measure like we implemented for GDP and the physical capital. Further correction can be made by other academical agents.

CONCLUSION

The results indicate differing impacts of physical and human capital on GDP, both in the short and long run, underscoring the importance of investment priorities and policy considerations for sustainable economic development. Suggestion for investment priority is considering sustained long-term growth requires substantial investments in physical capital to enhance productivity and competitiveness. Suggestion for policymaking is prioritizing policies that promote both physical and human capital development in Indonesia. Further research are warranted to explore the interactions between physical and human capital dynamics and their implications for Indonesia's economic trajectory.

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