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An Engle-Granger and Johansen Cointegration Approach in Testing the Validity of Fisher Hypothesis in the Philippines

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Abstract

This study contributes to the existing literature and tries to analyze the validity of the Fisher hypothesis in the Philippines. Using monthly data from January 1995 to December 2020, the empirical analysis used the Engle-Granger and Johansen cointegration testing technique. The correlation coefficient suggests a strong positive association. All things being equal, a rise in inflation leads to a rise in the nominal interest rate. The unit-root tests show that inflation and the nominal interest rate are both stationary. Based on both Engle-Granger and cointegrating regression Durbin-Watson tests, the nominal interest rate and inflation are cointegrated. Likewise, the results from Johansen cointegration indicate that there exists a long-run relationship between the variables. However, we rejected a one-to-one relationship between nominal interest rate and inflation. The error correction term coefficient (ECM) shows that it is statistically significant suggesting that the nominal interest rate adjusts to the inflation rate with a lag. The Pair-wise Granger Causality test reported a bi-directional causal relationship between nominal interest rate and inflation. Inflation targeting has been the monetary policy framework of choice for most central banks. In essence, the conclusions of this study are useful to central banks because they help them better comprehend the long-run equilibrium relationship between the nominal interest rate and inflation.

Keywords: Fischer Hypothesis, Inflation, Interest Rates, Engle-Granger, Johansen Cointegration

JEL Classification Code: C22, E31, E43

1. Introduction

Interest rates and inflation are important macro-economic variables as their behavior has a huge influence on economic growth (Hayat et al., 2021; Dinh, 2020a). Better knowledge about the link between interest rates and inflation is crucial for efficient and timely economic decisions specific to monetary policy. American economist Irvin Fisher proposed that nominal interest rates behave positively with inflation in the long run. Fisher (1930), tested this relationship for the UK and the USA and found strong correlations running from the changes in inflation to the changes in nominal interest rates. It appears that in the long run, the Fisher effect is more obvious (Crowder, 1995; Crowder & Hoffman, 1996; Panopoulou & Pantelidis, 2015), simply because interest rates are highly random in the short run hence, they have no significance in predicting inflation. At the macroeconomic level, interest rates affect savings and investment spending, which may interrupt economic growth. Thus, it is important for government policymakers to have a better understanding of what drives interest rates (Ito, 2009, 2016). As interest rates are important determinants of savings and investment spending, and therefore crucial to economic growth, the Fisher hypothesis has important policy implications for the behavior of interest rates and the efficiency of financial markets (Yaya, 2015).

Inflation targeting brings sanity to the financial market (Taderera et al., 2021; Kumar et al., 2020). Monetary authorities can allow inflation, while the interest rate can

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be used as a monetary policy tool to achieve the targeted inflation level that will positively impact economic growth. An important element for the successful conduct of monetary policy is the ability to manage inflation. For instance, it is crucial that inflation expectations are well anchored, as this allows central banks to achieve price stability while helping at reducing interest rates volatility (Ehrmann, 2015; Davis, 2014). Currently, the Bangko Sentral ng Pilipinas (BSP) and most central banks have espoused inflation targeting as their monetary policy framework. Under this framework, the Fisher hypothesis is of essence because interest rates can be used to target and control inflation uncertainties. Inflation targeting enhances BSP's monetary policy credibility because it promotes transparency, accountability, and a good communication strategy (Guinigundo, 2016). In this paper, we applied the Engle-Granger (1987) and Johansen (1991) cointegration approach to test the true dynamics of nominal interest rate and inflation under the Fisher hypothesis framework. It is applied for a lower middle-income country like the Philippines with monthly data on the nominal interest rate measured in terms of the 91-day treasury bill rate and headline inflation ranging from January 1995 to 2020.

2. Literature Review

2.1. Early Empirical Studies

Fama (1975) argued that the nominal interest rate is the best possible predictor of inflation and claims the validity of the Fisher effect in the United States. Employing ADF and Philips-Perron tests, Rose (1988) claimed the nonstationary of US ex-post real interest rate, which contradicts the assumption of constant expected real interest rate intrinsic in the Fisher hypothesis. Mishkin (1992) applied Engle and Granger (1987) cointegration procedure and emphasized that the nominal interest rate and the inflation have cointegration properties and that the long-run Fisher effect exists. Modeling inflation by a Markov regime-switching process, Evans and Lewis (1995) argued that the rational expectation of rare shifts in the inflation process could have led to a significant downward bias in the estimate of the long-run Fisher effect. Crowder and Hoffman (1996) considered the tax-adjusted Fisher equation in Johansen (1988) cointegration framework claiming that the estimated Fisher effect follows the theoretically projected value.

2.2. Studies from Developed and Developing Countries

Existing literature has thus affirmed the Fisher effect portrayed by various works from developed and developing countries. Payne and Ewing (1997) evaluated the Fisher effect for nine developing countries. The Johansen and Juselius cointegration approach confirmed a long-run relationship for Sri Lanka, Malaysia, Singapore, and Pakistan, while there was no evidence of a Fisher effect for Argentina, Fiji, India, Niger, and Thailand. A study by Berument and Jelassi (2002) on 26 developed and developing countries where they run a panel cointegration analysis concluded the validity of the Fisher Hypothesis. Using long- and short-term interest rates to test the Fisher hypothesis for 14 OECD countries Panapoulou (2005) concluded that there is a strong relationship between the variables. The work of Ersan (2008) focused on G-5 countries and Turkey. His findings supported the Fisher hypothesis. Ahmad (2010) tested the presence of the Fisher effect for 8 Asian countries. His findings supported the Fisher hypothesis. Toyoshima and Hamori (2011) tested the long-term Fisher effect by panel cointegration for the United States, Great Britain, and Japan, and showed that there is a strong connection between interest rates and inflation rates. Badillo et al. (2011) verified the Fisher hypothesis for a panel of 15 EU countries. Results showed that ignoring the cross-sectional dependence generated by global stochastic trends could erroneously infer that there is a full Fisher effect. However, when explicitly introducing the common factors in the Fisher equation, the slope parameter on inflation is significantly lower than unity, which implies the existence of a partial Fisher effect. Jareno and Tolentino (2013) found a positive and significant relationship between variations in the current expected inflation rate and variations in the nominal interest rates for the whole of Europe. The Fisher effect covered Germany, Spain, and Finland. İncekara et al. (2012) validated the long-run Fisher effect between the first quarter of 1989 and fourth quarter of 2011 for the Turkish economy.

Zainal et al. (2014) explained the effectiveness of the Fisher effect on the Malaysian money market between 2000 to 2012. The estimation results show that there is long-run co-integration between inflation rate, 3-months treasury bills rate, and interbank rate. Overall, the Fisher effect exists in Malaysia. Panapoulou and Pantelidis (2015) observed interest rates and inflation for 19 OECD countries. It was evident that when employing simulated critical values, 17 out of 19 OECD countries provide support to the existence of a long-run Fisher effect where interest rates move one for one with inflation. Yaya (2015) validated the Fisher hypothesis by employing the bounds test to cointegration. The full Fisher effect was evident in Kenya. A partial Fisher effect or a positive but less than one-for-one responsiveness of nominal interest rates to changes in inflation rates in Cote d'Ivoire and Gabon was found.

Employing Gregory and Hansen's co-integration between inflation rate and nominal interest rates, Uyaebo et al. (2016) obtained a 0.08 Fisher coefficient in the cointegrating relation implying a weak form for Nigeria during the period 1970–2014. He (2018) validated the existence of the Fisher effect in China and South Korea. Specifically, the Fisher effect in South Korea is more evident than that of in China. Gocer and Ongan (2020) approached the Fisher effect from the nonlinear ARDL model for the UK. The empirical findings indicate that long-run partial Fisher effects are valid for the UK only in the period of 1995M1–2008M9 and not for the period of 2008M10–2018M1. Also, higher degree partial Fisher effects are detected in longer maturity UK interest rates. This means that while increases in inflation rates raise the nominal interest rates, decreases have no effect in the short run.

2.3. Some Selected Studies Nullifying the Fisher Effect

Olekalns (1996) for instance, used data from 1964 to 1993, rejected the Fisher hypothesis. Hawtrey (1997) also tested for the Fisher effect in Australia for the period 1969–1994 using the Johansen methodology. He found that the Fisher effect fails prior to the financial deregulation in the 1980s. Hasan (1999) revealed the failure of interest rates as a hedge against inflation as a predictor of inflation from 1957–1991. In addition, Ghazalli and Ramlee (2003) used an autoregressive fractionally integrated moving averages model (ARFIMA) to test for the Fisher effect in G7 countries. Using data from 1974–1996 the study revealed that interest rates in the G7 countries were not linked to inflation in the long run. Further evidence on the rejection of the Fisher effect was provided by Coppock and Poitras (2000) using bounded influence estimations. It was found out that interest rates failed to adjust to inflation due to variations in implicit liquidity premiums on financial assets.

3. Methodology

According to the Fisher hypothesis the relationship among real interest rate (RINTR), nominal interest rate (NINTR) and inflation (INFL) can be stated as RINTR = NINTR – INFL, rearranging gives NINTR = RINTR + INFL. Since the nominal rate of interest is the sum of the real rate of interest and inflation, it follows that increases in inflation will increase the nominal interest rate, while the real rate of interest will remain unchanged. In fact, there is a one-for-one adjustment of the nominal interest rate to changes in inflation. This study examines the validity of the Fisher hypothesis by employing cointegration techniques such as Engle-Granger (1987) approach. The Engle-Granger approach involves two steps: first, a static regression model is computed, then an auxiliary time-series dynamic regression is run to test whether the residuals from the static regression are stationary or not as follows:

$$\text{NINTR}_t = \alpha + \beta\ \text{INFL}_t\ u_t \tag{1}$$

where α and β as parameter estimates and u are the residual term. In equation (1), NITR_t and INFL_t are co-integrated if they have the same order and u_t is stationary. On the other hand, Johansen (1991) and Johansen and Juselius (1990) have constructed a maximum likelihood approach for estimating α and β, as well as a likelihood ratio (LR) test for detecting the number of significant cointegrating vectors (r). There are two statistics from the Johansen vector autoregressive tests that determine the rank of the cointegration space, the LR test based on the maximum eigenvalue ($\lambda_{\max}$) and the LR test based on the trace statistic. The procedure is based on a vector autoregression (VAR) (Dinh, 2020b; Nguyen & Do, 2020; Yuliadi, 2020) of order p developed by Johansen (1991; 1995):

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bz_t + \varepsilon_t \tag{2}$$

where y_t is a vector of non-stationary $I(1)$ variables (nominal interest rate and inflation), z_t is a vector of deterministic variables and ε_t is a vector of innovations. The VAR may therefore be reformulated as:

$$\Delta y_t = \Pi y_{t-1} + \sum\nolimits_{i=1}^{p-1} + \Gamma_i \Delta y_{t-p} + Bz_t + \varepsilon_t \tag{3}$$

where $\Pi = \sum\nolimits_{i=1}^{p} A_{i-1}$ and $\Gamma_i = \sum\nolimits_{j=i+1}^{p} A_j$. Estimates of Γ_i contain information on the short-run adjustments, while estimates of Π contain information on the long-run adjustments, in changes in y_t. The number of linearly dependent cointegrating vectors that exist in the system is referred to as the cointegrating rank of the system. Using cointegration techniques makes sense because Fisher's hypothesis is better interpreted as a long-run equilibrium condition (Österholm, 2009; Junttila, 2001; Granville & Mallick, 2004). The nominal rate of interest and inflation need to be integrated in the same order for the Fisher hypothesis to be empirically relevant. In other words, the existence of cointegration or long-run relationship between inflation and nominal rate of interest rate confirms and supports the Fisher hypothesis in the Philippines.

In addition to testing if the nominal rate of interest and inflation have a cointegrating relation, the cointegration vector (1, 1) (i,e., $\beta = 1$) is checked using the equation (Ito, 2009, 2016; Toyoshima & Hamori, 2011):

$$\text{NINTR}_t = \alpha_t + \beta_t \text{INFL}_t \sum\nolimits_{j=-K}^{K} \delta_t \Delta\text{INFL}_{t-j} + u_t \tag{4}$$

If $\beta = 1$, the nominal interest rate moves one-for-one with the rate of inflation in the long run (i.e., full Fisher effect). If $\beta < 1$, it is known as the partial Fisher effect.

The short-run dynamics of the model can be established within an error correction model. To estimate the Fisher effect, we will use a simple formulation of an error correction model. We can formulate a simple ECM (Nguyen & Do, 2020) as:

$$\Delta \text{NINTR}_t = \omega_0 + \omega_1 \Delta \text{INFL}_t + \Omega u_{t-1} + \upsilon_t \quad (5)$$

$$u_{t-1} = \text{NINTR}_{t-1} - \theta - \delta \text{INFL}_{t-1} \quad (6)$$

Specifically, from the ECM expressed in equation (5), ω_1 captures any immediate, short-term, or contemporaneous effect that INFL has on NINTR. The coefficient δ reflects the long-run equilibrium effect of INFL on NINTR and the absolute value of Ω decides how quickly the equilibrium is restored. We can therefore safely say that ω_1 and Ω are the short-run parameters while δ is the long-run parameter. Lastly, the Granger causality test was used to determine the direction of causality for the variables (Yuliadi, 2020). The monthly data for inflation and interest rates from January 1995 to December 2020 were sourced from the online statistical database of the Bangko Sentral ng Pilipinas (BSP). The inflation series is the headline inflation with 2012 as the base year and the nominal rate of interest is based on the 91-day treasury bill rate (TBILL).

Table 1: Descriptive Statistics

	TBILL	INFL
Mean	5.66	4.56
Maximum	19.10	10.70
Minimum	0.00	–0.40
Std. Dev.	4.27	2.41
Skewness	0.85	0.54
Kurtosis	2.90	2.72
Jarque-Bera	37.94	15.98
Probability	0.00	0.00

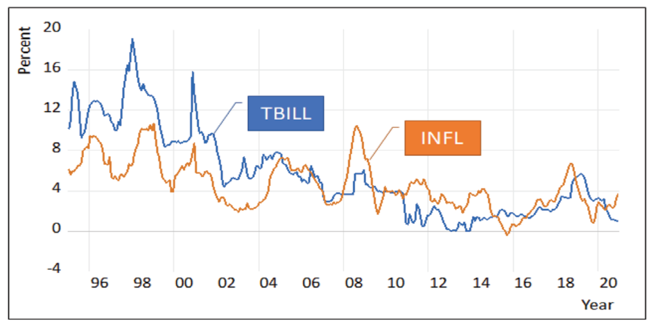

Figure 1: Behavior of 91-Day Treasury Bill Rate and Inflation

4. Results and Discussion

4.1. Descriptive Analysis and Correlation Diagnostics

Table 1 provides the descriptive statistics. The 91-day treasury bill rate and inflation have mean values of 5.66 percent and 4.56 percent, respectively. The highest value was recorded at 4.72 percent for the 91-day treasury bill rate. The highest inflation was recorded in January 1999 at 10.70 percent while the lowest rate was at –0.40 percent in September 2015. Obviously, the 91-day treasury bill rate shows more variations as depicted by the value of its standard deviation at 4.27, compared with more stable inflation with a standard deviation of 2.41. Besides, the skewness of inflation is 0.54 and the kurtosis is 2.72. The Jarque-Bera statistics reject the null hypothesis of normality at a 1 percent significant level. Figure 1 shows the trend of the 91-day treasury bill rate and inflation from January 1995 to December 2020.

The degree of association between the 91-day treasury bill rate and inflation was calculated and further supported by the scatter diagrams and box plots as shown in Figure 1. The corresponding correlation pattern indicates some form of positive linear association between the 91-day treasury bill rate and inflation. The correlation coefficient of 0.70 suggests a strong positive association. It is expected that increases in inflation will lead to increases in the 91-day treasury bill rate. All things being equal, a rise in the inflation rate will eventually cause a rise in the 91-day treasury bill rate. Similarly, a fall in the inflation rate will eventually cause a fall in the 91-day treasury bill rate. Mishkin (1992) noted that the presence of a long-run Fisher effect suggests that when inflation and interest rates exhibit trends (see Figure 1), these two time-series will move together and, thus, there will be a strong association. Thus, a Fisher effect seems strong in the Philippines from January 1995 to December 2020 (Figure 2).

4.2. Long-Run Equilibrium Condition

The ADF, ADF-GLS, and PP tests were run with an intercept and a time trend to improve their power and size. The results of applying these tests are reported in Table 2. The ADF, GLS-DF, and PP tests show that the 90-day treasury bill rate and inflation do not have unit roots or are stationary at both the level and first difference. This indicates that the variables have the same order of integration, that is $I(0)$ and $I(1)$.

We estimated equation (1) where we regressed the 91-day treasury bill rate on inflation and obtained the results in Table 3. The *t*-statistic for inflation is 17.16 with a 0.00 probability value. We say that inflation is statistically significant at the 1 percent level. The *R*-squared value suggests that about 49 percent of the variation in the average 91-day treasury bill rate is explained by inflation. The *F*-statistic of 294.50 is highly significant, as the computed probability value is 0.00.

The conventional Engle-Granger (1987) test results of bivariate cointegration between the 91-day treasury bill rate and inflation are presented in Table 4. The Engle-Granger 1 percent critical value is –3.98. Since the computed *t*-statistic of –4.37 is much more negative, we conclude that the residuals from the regression of TBILL on INFL are *I*(0), that is, they are stationary. Thus, the coefficient of 1.24 in Table 3 represents the long-run coefficient. In other words, the cointegration between the 91-day treasury bill and inflation implies a long-run Fisher effect or stationary linear combination. Likewise, as indicated by the computed cointegrating regression Durbin-Watson value of 2.02, the 91-day treasury bill rate and inflation are cointegrated, thus reinforcing the findings based on the Engle-Granger test.

According to Table 5, the 91-day treasury bill rate and inflation are cointegrated. The trace statistic and maximum eigenvalue statistic indicate 2 cointegrating equations. Both tests reject the null hypothesis of no cointegration at the 1% level of significance. The cointegration results suggest that there is a long-run dynamic equilibrium between the 91-day treasury bill rate and inflation, and the bivariate system keeps returning to this equilibrium regardless of disturbances.

There is strong evidence that the nominal interest rates and inflation are cointegrated and the path of adjustment to the long-term equilibrium must be one-for-one. Following Johansen and Juselius (1990), the normalized cointegrating vectors can be constructed from Table 6 as follows: TBILL = 1.45 INFL**.** In the long run, a 1 percent increase in inflation will lead to a 1.45 percent increase in the 91–day treasury bill rate. This estimate appears encouraging, as it is not very far from the most traditional interpretation of the Fisher hypothesis which suggests the cointegrating vector $\beta' = (1 -1)$. Restrictions are imposed on cointegrating vectors to test whether the 91-day treasury bill rate, increases one-for-one with inflation. The null hypothesis of $\beta = 1$ can be

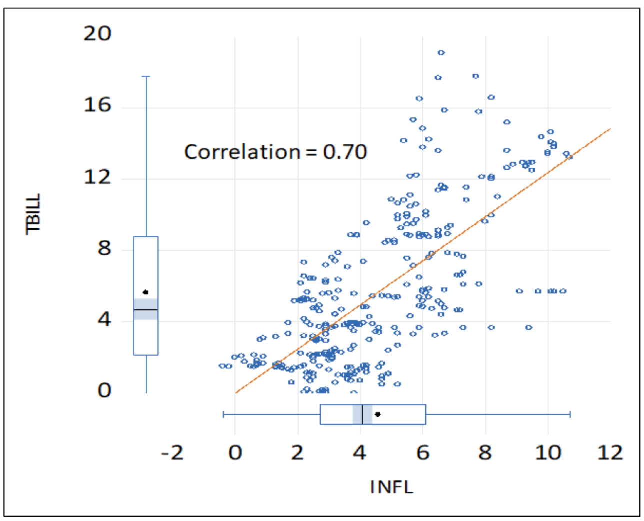

Figure 2: Correlation, Scatter Diagram, and Box Plots

Table 3: Regression Results

Variables	Coefficient	*t*-statistic	Prob.
C	0.01	0.02	0.98
INFL	1.24	17.16	0.00
R-squared	0.49	*F*-statistic	294.50
Durbin-Watson	0.08	Prob.	0.00

Table 4: Cointegration Test: Engle-Granger Approach

	Durbin-Watson	ADF (RESID)	
		t-statistic	Prob.
TBILL = *f*(INFL)	2.02	–4.37***	0.00

Note: ***denotes significance at the 1%.

Table 2: Unit Root Test Results

Variables	Augmented Dickey-Fuller (ADF)		GLSDickey-Fuller (GLS-DF)		Phillips-Perron (PP)	
	Trend and Intercept		Trend and Intercept		Trend and Intercept	
	Level	First Difference	Level	First Difference	Level	First Difference
INFL	–4.53***	–8.58***	–4.41***	–11.18***	–3.83**	–11.83***
TBILL	–3.37*	–14.16***	–3.24**	–8.34**	–3.15*	–12.91***

Note: ***, **, * denotes significance at the 1%, 5% and 10% level.

Table 5: Cointegration Test: Johansen Approach

Hypothesized No. of CE(s)	Trace Test			Maximum Eigenvalue Test		
	Statistic	0.05 Critical Value	Prob.	Statistic	0.05 Critical Value	Prob.
	TBILL = *f*(INFL)					
None*	17.67	12.32	0.00	13.57	11.22	0.02
At most 1	4.10	4.13	0.05	4.10	4.13	0.05

Note: Trace test and max-eigenvalue test indicate 1 cointegrating equation at 0.01 level. *denotes significance at 5%.

Table 6: Normalized Cointegrating Vector and Imposed Restrictions

	β	Ho: β =1	Ho: β = 0
(TBILL) = *f*(INFL)	–1.45	10.92 (0.00)***	294.50 (0.00)***
Error Correction	Coefficient	*t*-statistic	Prob.
ECM(–1)	–0.9218	–10.6435	0.00

Note: *** denotes significance at the 1% level.

rejected, providing no evidence of the long-run full one-for-one Fisher effect in the case of the Philippines covering the period of January 1995–December 2020.

Also, by estimating equation (5), we have the ECM result presented in Table 6. The probability value of the error correction term shows that it is statistically significant at a 1% level, thus suggesting that the 90-day treasury bill rate adjusts to changes in inflation with a lag. We, therefore, infer that about 92.18 percent of the disequilibrium between long-term and short-term nominal interest rates is corrected each month. If the 90-day treasury bill rate is one percentage point above (or below) the inflation, then the 90-day treasury bill rate will start falling (or rising) by about 0.9218 percentage points on average the following month.

Having ascertained that a cointegrating relationship exists between the 91-day treasury bill rate and inflation, the final step is to verify if inflation Granger causes nominal interest. The results of the Pair-wise Granger Causality test are reported in Table 7. With 3 lags at a 10% level of significance, the test suggests that causality runs from inflation to the 91-day treasury bill rate as posed by Fisher Hypothesis. Likewise, we see that the 91-day treasury bill rate causes inflation at a 1% significance level. These findings point to a bi-directional causal relationship which means that in the long run, there is no need to impose strict control on both variables (Hayat et al., 2021).

Table 7: Pairwise Granger Causality Test

Null Hypothesis	Lag	*F*-Statistic	Prob.	Decision
INFL does not Granger Cause TBILL	3	2.21	0.08	Reject
TBILL does not Granger Cause INFL	3	9.74	0.00	Reject

5. Conclusion

This paper analyzes the validity of the Fisher hypothesis in the Philippines employing the Engle-Granger and Johansen cointegration approach using monthly data from January 1995 to December 2020. The correlation coefficient suggests a strong positive association. Likewise, regression estimates convey a significant positive effect of inflation on the 91-day treasury bill rate. The outcomes of the Engle-Granger and Johansen cointegration tests provide evidence in support of the long-run Fisher hypothesis, that is, there exists a long-run positive and significant equilibrium relationship between nominal interest rate and inflation in the Philippines. However, results show the absence of a long-run one-for-one Fisher effect. The estimated short-run dynamics of the model suggested that about 92.18 percent of the disequilibrium is corrected each month by changes in nominal interest rate. The Pairwise Granger causality test has demonstrated the bidirectional causal relationship between the 91-day treasury bill rate and the rate of inflation. Thus, we can conclude that the predictability of the nominal interest rate relies on the variations of the inflation rate. Based on the above conclusions, policies that aim to stabilize the general price level and maintains interest rates at a reasonable level must be encouraged for the Philippine economy's balanced and sustainable economic growth and development.

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