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Towards Greater Efficiency: Estimating the Philippines' Total Factor Productivity Growth and its Determinants

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Abstract

**Towards Greater Efficiency:
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This article presents an estimate of TFP growth from 1989 to 2023 covering the pandemic period and a model on the determinants of TFP growth over the short run and long run using an error correction model. Expansion in domestic economic output, partly offset by worsening terms of trade, contributed to the increase in TFP growth in 2022 to 2023, albeit still below pre-pandemic trends. Moving forwards, acceleration in human capital development, particularly education , healthcare, and social work activities, could help improve overall productivity as well as enhance the country's productive capacity, bringing the economy to a higher economic growth path.

JEL classification	:	C32, O47
Key words	:	Total factor productivity, Philippines, error correction model

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I. Introduction

Along with the factors of production, an important driver of economic growth is total factor productivity (TFP). Typically interpreted as a measure of overall productivity or efficiency, TFP is the portion of output growth that is not attributed to the accumulation of capital and labor. At the same time, the additional output gained from increasing capital and labor would eventually diminish. Thus, an increase in TFP growth could help enhance the country's productive capacity and thrust the economy to a higher economic growth path. Examining the recent trends in TFP growth and the key factors driving productivity gains are essential in the development of policies toward robust and sustainable economic growth.

Given the importance of productivity measures, estimates of TFP growth are among the range of indicators monitored by the Bangko Sentral ng Pilipinas as part of its overall macroeconomic assessment and policy analysis. The Department of Economic Research uses the growth accounting method as applied to the Cobb-Douglas production function in estimating TFP growth (Cororaton 2002; D'Auria et al. 2010; Glindro and Amodia 2015). Meanwhile, the long-term trends of TFP growth and labor are extracted using the one-sided Hodrick-Prescott filter and Beveridge-Nelson filter. While the growth accounting method provides a theoretically consistent estimate of TFP growth, this methodology is not sufficient to analyze the factors driving the movements in TFP growth.[1]

The main contribution of this study is to provide an estimate of TFP growth from 1989 to 2022 including the pandemic period, and to develop a model on the determinants of TFP growth. The short-run and long-run drivers of TFP growth are empirically investigated using an error correction (ECM) model, complementing the growth accounting methodology used in estimating TFP growth. The estimates incorporated the National Accounts of the Philippines as of Q4 2022 and labor data based on December 2022 Labor Force Survey from the Philippine Statistics Authority (PSA).

Results of the estimation indicate improvement in TFP growth in 2022 following its decline during the height of the COVID-19 pandemic. The rise in TFP growth is in line with the observed higher efficiency of capital utilization during the year. Although still below pre-pandemic trends, TFP growth increased in 2022 owing largely to strong economic output partly offset by worsening terms of trade amid the peso depreciation. Moving forward, sustained domestic economic growth and labor market improvements could help increase the country's overall productivity and productive capacity. Investment in human capital development particularly education, healthcare, and social work activities, and acceleration in infrastructure spending could likewise contribute to improved efficiency.

The rest of this article is organized as follows. Section II presents a review of literature on the role of productivity in the economic growth of different countries as well as previous TFP growth estimates in the Philippines. The potential drivers of TFP growth along with common estimation methods are extensively explained in this section. Section III discusses the estimates of TFP growth as of Q4 2022. A summary of the data and methodology used is presented in Section IV followed by

[1] The criticisms of the growth accounting method are summarized as Box Article 1 in Glindro and Amodia (2015) based on Bosworth and Collins (2003).

an analysis of short-run and long-run determinants of TFP growth in the next section. The final section concludes.

II. Review of Related Literature

TFP growth plays a key role in accelerating growth in many countries

In many countries, productivity growth is found to be a more important driver of economic growth than the accumulation of factors of production. Using a standard growth accounting framework in a sample of 25 countries, Eichengreen at al. (2012) found that the slowdown in TFP growth explained around 85 percent of the economic growth slowdown of the countries studied. As the contribution of TFP growth largely exceeded the contribution of capital and labor accumulation, the authors posited that economic growth slowdowns are largely influenced by slowdowns in productivity growth. Similarly, the slower economic growth noted for middle-income countries in the period 1975 to 2014 reflected largely the decline in TFP growth while capital and labor growth had less impact (Kim and Park 2017). In the same study, an increase in TFP growth was observed for country groups transitioning to a higher income group, e.g., from lower-middle income to upper-middle income.

Productivity growth had minimal impact on boosting economic growth in the Philippines in the past but shows improvement

However, the Philippines among other emerging and developing economies had a different case where capital accumulation had a greater contribution than productivity growth. Kim et al. (2010) concluded after analyzing productivity in 53 countries that developing economies were behind developed economies in terms of technical efficiency (i.e., the utilization of existing technologies). In the Philippines, capital stock growth accounted for about 75 percent of the average growth for the period 1960 to 1996 while productivity had a negative contribution (Austria 1998). Nonetheless, the estimated share of TFP to output growth turned positive in the 1990s and continued to rise in the early part of the 2000s (Cham and Canlas 2008). This finding is broadly consistent with the results of Park (2010) showing that some Asian economies[2] transitioned from input-driven growth toward productivity-based growth in 2000. Moreover, a more recent study by Glindro and Amodia (2015) suggested that the share of TFP growth to potential output growth in the country rose from less than five percent in the period 1989 to 1992 to around 40 percent starting 2002 until Q1 2016, broadly at par with the contribution of capital stock during the said period.[3] Given the role of productivity in economic growth and the historical trends observed, the next question directs to what factors could drive the increase in TFP growth.

Human capital as well as research and development promote innovation and are needed to transition to a modernized economy

Several studies have tried to understand the dynamics of TFP over time, specifically the drivers of TFP growth. These drivers are seen to improve TFP at a gradual pace as the pathways through which the positive impact stemming from these factors

[2] This holds both for newly industrialized economies (Hong Kong, Korea, Singapore, and Taiwan) and developing economies (Indonesia, Malaysia, Thailand, India, Pakistan, Vietnam) in Asia.
[3] The percent share of TFP growth in potential output growth is derived from Table 1 of Glindro and Amodia (2015), p. 9.

takes time to materialize and be fully absorbed by the economy. Take, for instance, human capital as well as research and development (R&D), which are noted to be among the main drivers of TFP growth across several economies as these intangibles are said to promote innovation (Kim and Park 2017). The idea of accumulating human capital through education and technological advancement through R&D as drivers of productivity and long-run growth had been in the literature since the mid-1980s (Kim and Loayza 2019). This is motivated by the endogenous growth theory that states that investment in human and physical capital as well as the production of knowledge through research supports that growth process (Crafts 1995). Hence, investment in R&D coupled with the development of human capital are needed to transition to a modernized economy with highly skilled and well-educated professionals.

Macroeconomic stability attracts more investments and fosters a healthy business environment

Apart from the two factors highlighted above, macroeconomic stability is also a key consideration in improving the productivity and performance of workers and firms in a country. Having strong institutions and ensuring stable economic conditions attract more investments to the country and are conducive to promoting a healthy business environment. This, in turn, increases economic activity and encourages competition while incentivizing improvements in productivity (World Bank 2018). This is where government can play a significant role in steering the direction of economic growth. One can classify the influence of government on productivity into two groups—the first highlights the positive impact of government spending owing to the beneficial externalities arising from the development of institutions, infrastructures, and interventions to correct market failures while the second group notes how a large government can hinder productivity owing to the inefficiencies and distortions arising from interventions (Loko and Diouf 2009). For instance, the development of infrastructure supports economic activity through increased competitiveness of firms due to lower trade costs derived from the efficient flow of services and goods through high-quality infrastructure (World Bank 2018). In contrast, government consumption can introduce distortions, through taxation and expenditure programs but does not have an offsetting stimulus to investments, savings, and growth (Barro 1991).

A well-functioning financial system and economic openness also contribute to improving productivity

Extending the discussion on a conducive business environment, a well-functioning financial system and economic openness also contribute to improving productivity. The former allocates capital more efficiently and, in turn, supports the development of the real sector while the latter can benefit from knowledge spillovers and technology diffusion which can enhance productivity. To have a well-developed financial system is to have reduced frictions—such as costs of acquiring information, enforcing contracts, and making transactions—that impede economic activity (Demirguc-Kunt and Levine 2008). For instance, the presence of a large and liquid stock market encourages sharing of information, allocating capital, monitoring of firm behavior, managing of risks, mobilizing of savings, and reducing transaction costs (Estrada et al. 2010). Meanwhile, openness can pertain to either trade or financial integration. Openness to trade can generate economies of scale and productivity gains, especially if the country diversifies its expo2rt basket towards sophisticated products while foreign direct investments (FDI) is said to provide a channel for transferring technology and introducing innovations and good business practices. However, the impact of FDI on productivity is dependent on other factors, such as the country's absorptive capacity as well as the type of sector that receives the inflow (Loko and Diouf 2009). In addition, Wang (2009) found evidence that FDI inflows to the manufacturing sector had a more significant positive effect on economic growth relative to other nonmanufacturing sectors. Hence, increasing the share of high-productivity sectors, such as manufacturing, can also promote more efficient use of resources.

As stated by Romer (1994), making use of all the available evidence, and moving past the standard neoclassical prescription, one can progress toward a better understanding of the determinants of long-run economic growth and provide more insightful policies towards this goal. Hence, it is to this end that the authors explore the determinants of TFP growth in the country using all available information at the time of the study to provide insights that could support evidence-based policy decisions.

Previous studies use panel regression to analyze the key drivers of TFP growth

To establish the relationships discussed in the previous section, several studies have implemented various methods, depending on the available data. Given that some of the relevant variables have limited information—such as research and development, human capital indicators, and competitiveness, to name a few—most studies employ a panel regression model. This type of model would address the data gaps of certain indicators for an individual country. In addition, the analysis may even be brought down to a firm-level perspective if data permits (see Demir et al. 2022; Kailthya and Kambhampti 2022).

Policymakers, however, may be more inclined to understand the drivers of TFP that are specific to their jurisdictions. While it is useful to understand the underlying dynamics of TFP determinants across multiple countries, the magnitude and significance of the relationship may vary per country. Hence, to have a better gauge of the key factors that may require more focus in terms of policy action, having an analysis at the individual country level has its advantages. With the plethora of evidence-based research, countries have become more proactive in terms of collecting relevant economic data. In addition, one can use proxies for certain variables that are expected to have a high correlation with the target series. With a longer reference period, time series models can be implemented to establish the historical relationship of variables for a specific country.

ARDL and ECM models are common time series models that can estimate both the short- and long-run relationship between macroeconomic indicators and TFP

Among the list of time series models, studies on TFP usually employ the autoregressive distributed lag (ARDL) model or the error correction model (ECM). Both methods can estimate the short-run and long-run relationship between macroeconomic indicators and TFP. The latter can be derived from the former model through a simple linear transformation—i.e., the ARDL model can be represented and reparametrized to have an equivalent error correction form (Pesaran and Shin 1998).

In estimating the existence of a long-run relationship across variables, two possible cointegration techniques can be employed. The first approach involves cases in which all the underlying variables are integrated of order one while the second approach provides more flexibility by allowing the underlying regressors to be either $I(0)$ or $I(1)$ (Pesaran et al. 2001). The first approach includes the residual-based tests of Engle and Granger (1987) and Phillips and Ouliaris (1990) and the Johansen (1995) system-based reduced rank regression approach for testing cointegration. However, later studies (Pesaran and Shin 1998; Pesaran et al. 2001) have shown that these tests are sensitive to the stationarity of the data and sample size, usually requiring identical orders of integration. This, in turn, requires pretesting for the presence of a unit root in each of the variables under consideration, which can be subject to misclassification, particularly since unit root tests are known to suffer size and power problems in many cases of interest (Perron and Ng 1996).

The second approach developed by Pesaran and Shin (1998) and Pesaran et al. (2001) avoids the pretesting problem and yields consistent estimates of the long-run coefficients that are asymptotically normal irrespective of the order of integration of the regressors. The ARDL approach has gained considerable importance in recent empirical literature because of its various econometric advantages over other methods of cointegration analysis. An advantage of the ARDL approach is that it assumes only a single reduced-form equation relationship exists between the dependent and independent variables, mitigating contemporaneous causation which may cause biased estimates (Nkoro and Uko 2016; Malik et al. 2021). This works when all or some of the variables are $I(0)$, $I(1)$, or even mutually cointegrated. The ECM can then be derived from the ARDL model through a simple linear transformation, which integrates short-run adjustments with long-run equilibrium without losing long-run information. The associated ECM chooses the optimal number of lags of the dependent variable (p) and independent variables ($q_1, \ldots, q_9$) to capture the data-generating process within a general-to-specific modelling framework. Furthermore, estimates from the ARDL model are seen to be robust and consistent under most finite sample settings, with critical values for sample sizes ranging from 30 to 80 provided by Narayan (2005).

In the Philippines, previous studies generally focus on estimating TFP using different approaches, including growth accounting (Cororaton 2002) or the input-output table (Rodriguez et al. 2013). Those studies that aim to identify the determinants of TFP mainly employ panel regression for regional and firm-level data (see Teruel and Dumagan 2013; Catacutan 2022) or simple regression analysis for macro variables (see Llanto 2012). The former focuses on specific sectors, such as agriculture and manufacturing while the latter provides an estimate for the whole economy. However, as of writing, studies that try to establish both long-run and short-run dynamics of TFP and macro variables for the Philippines remain limited. It is to this end that this study attempts to add value to this pool of knowledge.

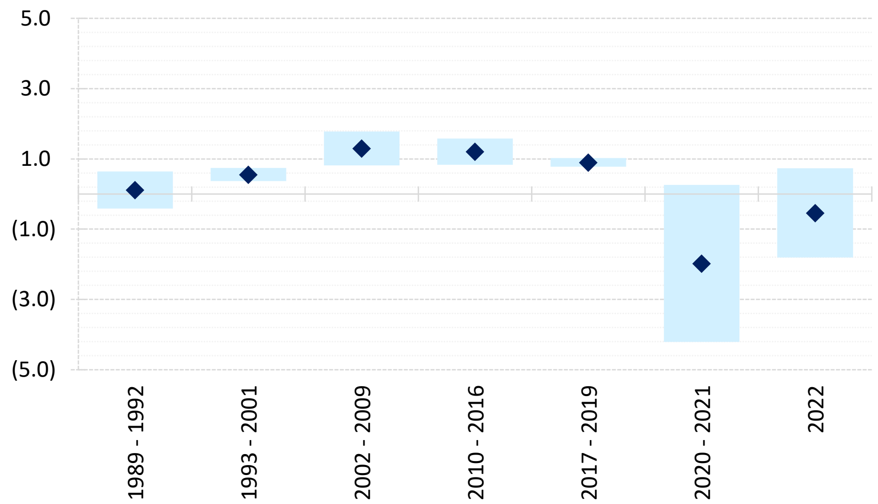
III. Estimates of TFP growth and ICOR

Productivity declined amid the limited operational capacity of firms during the pandemic

Productivity growth improved steadily since 1989 but exhibited a slight decline before the onset of the COVID-19 pandemic in 2020. The implementation of various structural reforms including trade and foreign exchange liberalization, investment and banking reforms, and privatization contributed to productivity improvements from the mid-1980s towards 2000 (Austria 1998; Cororaton 2002). Moreover, there was an observed increase in the share to total employment of wage and salary workers from 2002 to 2016 as well as a rise in certification rates of Technical Education and Skills Development Authority and productivity of Business Process Outsourcing employees from 2006 to 2012, suggesting higher labor productivity during the said periods (Glindro and Amodia 2015). However, the substantial growth in capital stock in the period 2017 to 2019 was accompanied by slower efficiency gains. Various arguments have been proposed to explain the slower productivity growth seen across countries before the global health crisis in 2020. For instance, the lack of innovations and skills to adopt digital technologies in organizations and businesses along with the structural shift from manufacturing to services could have contributed to productivity slowdown during the period (OECD 2021).

At the height of the COVID-19 pandemic in 2020 to 2021, the trend TFP growth in the Philippines declined to around -4.3 to 0.3 percent (Figure 1). The drop in overall productivity reflected the significant decrease in the operational capacity of firms when the government implemented strict community quarantine protocols to curb the spread of COVID-19 cases. These necessary measures resulted in reduced business operations, job losses, and generally shorter work hours in various economic sectors, particularly those with contact-intensive operations.

Figure 1. TFP Growth (in %, stylized per sub-period from 1989 to 2022)



Source: Authors' estimates
Note: Estimates using one-sided Hodrick-Prescott filter and Beveridge-Nelson filter served as the basis for the approximate range of values of TFP growth (light blue shaded region) while their simple average was used as the basis for the point estimate (dark blue marker).

The decline in TFP growth estimates provides an indication of the extent of economic scarring from the pandemic and the possible depth of long-term economic damage from lost productivity. Estimates by the National Economic and Development Authority (NEDA) point to a PHP4.5-trillion productivity loss in human capital investment and returns in the next 40 years due to premature deaths, sickness, inability to access medical treatment, and additional healthcare costs. Meanwhile, the impact on future wages and productivity of school closure in 2020 over the next 40 years of the students' lifetimes in the labor force was approximately PHP11 trillion (NEDA 2021). Furthermore, Ulep (2021) estimates that the long-run productivity losses due to the direct and indirect health impact of the COVID-19 pandemic are roughly PHP2.3 million. This estimate includes the effect of the reduced access to essential healthcare services in the country due to mobility restrictions, overburdened health facilities, lower income, and widespread fear of getting infected by the coronavirus.

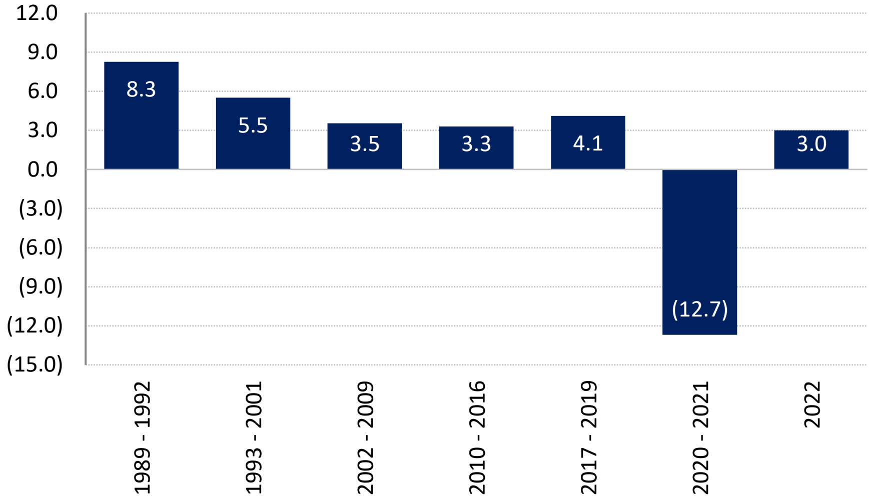
Nonetheless, there were observed improvements in estimated TFP growth amid the easing of mobility restrictions, continued normalization of business operations, and resumption of face-to-face classes. Improvements in the industry and services sectors pointed to the strong momentum of economic recovery. The industry and services sectors expanded by 6.5 percent and 9.2 percent in 2022, respectively, a turnaround from their average contraction of 2.3 percent and 1.9 percent in the period 2020 to 2021. At the same time, labor market conditions continued to improve along with the full reopening of the economy. The unemployment rate declined to 4.4 percent in Q4 2022 from 6.8 percent in the same period last year. There were also 6.5 million more employed individuals in December 2022 relative to the pre-pandemic period. In addition, the adoption of digital technologies may have accelerated during the pandemic period to adapt with the hybrid setup in firms and schools but its impact on productivity is yet to be seen. Given the upward trend in the quarterly path of trend TFP growth, the average range of TFP growth recovered to about -1.9 to 0.8 percent in 2022. However, the estimated TFP remains below pre-pandemic values, suggesting the need for more effective policy actions to boost productivity.

Efficiency in capital utilization improves in line with the moderate rise in TFP growth

The incremental capital-output ratio (ICOR) indicates the efficiency in the utilization of additional capital with respect to the output produced. Broadly speaking, lower ICOR implies greater efficiency.

The latest estimates indicate improving efficiency of capital utilization, consistent with the moderate rise in TFP growth. Figure 2 shows the estimated ICOR from 1989 to 2022, computed as the quarterly share of investment to GDP over the annual average growth rate of real GDP. The estimated ICOR was almost halved from 8.3 in the period 1989 to 1992 to about 4.1 in 2017 to 2019, suggesting efficiency gains in the past 30 years. However, ICOR declined to -12.7 in the period 2020 to 2021 given the deep contraction in domestic output during the pandemic. While capital accumulation continued, its slower pace of growth was not enough to offset the decline in labor supply and productivity resulting in output growth contraction. Nonetheless, ICOR improved to 3.0 in 2022, surpassing its pre-pandemic levels, given faster domestic output growth relative to the previous subperiods even with a comparable share of investment to GDP.

Figure 2. ICOR (stylized per subperiod from 1989 to 2022)



Source: Authors' estimates

IV. Data and Methodology

The subsequent analysis makes use of the estimated TFP growth in the previous section as the dependent variable, measured as an index with 2018 as the base year. The independent variables can be classified into three factors: (1) macroeconomic factors, which consist of gross domestic product (GDP), national government expenditure (GOVT), and stock market capitalization (PSE); (2) openness, as measured by terms of trade (TOT) and foreign direct investments in the manufacturing sector (MANUFDI); and (3) labor and capital quality, as proxied by the gross value added in education (EDUC) and human health and social work activities (HEALTH), labor productivity in the manufacturing subsector (MANUEMP), and public construction (CNS). Detailed descriptions of these variables are presented in *Table 1*.

Table 1. Summary of variables included in the regression

Variable	Measurement	Source
Total factor productivity (TFP)	Growth accounting method, computed from real GDP, labor force, and gross fixed capital formation, measured as an index, with 2018=100	Authors' computation
Gross domestic product (GDP)	National income account, in constant 2018 prices	PSA
National government expenditure (GOVT)	Expenditure data from the national government cash operations report, as percentage of nominal GDP	Bureau of the Treasury
Stock market capitalization (PSE)	Philippine Stock Exchange market capitalization, as percentage of annualized nominal GDP	CEIC
Terms of trade (TOT)	Ratio of export price index to import price index	PSA
Foreign direct investment inflows in manufacturing (MANUFDI)	Net incurrence of liabilities in the direct investment account of the BOP for the manufacturing subsector, as percentage of nominal GDP	BSP

Variable	Measurement	Source
Education (EDUC)	Gross value added in education subsector, as percentage of real GDP	PSA
Human health and social work activities (HEALTH)	Gross value added in human health and social work activities, as percentage of real GDP	PSA
Employment in manufacturing (MANUEMP)	Total number of persons employed in the manufacturing subsector, as percentage of the gross value added in manufacturing	PSA
Public construction (CONS)	General government construction component of the gross fixed capital formation, as percentage of real GDP	PSA

Source: Authors' compilation
Notes: All variables are seasonally adjusted using the four-quarter moving average method.

The study estimates an ARDL model to examine both the contemporaneous and lagged relationship between the dependent and independent variables. Given the dependent variable TFP_t and explanatory variables $GDP_t, GOVT_t, PSE_t, TOT_t$, $MANUFDI_t, EDUC_t, HEALTH_t$, $MANUEMP_t$, and CNS_t, the general ARDL$(p, q_1, \dots, q_9)$ is given by:

$$TFP_t = a_0 + \sum_{i=1}^{p} \psi_i TFP_{t-i} + \sum_{l_1=0}^{q_1} \beta_{1,l_1} GDP_{t-l_1} + \sum_{l_2=0}^{q_2} \beta_{2,l_2} GOVT_{t-l_2} + \sum_{l_3=0}^{q_3} \beta_{3,l_3} PSE_{t-l_3} + \sum_{l_4=0}^{q_4} \beta_{4,l_4} TOT_{t-l_4} + \sum_{l_5=0}^{q_5} \beta_{5,l_5} MANUFDI_{t-l_5} + \sum_{l_6=0}^{q_6} \beta_{6,l_6} EDUC_{t-l_6} + \sum_{l_7=0}^{q_7} \beta_{7,l_7} HEALTH_{t-l_7} + \sum_{l_8=0}^{q_8} \beta_{8,l_8} MANUEMP_{t-l_8} \sum_{l_9=0}^{q_9} \beta_{9,l_9} CONS_{t-l_9} + \epsilon_t \quad (1)$$

where ϵ_t are the innovations, a_0 is a constant term, and ψ_i, and $\beta_{1,l_1}, \dots \beta_{9,l_9}$ are the respective coefficients associated with the lags of TFP_t and lags of the other nine regressors.

Following the approach by Pesaran and Shin (1998), the ARDL model in equation (1) is reparametrized into its ECM form in equation (2) to distinguish the short-run dynamics and long-run relationships of the variables.

$$\begin{aligned}\Delta TFP_t = a_0 &+ \sum_{i=1}^{p-1} \psi_i \Delta TFP_{t-i} + \sum_{l_1=0}^{q_1-1} \beta_{1,l_1} \Delta GDP_{t-l_1} + \sum_{l_2=0}^{q_2-1} \beta_{2,l_2} \Delta GOVT_{t-l_2} + \sum_{l_3=0}^{q_3-1} \beta_{3,l_3} \Delta PSE_{t-l_3} \\ &+ \sum_{l_4=0}^{q_4-1} \beta_{4,l_4} \Delta TOT_{t-l_4} + \sum_{l_5=0}^{q_5-1} \beta_{5,l_5} \Delta MANUFDI_{t-l_5} + \sum_{l_6=0}^{q_6-1} \beta_{6,l_6} \Delta EDUC_{t-l_6} \\ &+ \sum_{l_7=0}^{q_7-1} \beta_{7,l_7} \Delta HEALTH_{t-l_7} + \sum_{l_8=0}^{q_8-1} \beta_{8,l_8} \Delta MANUEMP_{t-l_8} \sum_{l_9=0}^{q_9-1} \beta_{9,l_9} \Delta CONS_{t-l_9} \\ &\underbrace{+ \alpha \begin{pmatrix} TFP_{t-1} - \gamma_1 GDP_{t-1} - \gamma_2 GOVT_{t-1} - \gamma_3 PSE_{t-1} - \gamma_4 TOT_{t-1} - \gamma_5 MANUFDI_{t-1} \\ -\gamma_6 EDUC_{t-1} - \gamma_7 HEALTH_{t-1} - \gamma_9 MANUEMP_{t-1} - CONS_{t-1} \end{pmatrix}}_{\text{error correction term}} + \epsilon_t \end{aligned} \quad (2)$$

where

$$\alpha = 1 - \sum_{i=1}^{p} \psi_i \qquad \text{and} \qquad \gamma_j = \sum_{l_j=0}^{q_j} \beta_{j,l_j} \Big/ (1 - \sum_{i=1}^{p} \psi_i)\,, j = 1, \dots, 9$$

The symbol Δ in equation (2) is the difference operator, and the scalar α is the speed of adjustment, which shows how much of the disequilibrium is corrected in each period while $\gamma_1, .., \gamma_9$ represents the long-run coefficients. The selection of optimal lag length $(p, q_1, \dots, q_9)$ is determined using the Schwarz information criterion (SIC). Before regressing the ARDL model, the integration levels of all variables must be checked to ensure that no series is integrated of order 2.

A joint F-bounds test is then performed on the null hypothesis in equation (3) to determine if a cointegrating relationship exists.

$$H_0^F: (\alpha = 0) \cap \left(\bigcap_{j=1}^{9} \sum_{l_j=0}^{q_j} \beta_{j,l_j} = 0 \right) \quad (3)$$

If the analysis indicates that the null hypothesis of no equilibrating relationship is rejected, a final t-bounds test is performed on the single null hypothesis in equation (4) to see if the cointegrating relationship is nonsensical.

$$H_0^t: \alpha = 0 \quad (4)$$

V. Estimated determinants of TFP growth

The estimation process starts by ensuring that no series under consideration is integrated of order 2 or higher. This can be done using the standard augmented Dickey-Fuller (ADF) test. However, previous studies have shown that the ADF test tends to have low power in certain circumstances, particularly for stationary processes with near unit roots (DeJong et al. 1992). Thus, alternative tests developed by Phillips and Perron (PP) and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) were also considered to ensure the consistency of the results. The ADF and PP tests are referred to as unit root tests, which test the null hypothesis that the series has a unit root (equivalently, it tests whether the series is integrated of order 1 or higher). The KPSS test, on the other hand, is a stationarity test, with a null hypothesis that the series is $I(0)$.

The results in *Table 2* present the computed test statistics as well as the corresponding critical values of the ADF, PP, and KPSS tests. The PP test indicates that all the variables are stationary at the one percent level of significance. The ADF test, on the other hand, fails to reject the null hypothesis that $\Delta\log(TFP)$ has a unit root while the KPSS test rejects the null hypothesis that $\Delta\log(MANUEMP)$ is stationary. A separate breakpoint unit root tests based on ADF are performed for $\Delta\log(TFP)$ and $\Delta\log(MANUEMP)$ (*Table* **3**), the results of which indicate that both series are stationary, with breaks identified in 2019Q4 for $\Delta\log(TFP)$ and in 2008Q4 for $\Delta\log(MANUEMP)$.[4] This ensures that the application of an ARDL model will be suitable to proceed with the long-run relationship between the variables under investigation. Figure 3 and Figure 4 plot $\log(TFP)$ $\log(MANUEMP)$, respectively.

Table 2. Unit root tests

Variable	ADF Test		PP Test		KPSS Test	
Δlog(TFP)	(1.53)		(7.39)	***	0.56	
Δlog(GDP)	(3.76)	***	(3.53)	***	0.11	
Δlog(GOVT)	(6.02)	***	(6.11)	***	0.30	
Δlog(PSE)	(4.34)	***	(2.56)	***	0.07	
Δlog(TOT)	(5.92)	***	(6.05)	***	0.26	
Δlog(MANUFDI)	(7.44)	***	(4.67)	***	0.03	
Δlog(EDUC)	(3.35)	***	(5.35)	***	0.25	
Δlog(HEALTH)	(4.22)	***	(4.34)	***	0.17	
Δlog(MANUEMP)	(5.49)	***	(5.27)	***	1.12	***
Δlog(CONS)	(5.57)	***	(5.63)	***	0.09	
Test critical values						
1% level	(3.53)		(3.53)		0.74	
5% level	(2.90)		(2.90)		0.46	
10% level	(2.59)		(2.59)		0.35	

Source: Authors' computation
Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively

[4] Employment in the manufacturing sub-sector saw a substantial decline in 2008, following the slump in global demand due to the Global Financial Crisis (Balisacan et al. 2010), while trend TFP levels started to decline at the onset of the pandemic.

Table 3. Breakpoint unit root tests

	Δlog(TFP)		Δlog(MANUEMP)	
Break period	2019Q4		2008Q4	
ADF test statistic	(4.06)	*	(7.30)	***
Test critical values				
1% level	(4.73)		(4.95)	
5% level	(4.19)		(4.44)	
10% level	(3.86)		(4.19)	

Source: Authors' computation
Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively

Figure 3. Graph of log(TFP)

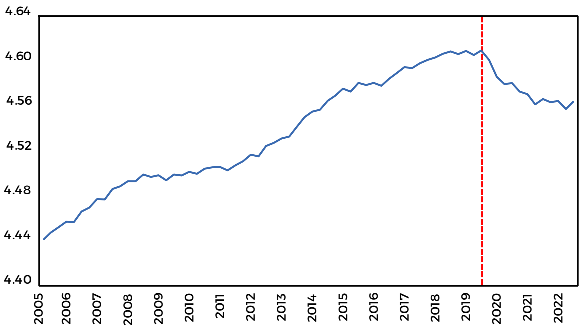
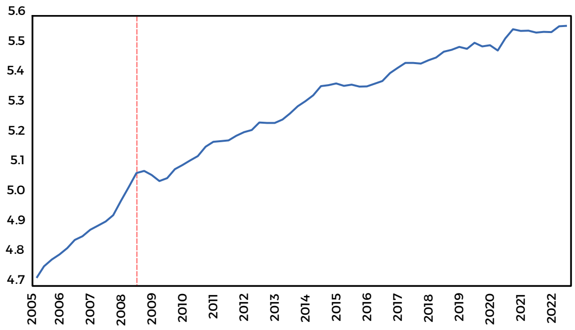


Figure 4. Graph of log(MANUEMP)



Source: Authors' computation

Before carrying out the ARDL model, it is important to include an optimal lag length to select the model with the best fit among the various alternatives. A common approach to this is the use of information criteria, which choose models by trading off model fit against a penalty for model complexity, as measured by the number of parameters estimated in the model (Elliot and Timmerman 2016). Several information criteria have been suggested in the literature, the two most popular of which are the SIC, proposed by Schwarz (1978), and the Akaike information criterion (AIC) from Akaike (1974). For this study, the SIC is chosen since it imposes a larger penalty for every additional regressor included in the equation, thereby selecting a more parsimonious model compared to the AIC (Enders 2015).

The ARDL model in equation (1) is estimated using the standard least squares technique (*Table 4*). The unrestricted constant and no trend case is implemented in the regression, with $\Delta \log(MANUEMP)$ held fixed. Heteroskedasticity and autocorrelation corrected standard errors are used to ensure consistency and efficiency of parameter estimates (Newey and West 1987).

To test for the presence of cointegration, the results of the bounds test are reported in
Table **5**. The F-statistic value 21.04 is evidently greater than the $I(1)$ critical value bound, which indicates that we reject the null hypothesis that there is no equilibrating relationship. Moreover, the t-statistics is |-4.36| = 4.36 and is greater than the absolute value of the $I(0)$ t-bound, which implies that we should reject the t-bounds test null hypothesis of nonsensical cointegrating relationship and conclude that the cointegrating relationship is either of the usual kind or is valid

but degenerate.[5] A further look into the fit between the dependent variable $\log(TFP)$ and the equilibrating equation in

Figure **5** supports the conclusion that the relationship is valid.

Table 4. ARDL model estimate

Variable	Coefficient	Std error	t-stat	
log(TFP)				
Lag 1	0.160	0.09	1.86	*
Lag 2	0.080	0.05	1.51	
Lag 3	(0.140)	0.08	(1.76)	*
Lag 4	0.637	0.08	8.43	***
log(GDP)				
Lag 0	0.275	0.03	7.98	***
Lag 1	(0.186)	0.03	(5.56)	***
log(GOVT)				
Lag 0	(0.063)	0.01	(6.39)	***
log(PSE)				
Lag 0	0.015	0.01	1.41	
Lag 1	(0.021)	0.02	(0.94)	
Lag 2	0.009	0.02	0.37	
Lag 3	0.080	0.02	4.74	***
Lag 4	(0.050)	0.01	(3.88)	***
log(TOT)				
Lag 0	0.076	0.02	3.09	***
Lag 1	0.088	0.03	3.26	***
Lag 2	(0.006)	0.02	(0.24)	
Lag 3	(0.041)	0.02	(1.73)	*
Lag 4	(0.064)	0.03	(2.25)	**
log(MANUFDI)				
Lag 0	0.002	0.00	0.74	
Lag 1	0.009	0.00	2.81	***
log(EDUC)				
Lag 0	0.088	0.02	4.03	***
log(HEALTH)				
Lag 0	0.046	0.03	1.53	
Lag 1	0.046	0.05	1.00	
Lag 2	(0.079)	0.03	(2.51)	**
log(CONS)				
Lag 0	0.006	0.00	2.59	**
Δlog(MANUEMP)				
Lag 0	0.091	0.02	5.38	***
Intercept	(0.512)	0.24	(2.09)	**
R-squared	0.99			
Adj R-squared	0.99			
F-stat	2440.20			
Prob(F-stat)	0.00			
DW stat	2.10			

Source: Authors' computation
Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively

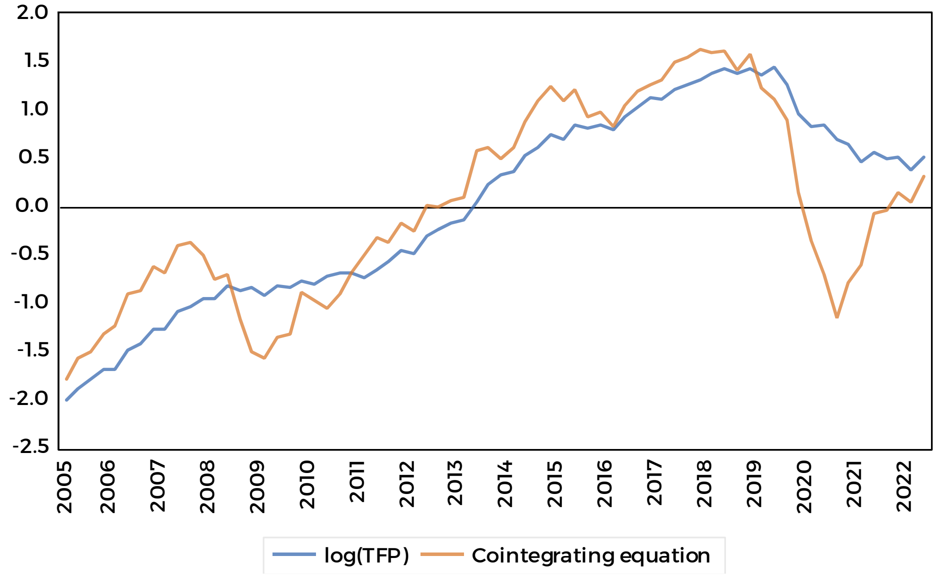
[5] A degenerate cointegrating relationship is generally characterized as having a stable relationship in the short-run, but dissipates in the long-run (Giles 2017; Pesaran et al. 2001)

Table 5. Bounds tests

	F-stat		t-stat	
	21.04	***	(4.36)	***
Pesaran et al. (2001) critical values				
	I(0)	I(1)	I(0)	I(1)
1% level	2.79	4.10	(3.43)	(5.37)
5% level	2.22	3.39	(2.86)	(4.72)
10% level	1.95	3.06	(2.57)	(4.40)

Source: Authors' computation
Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively

Figure 5. Graph of log(TFP) and its equilibrating equation, standardized



Source: Authors' computation

Having established that a cointegrating relationship exists among the variables through the bounds tests, the long-run form of the model is estimated to determine any significant long-run equilibrium relationship. *Table 6* shows the results of long-run estimation, which represents the γ_j's in equation (2). The effects of the determinants of TFP were further examined to know whether the identified regressors have a significant short-run impact on TFP. The estimation of the ψ_i's and the β_{j,l_j}'s in equation (2) are presented in *Table 7*.

Table 6. Long-run relationship

Variable	Coefficient	Std error	t-stat	
log(GDP)	0.339	0.04	8.89	***
log(GOVT)	(0.239)	0.08	(3.17)	***
log(PSE)	0.125	0.03	4.64	***
log(TOT)	0.203	0.10	2.07	**
log(MANUFDI)	0.043	0.01	4.01	***
log(EDUC)	0.333	0.12	2.82	***
log(HEALTH)	0.051	0.05	1.01	
log(CONS)	0.024	0.01	2.72	***

Source: Authors' computation
Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively

Table 7. Short-run dynamics and speed of adjustment

Variable	Coefficient	Std error	t-stat	
Δlog(TFP)				
Lag 1	(0.577)	0.05	(10.68)	***
Lag 2	(0.497)	0.06	(7.66)	***
Lag 3	(0.637)	0.06	(10.83)	***
Δlog(GDP)				
Lag 0	0.275	0.03	10.80	***
Δlog(PSE)				
Lag 0	0.015	0.01	1.71	*
Lag 1	(0.039)	0.01	(2.82)	**
Lag 2	(0.030)	0.01	(2.09)	**
Lag 3	0.050	0.01	5.38	***
Δlog(TOT)				
Lag 0	0.076	0.02	3.76	***
Lag 1	0.111	0.02	4.76	***
Lag 2	0.105	0.02	5.28	***
Lag 3	0.064	0.02	3.47	***
Δlog(MANUFDI)				
Lag 0	0.002	0.00	0.91	
Δlog(HEALTH)				
Lag 0	0.046	0.02	1.92	*
Lag 1	0.079	0.02	3.30	***
Δlog(MANUEMP)				
Lag 0	0.091	0.01	6.83	***
CointEq	(0.263)	0.02	(14.96)	***
Intercept	(0.512)	0.03	(15.01)	***
R-squared	0.93			
Adj R-squared	0.90			
F-stat	38.85			
Prob(F-stat)	0.00			
DW stat	2.10			

Source: Authors' computation
Notes: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively

TFP is positively influenced by improving economic activity and trade openness in the short-run and long-run

The results of the model suggest that TFP is positively influenced by improving economic activity and TOT both in the short and long run. Economic activity, however, has a greater impact on TFP in the long run as indicated by the higher elasticity relative to short-run estimate. In contrast, the effect of improvements in TOT on TFP is greater in the short run as indicated by the higher total value of the short-run coefficients. Nonetheless, these two factors are seen to have the most impact on productivity gains for the Philippines as strong economic activity could encourage competition while trade openness could generate economies of scale, leading to productivity gains.

Education services, stock market development, FDI to manufacturing, and public construction have positive effects on TFP growth over time; Healthcare and social work-related activities as well as the efficiency of the manufacturing sector have a more immediate impact

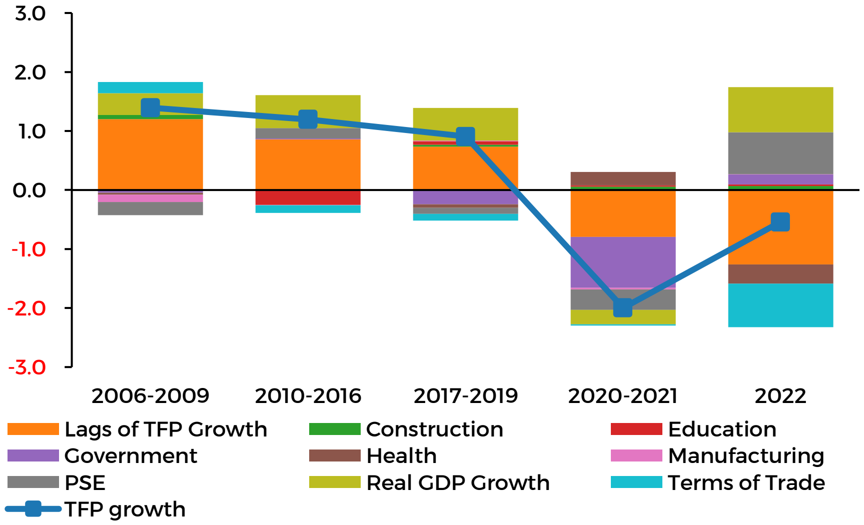
For the other determinants, education services, stock market development, FDI to manufacturing, and public construction have positive effects on TFP growth over time, while healthcare and social work-related activities as well as the efficiency of the manufacturing sector have a more immediate impact. The long-run elasticity of the education variable is the second highest among the long-run indicators. Meanwhile, activities related to health and social work significantly contribute to productivity in the short run. These findings support the claim that investing in human capital development could help advance the quality of labor in the country over the long term. The results also support the finding that a well-developed financial system which could help allocate capital more efficiently along with foreign direct investments to the manufacturing sector could support development in the real sector. The proxy for financial development is based on the stock market, which may be quite volatile in the short run due to investors' reaction on the latest market development. In the long run, there is statistical evidence that a larger stock market relative to GDP does have a positive impact on productivity. Meanwhile, FDI investments to the manufacturing sector do facilitate improvements in long-run productivity while the efficiency of the sector is more important in the short run.

Finally, the ratio of government expenditure to GDP, which is the proxy for government size, provides evidence in favor of the government burden argument as indicated by the negative coefficient. This is in line with other studies that suggest that large government spending can hinder productivity because of inefficiencies and distortions arising from interventions. However, government spending on construction is seen to have a positive long-run impact on TFP growth since said spending contributes to a more conducive economic environment to firms.

As shown in

Figure **6**, TFP growth was weighed heavily by the contraction in real GDP and the drop in stock market capitalization in the period 2020 to 2021. Government spending also rose in 2020 to support the needs of the country and keep it afloat during the lockdowns. Nonetheless, this spending was seen to be transitory in nature and not geared toward improving productivity. In 2022, domestic output growth, stock market capitalization, and government construction spending bounced back, contributing positively to TFP growth. However, the fall in health and social work spending as well as terms of trade amid higher global oil prices and peso depreciation posed a drag on TFP growth during the year. Nonetheless, there has been observed recovery among the long-run determinants of TFP as the economy posted strong growth performance in recent quarters.

Figure 6. Decomposition of average TFP to its determinants, (stylized per subperiod from 2006 to 2022)



Source: Authors' computation

Furthermore, the speed of adjustment, denoted as α in equation (2), is another measure to determine the amount of short-run deviation from the long-run relationship that is corrected each quarter. As expected, the α coefficient, represented in *Table 7* as CointEq, is negative with an associated estimate of -0.263. This implies that about 26.3 percent of any movements into disequilibrium are corrected for within one quarter, ceteris paribus. Moreover, given the large t-statistic, we can also conclude that the coefficient is highly significant.

VI. Conclusion

Given the value of productivity in sustaining and accelerating growth, it is essential to prioritize policy measures that will boost the factors driving TFP growth. The government has put in place a comprehensive plan to achieve social and economic transformation as outlined in the Philippine Development Plan (PDP) 2023-2028. This must be followed through by effective implementation, efficient spending, and impact evaluation to maximize the benefits of government programs on the country's productivity and economic growth.

TFP growth has improved since the height of the COVID-19 pandemic and the prospects point to continued recovery. Estimates using ECM provide empirical evidence that improvements in domestic economic activity and terms of trade could improve productivity over the long run. Strong economic activity could encourage competition, while trade openness could generate economies of scale, leading to productivity gains. Investing in human capital development could help advance the quality of labor in the country over the long term. In addition, a well-developed financial system (proxied by stock market capitalization) which could help allocate capital more efficiently along with FDI to the manufacturing sector could support development in the real sector. Results of the model also suggest that government programs targeted towards creating a more conducive business environment, such as higher infrastructure spending and more efficient government interventions, are seen to have a positive impact on long-run productivity.

Increased investments in human resources and infrastructure amid a stable macro environment could help improve overall productivity

Moving forward, sustained domestic economic growth and labor market improvements could help improve the country's overall productivity. However, there may be a need to catch up due to lost productivity during the pandemic. As part of its medium-term socioeconomic goals, the National Government (NG) targets real GDP to expand by 6.5 to 8.0 percent in 2023 until 2028, and the unemployment rate to reduce to 4.0 to 5.0 percent by 2028.[6] Alongside sustained economic growth, the government aims to push for broader and deeper financial inclusion, accelerate and strengthen financial innovation, and ensure a healthy financial sector to safeguard macroeconomic stability (NEDA 2023).

The implementation of various structural reforms is seen to promote competition and foster a more conducive investment environment. These include the amendments to the Retail Trade Liberalization Act which lowered the capital requirement for foreign retailers (RA 11595). Moreover, the Foreign Investments Act was amended in 2022 to allow full ownership by foreign investors of small and medium enterprises (RA 11647). In the same year, the amendments to the Public Service Act, which allowed full foreign ownership of public services in the country, was enacted (RA 11659). Further legislative agenda in the pipeline such as the National Quality Infrastructure Act as well as amendments to the Export and Industry Development Act aim to promote trade and investments in the country (NEDA 2023). These series of institutional reforms are expected to boost employment, productivity, and economic growth.

Moreover, government programs that will enhance human capital development, particularly education, healthcare, and social work activities could improve the quality of labor and in turn, overall productivity. OECD (2022) proposed investments in (1) enhanced preventive care, (2) mass population programs, (3) sufficient core equipment, (4) well-harnessed health information, (5) sufficient health and long-term care professionals, and (6) medical reserve to promote a more productive workforce and minimize required restrictions in face of future health shocks. Meanwhile, the NG laid out strategies in the PDP 2023-2028 to increase the income-earning ability of the country's labor force, among others. These strategies include focusing on educational qualifications, skills, and competencies, enhancing access to employment opportunities, and improving labor market governance.

Lastly, the NG's planned fiscal consolidation, while allocating 5.0 to 6.0 percent of GDP on infrastructure programs from 2023 to 2028 could support productivity and accelerate economic growth. In particular, the Development Budget Coordination Committee (DBCC) projects the fiscal deficit-to-GDP ratio to decline from 6.1 percent in 2023 to 3.0 percent in 2028, supported by proposed tax revenue measures such as the Passive Income and Financial Intermediary Taxation Act, value-added tax (VAT) on digital service providers, and excise taxes on single-use plastics and pre-mixed alcohol (DBM 2023).

[6] The DBCC, during its meeting on 24 April 2023, revised its GDP growth targets to 6.0 to 7.0 percent for 2023 and 6.5 to 8.0 percent for 2024 to 2028.

References

Akaike, H. 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19(6):716-723

Austria, M. 1998. Productivity growth in the Philippines after the industrial reforms. PIDS Discussion Paper Series No. 98-26. Makati City: Philippine Institute for Development Studies.

Balisacan, A.M., S.F. Piza, D. Mapa, C. Abad Santos, and D.M. Odra. 2010. Social impact of the global financial crisis in the Philippines. Mandaluyong City, Philippines: Asian Development Bank.

Barro, R.J. 1991. Economic growth in a cross section of countries. *The Quarterly Journal of Economics* 106(2):407-443.

Bosworth, B. and S. Collins. 2003. The empirics of growth: an update. *Brookings Paper on Economic Activity* 34(2):113-206.

Catacutan, Z. 2022. Determinants of total factor productivity across Philippine manufacturing firms: a simultaneous quantile regression analysis. *International Journal of Economics, Business and Accounting Research* 6(2):990-1004.

Cham, M. and D. Canlas. 2008. Notes on Philippine economic growth and its sources. *Philippine Review of Economics* 45(1):1-14.

Cororaton, C.B. 2002. Total factor productivity in the Philippines. PIDS Discussion Paper Series No. 2002-01. Makati City: Philippine Institute for Development Studies.

Cororaton, C.B. 2005. Total factor productivity growth in the Philippines: 1960-2000. *Asian Development Review* 22(1):97-113.

Crafts, N.F.R. 1995. Exogenous or endogenous growth? The industrial revolution reconsidered. *The Journal of Economic History* 55(4):745-772.

D'Auria, F., C. Denis, K. Havik, K. McMorrow, C. Planas, R. Raciborski, W. Röger, and A. Rossi. 2010. The production function methodology for calculating potential growth rates and output gaps. European Economy Economic Papers 2008-2015 420. Brussels: Directorate-General for Economic and Financial Affairs, European Commission.

DeJong, D.N., J.C. Nankervis, and C. Whiteman. 1992. The power problems of unit root test in time series with autoregressive errors. *Journal of Econometrics* 53(1-3):323-343.

Demir, F., C. Hu, J. Liu, and H. Shen. 2022. Local corruption, total factor productivity and firm heterogeneity: empirical evidence from Chinese manufacturing firms. *World Development* 151(C).

Demirguc-Kunt, A. and R. Levine. 2008. Finance, financial sector policies, and long-run growth. Policy Research Working Papers 4469. Washington, DC: World Bank.

Department of Budget and Management (DBM). 2023. Review of the medium-term macroeconomic assumptions and fiscal program for FY 2023 to 2028. DBM Press Releases. https://www.dbm.gov.ph/index.php/secretary-s-corner/press-releases/list-of-press-releases/2704-184th-dbcc-meeting-joint-statement (accessed on May 19, 2023).

Eichengreen, B., D. Park, and K. Shin. 2012. When fast-growing economies slow down: international evidence and implications for China. *Asian Economic Papers*, 11(1):42-87

Elliott, G. and A. Timmermann. 2016. *Economic forecasting.* Princeton, NJ: Princeton University Press.

Enders, W. 2015. *Applied econometric time series* (4th ed.). Hoboken, NJ: Wiley.

Engle, R.F. and C.W. Granger. 1987. Co-integration and error correction: representation, estimation, and testing. *Econometrica* 55(2):251-276.

Estrada, G., D. Park, and A. Ramayandi. 2010. Financial Development and Economic Growth in Developing Asia. ADB Economics Working Paper Series No. 233. Mandaluyong City: Asian Development Bank.

Giles, D. 2017. Autoregressive distributed lag (ARDL) estimation. Part 2 - inference. EViews Econometric Analysis Insight Blog: https://blog.eviews.com/2017/05/autoregressive-distributed-lag-ardl_8.html (accessed on May 19, 2023).

Glindro, E.T. and R.A. Amodia. 2015. Decomposing sources of potential growth in the Philippines. *Bangko Sentral Review* 17(1):1-18.

Johansen, S. 1995. *Likelihood-based inference in cointegrated vector autoregressive models.* Oxford: Oxford University Press.

Kailthya, S. and U. Kambhampati. 2022. Road to productivity: effects of roads on total factor productivity in Indian manufacturing. *Journal of Comparative Economics* 50(1):174-195.

Kim, J. and J. Park. 2017. The role of total factor productivity in middle income countries. ADB Economics Working Paper Series No. 527. Mandaluyong City: Asian Development Bank.

Kim, S., D. Park, and J. Park. 2010. Productivity growth across the world, 1991-2003. ADB Economics Working Paper Series No. 212. Mandaluyong City: Asian Development Bank.

Kim, Y.E. and N.V. Loayza. 2019. Productivity growth: patterns and determinants across the world. Policy Research Working Paper 8852. Washington, DC: World Bank.

Llanto, G.M. 2012. Philippine productivity dynamics in the last five decades and determinants of total factor productivity. PIDS Discussion Paper Series No. 2012-11. Makati City: Philippine Institute for Development Studies.

Loko, B. and M.A. Diouf. 2009. Revisiting the determinants of productivity growth: what's new? IMF Working Paper 2009/225. Washington, DC: International Monetary Fund.

Malik, M.A., T. Masood, and M.A. Sheikh. 2021. Econometric analysis of total factor productivity in India. *The Indian Economic Journal* 69(1):88-104.

Narayan, P.K. 2005. The saving and investment nexus for China: evidence from cointegration tests. *Applied Economics* 37(17):1979-1990.

National Economic and Development Authority (NEDA). 2021. COVID-19 Pandemic to cost PHP 41.4 T for the next 40 years. NEDA Media Releases. https://neda.gov.ph/covid-19-pandemic-to-cost-php-41-4-t-for-the-next-40-years-neda/ (accessed on May 19, 2023).

———. 2023. Philippine development plan 2023-2028. Pasig City, Philippines: NEDA.

Newey, W.K. and K.D. West. 1987. A simple, positive semi-definite heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica* 55(3):703-708.

Nkoro, E. and A.K. Uko. 2016. Autoregressive distributed lag (ARDL) cointegration technique: application and interpretation. *Journal of Statistical and Econometric Methods* 5(4):63-91.

Organization for Economic Cooperation and Development (OECD). 2021. Productivity and economic growth. In OECD compendium of productivity indicators 2021. Paris: OECD Publishing.

———. 2022. Investing in health systems to protect society and boost the economy: priority investments and order-of-magnitude cost estimates (abridged version). OECD Policy Responses to Coronavirus (COVID-19). Paris: OECD

Park, J. 2010. Projection of long-term total factor productivity growth for 12 Asian economies. ADB Economics Working Paper Series No. 227. Mandaluyong City: Asian Development Bank.

Perron, P. and S. Ng. 1996. Useful modifications to some unit root tests with dependent errors and their local asymptotic properties. *The Review of Economic Studies* 63(3):435-463.

Pesaran, M. and Y. Shin. 1999. An autoregressive distributed-lag modelling approach to cointegration analysis. In Econometrics and economic theory in the 20th century: the Ragnar Frisch centennial symposium, edited by S. Strøm. Cambridge: Cambridge University Press.

Pesaran, M.H. Y. Shin, and R.J. Smitch. 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* 16(3):289-326.

Phillips, P.C. and S. Ouliaris. 1990. Asymptotic properties of residual based tests for cointegration. *Econometrica,* 58(1):165-193

Republic Act 11595. An act amending the Retail Trade Liberalization Act of 2000. Manila, Philippines: Congress of the Philippines.

Republic Act 11647. An act amending the Foreign Investments Act of 1991. Manila, Philippines: Congress of the Philippines.

Republic Act 11659. An act amending the Public Service Act. Manila, Philippines: Congress of the Philippines.

Rodriguez, U.E., L.S. Cabanilla, and A.J.A. Quilloy. 2013. Estimating total factor productivity growth from the input-output table: an illustration in the poultry sector of the Philippines. *Philippine Journal of Development* 37(2):100-110.

Romer, P.M. 1994. The origins of endogenous growth. *The Journal of Economic Perspectives* 8(1):3-22.

Schwarz, G. 1978. Estimating the dimension of a model. *The Annals of Statistics* 6(2):461-464.

Teruel, R.G. and J.C. Dumagan. 2013. Measuring and explaining total factor productivity (TFP) growth and patterns in agriculture: a regional panel data framework. Productivity Growth in Philippine Agriculture No. 6. Los Baños, Laguna: Southeast Asian Regional Center for Graduate Study and Research in Agriculture.

Ulep, V. 2021. The Multifaceted Health Impacts of the COVID-19 Pandemic. PIDS Discussion Paper Series No. 2021-23. Makati City: Philippine Institute for Development Studies.

Wang, M. 2009. Manufacturing FDI and economic growth: evidence from Asian economies. *Applied Economics* 41(8):991–1002.

World Bank. 2018. *Growth and productivity in the Philippines: winning the future.* Washington, DC: World Bank.

APPENDIX

Residual diagnostics

The goodness of fit of the model estimate, as measured by the adjusted R^2 and Durbin-Watson (DW) test, are satisfactory (*Table A.1*), with the adjusted R^2 indicating that the estimated ECM has a predictive power of 0.90, suggesting that the model explains about 90 percent of the variation in the data. Meanwhile, the value of the DW statistic is found to be at 2.10, implying that the model is free from the autocorrelation problem.

To verify whether the residuals from the ARDL Model are serially uncorrelated, the Breusch-Godfrey Lagrange Multiplier (LM) test is conducted and the results of which are presented in *Table A.1.* Since the null hypothesis is that the residuals are serially uncorrelated, the F-statistic p-value of 0.25 in *Table A.1* indicates that there is no sufficient evidence to reject the null. Therefore, the residuals are serially uncorrelated. Similarly, to test for residual heteroskedasticity, the Breusch-Pagan-Godfrey test is implemented to verify the null hypothesis that the residuals are homoscedastic. The F-statistic p-value of 0.73 in *Table A.1* indicates that there is no sufficient evidence to reject the assumption that the residuals are homoskedastic. Following the results of these tests, the results of model estimates can be considered robust and consistent.

Table A.1. Residual diagnostic tests

	F-stat	p-value
Breusch-Godfrey serial correlation LM test	1.43	0.25
Breusch-Pagan-Godfrey heteroskedasticity test	0.79	0.73

Source: Authors' computation

To test for the stability of the short-run and long-run coefficient estimates of the ARDL model, we use the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) of recursive residuals, computed iteratively from nested sub-samples of the data, which are presented in Figure A1 and Figure A2. The figures indicate that the coefficients of the ECM are stable over the sample period since the plots of both CUSUM and CUSUMSQ statistics remain within the 5 percent critical bounds. Overall, results from Table A.1, Figure 1 and Figure 2 show that the model has desirable statistical and theoretical properties and can be used for policy analysis.

Figure A1. Graph of CUSUM

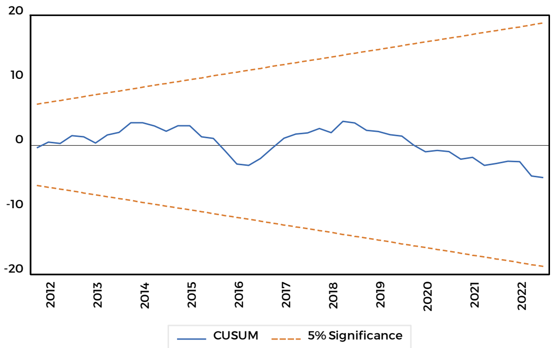
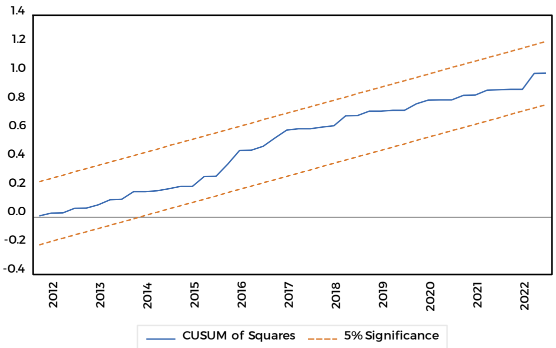


Figure A2. Graph of CUSUMQ



Source: Authors' computation