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Is there a role for Islamic finance and R&D in endogenous growth models in the case of Indonesia?

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ABSTRACT

The validity of growth models is debatable, more so in developing than in developed economies. We contribute to this debate by testing the relevance of semi-endogenous growth models in explaining Indonesia's economic growth transformation. Using historical time series data (1968 to 2018), we test growth models from a unique perspective by examining the roles of the Islamic financial market, the conventional financial system, and structural changes. We show that Indonesia's growth experience is best characterized by a semi-endogenous growth model driven by research activity and access to the financial system, particularly the Islamic financial market. We conclude that while linear models fail to support semi-endogenous growth models, nonlinear models do support them.

JEL Code: O3; O4.
Keywords: *Economic growth*; *Productivity*; *Semi-endogenous growth*; *Indonesia*

I. Introduction

This paper examines whether endogenous growth models can explain the growth story of Indonesia. Indonesia's gross domestic product (GDP) has increased from US$60 billion in 1960 to US$1,037 billion in 2016 (World Bank, 2017). During the same period, per capita GDP also grew impressively, from US$56 to US$3,570 (World Bank, 2017). Figures I and II show real GDP growth and its decadal average, respectively. Figure II shows that Indonesia's average economic growth rate over the 1971–1980 period was 7.4% per annum, followed by 5.1% per annum over the period 1981–1990. A further decline in the annual average growth rate (to 4%) is noted in the subsequent decade. Moreover, during the 1997/98 Asian financial crisis (AFC), Indonesia's growth rate declined severely to negative 13% per annum. Then, just as signs emerged of a post-AFC recovery, economic growth was dented by the Global Financial Crisis (GFC) of 2007/08. During the GFC, Indonesia's growth declined to 4.5%; among the crisis-affected countries, Indonesia's growth rate was considered healthy. This dip in growth due to the GFC was temporary.[1] The economy rebounded to record a 5.3% growth rate in the post-GFC period.

These trends, amidst stabilization and structural policy measures taken by the government and Bank Indonesia, seem to suggest that both exogenous and endogenous factors may be driving Indonesia's economic growth. The rapid growth of the earlier decades, for instance, was accompanied by significant gains in the development of human capital and diversification of the economy away from agriculture to manufacturing (Hofman, Rodrick-Jones, and Thee, 2004). In the 1960–2016 period, the share of agriculture in GDP fell from 51% to 13%. By comparison, the share of manufacturing in GDP increased from 8% to 21%

[1] Learning from the experience of the AFC, Indonesia's financial system improved its resistance to crises. This was evident during the GFC. The Indonesian economy before the GFC was more resilient than before the AFC, with an average growth rate of 5% during the GFC.

(Word Bank, 2017). Similarly, the services sector's share in GDP also increased, from 34% to 45% during the same period.

This data points to Indonesia's structural transformation towards a service sector–oriented economy. However, several issues related to the economy's productivity and sustained growth are not well understood. This is further complicated by the fact that the literature identifies several bottlenecks for economic growth, including the quality of infrastructure, human capital, and education (Juhro, 2016). Motivated by these issues, our aim is to test whether second-generation endogenous growth theories explain Indonesia's growth experience. That is, we aim to examine whether research and development (R&D) or innovations to the financial system (namely, the advent of the Islamic financial market) explain Indonesia's growth.

The neo-classical growth models articulated in Solow (1956) and Swan (1956) show that technological progress is exogenous to economic forces. However, the endogenous growth models of Romer (1986), Lucas (1988), and Grossman and Helpman (1991) show that technological progress is endogenous. Endogenous growth models argue that technological progress results from innovation, trade, competition, and education, among others.[2] Specifically, these models emphasize the role of human capital and R&D as major drivers of growth (see Sedgley, 2006; Madsen, Saxena, and Ang, 2010; Ang and Madsen, 2011). The assumptions that characterize these growth models are constant returns to knowledge and simplicity of new innovations. The main limitation of the earliest endogenous growth models (first-generation endogenous growth models) is that they are inconsistent with the growth experience of several countries (see Jones, 1995; Madsen, 2008).

[2] See also Nadiri and Prucha (1997). Technological progress within a country may spillover from one firm to another leading to a sustained long-run growth (see Sena, 2004).

The failure of first-generation models to explain growth has seen the rise of second-generation endogenous growth models, namely, the semi-endogenous (Jones, 1995; Kortum, 1997; Segerstrom, 1998) and the Schumpeterian growth models (Young, 1994; Aghion and Howitt, 1998; Peretto, 1998; Howitt, 2000). The semi-endogenous growth models relax the assumption of constant returns to knowledge, while Schumpeterian growth models maintain the assumption from first-generation models of constant returns to knowledge but assume increasing complexity of new innovations. These models have increasingly been used to explain the growth experience of industrialised countries (Coe and Helpman, 1995; Zachariadis, 2003, 2004; Kneller and Stevens, 2006; Sedgley, 2006; Ha and Howitt, 2007; Madsen, 2007, 2008). In an appendix (see Table A.1), a summary of existing studies is provided. We observe that despite the popularity of second-generation endogenous growth models, they have rarely been used to explain the growth experience of emerging or developing countries. There are two exceptions though. Madsen, Saxena, and Ang (2010) find that India's growth over the past five decades has been driven by research intensity – a finding consistent with the predictions of the Schumpeterian growth theory. Ang and Madsen (2011) find strong support for the Schumpeterian growth theory but only limited support for the semi-endogenous growth theory. These authors argue that R&D has played a key role in achieving growth in the Asian miracle economies. However, their sample does not include Indonesia.

Our study attempts to explain the growth experience of Indonesia by using endogenous growth models. A unique contribution of our study is that it extends the endogenous growth model to capture the role of the Islamic stock market (in addition to testing the role of the conventional financial market and the banking sector) in facilitating innovation. This is an important contribution to the literature given the growing role of Islamic financial markets. In spite of the rapid growth of Islamic financial markets, there is limited understanding on the impact of these markets on economic growth. Islamic stock markets strictly adhere to the principles of Islam, and thus operate differently from traditional stock markets (Kuran, 1995). Specifically, activity in Islamic stock markets rests on five principles, including a ban on excessive uncertainty (*gharar*), prohibition of interest (*riba*), prohibition of investing in 'unethical' industries (*haram*), interdiction of speculation (*maysir*) risk, and risk–return sharing (Hearn, Piesse, and Strange, 2011; Abbes and Trichilli, 2015). Several recent studies find a role for Islamic finance in Indonesia's development. Rizvi, Narayan, Sakti, and Syarifuddin (2019), for instance, show that Islamic banks have contributed to the stability of Indonesia's banking system. Phan, Narayan, Rahman, and Hutabarat (2019) demonstrate that financial technology firms offer competition to Indonesian banks. These studies and those noted in the footnote imply that Islamic finance is important for Indonesia's financial system and hence, as we argue, for economic growth.[3]

A prosperous Islamic stock market would therefore be an alternative vehicle for funding R&D activity. One of the main policy reforms in Indonesia has been to restructure and position the country as the global hub for the Islamic finance industry (Diela, 2017). The plan is to achieve this goal through the newly formed National Committee for Shariah Finance (Diela, 2017). Act no. 21 of 2008 was enacted to provide a more adequate legal base for development of Islamic banking in Indonesia (Bank Indonesia, 2018). Theory predicts that a well-functioning financial system spurs innovation, industrialisation, and entrepreneurship (Schumpeter, 1912; Grossman and Helpman, 1990). A well-developed financial system facilitates the flow of funds from surplus units (savers) to deficit units (borrowers) (Schumpeter, 1912). Moreover, a well-developed financial market allows proper assessment of risk, return, liquidity, and time–pattern of cash flows associated with new projects (see Levine, 1997; Brown, Fazzari, and Petersen, 2009). Prior studies show a growing Islamic

[3] For a literature on Islamic banking and its performance in the Indonesia context, see Anwar (2016); Anwar and Ali (2018); Aviliani et al. (2015); Ekananda (2017); Hidayati et al. (2017); Ibrahim (2019); Karim et al. (2016); Mulyaningsih et al. (2016); and Purwono and Yasin (2019).

financial market relative to the large conventional financial system (Pepinsky, 2013), and that Islamic finance significantly influences rural households' income (Fianto, Gan, Hu, and Roudaki, 2018), and by extension their investment in education and knowledge creation in Indonesia. Therefore, the recent policies of enhancing Islamic finance would influence innovation activity by providing entrepreneurs access to capital to execute their ideas.

Apart from extending the standard endogenous growth model to capture the role of Islamic financial markets, a contribution of our study is to model structural changes that may have impacted growth paths as can be seen in the Indonesian case. Structural shocks introduce nonlinear behaviour, and our focus, as a result, is on nonlinear approaches to modelling endogenous growth.[4] We are not the first to hypothesize a nonlinear relationship between growth and its determinants. Madsen, Saxena, and Ang (2010) argue that nonlinearity may exist in the total factor production growth function and address this issue by estimating growth models for both pre-reform and full samples of data. Their approach does not explicitly model the underlying nonlinearity or structural changes. We address this issue by using nonlinear cointegration techniques and dummy variables to demarcate structural changes. We show that Indonesia's growth experience is best characterized by the semi-endogenous growth model driven by research activity and growth in the Islamic finance industry. We show that while linear models fail to show support for semi-endogenous growth models, nonlinear models do support them. Our support for semi-endogenous growth models is broadly consistent with Barcenilla-Visús, López-Pueyo, and Sanaú-Villarroya (2014), who find support for semi-endogenous models in Finland, France, Italy, the US, Canada, and Spain for the period 1979–

[4] Several studies show that shocks do introduce nonlinear behaviour in macroeconomic and financial variables (see e.g. Perron, 1989; Stock and Watson, 1996; Bai, Lumsdaine, and Stock, 1998). These studies, therefore, recommend modelling these variables in nonlinear frameworks (Perron, 1989; Stock and Watson, 1996; Bai, Lumsdaine, and Stock, 1998; Lee and Strazicich, 2003; Banerjee and Urga, 2005; Narayan and Popp, 2010; Narayan, Liu, and Westerlund, 2016).

2001, and with Ang and Madsen (2011), who find some support for semi-endogenous models in China, India, Japan, Korea, Singapore, and Taiwan for the period 1953–2006.

Key implications from our results relate to the importance of R&D expenditure and Islamic stock markets for Indonesia. Indonesia is competing with neighbouring emerging markets for exports and investment. Boosting Islamic financial markets will spur total factor productivity (TFP) growth. Our study highlights the importance of R&D for Indonesia. Boosting R&D expenditure will aid economic growth. Policymakers, therefore, need to encourage innovation both in the real economy and the financial sector. Perhaps Indonesia needs a strategic approach to promoting and encouraging innovation at the firm and industry levels. This is something that is not yet part of Indonesia's development plans.

We proceed as follows. Section II presents a simple growth accounting exercise. Section III outlines the specification of the endogenous growth models. Section IV describes the data. Section V presents the results, and finally Section VI sets forth concluding remarks.

II. Motivation for estimating endogenous growth models for Indonesia

This section explains why we estimate an endogenous growth model for Indonesia. For many countries it is not clear whether productivity is contributing to economic growth. Endogenous growth models provide insights on the role of productivity in growth. That to-date Indonesia's endogenous growth path has not been investigated puts into question the relevance of productivity. We provide empirical evidence on this issue through a simple growth accounting exercise.

The neo-classical growth theory on growth accounting as laid out by Solow (1957) holds that economic growth is determined by labour, capital, and technology. The baseline assumption is that technology is exogenous. In functional form, the aggregate production function can be represented by:

$$Y = AK^{\alpha}L^{1-\alpha} \quad (1)$$

or

$$y = Ak^{\alpha} \tag{2}$$

where $y = Y/L$ and $k = K/L$ denote, respectively, output per capita and capital per capita; A is TFP; and α is the share of capital in output.

By taking the natural logarithm and differentiating Equation (2) with respect to time, we get economic growth, g, which is determined by growth in TFP (ΔA) and capital per capita (Δk) over time. That is,

$$\Delta y = \Delta A + \alpha \Delta k \tag{3}$$

The issue here is that output, labour, and capital are observable, but TFP (A) and the share of capital in output (α) are not; in application, these are inferred. From the so-called primal method, we assume that α is the share of capital income in national income (Aghion and Howitt, 2009), and we obtain ΔA by subtracting $\alpha \Delta k$ from Δy:

$$\Delta A = \Delta y - \alpha \Delta k \tag{4}$$

Due to its method of calculation, ΔA is referred to in the literature as the Solow residual (see Aghion and Howitt, 2009).

Using employment (L), real GDP (Y), and 1 minus the share of labour compensation in GDP (α) (i.e. $1 - LABSH = \alpha$) data from PWT 9.0 for the period of 1960–2014, we perform a simple growth accounting exercise for Indonesia. For this sample, we find that mean output per capita growth is 2.75%, mean TFP growth is 1.08%, and mean capital per capita growth is 1.68%.[5] The share (in GDP per capita growth) of capital per capita and TFP growth

[5] Previous studies also estimate TFP growth for Indonesia. Young (1994) estimates TFP growth of 1.2% for the period 1975 to 1980, the World Bank (1993) reports 1.6% for the period 1960 to 1989, and Klenow and Rodriguez-Clare (1997) estimate 1.91% for the period 1960 to 1985. And more recently, Goeltom and Juhro (2013) estimate TFP growth of 1.1% (nearly the same as our estimate, i.e. 1.08%) for the period 1971 to 2010.

is 1.11 and 0.39, respectively.[6] This simple exercise suggests that TFP growth is an important component of economic growth in Indonesia. The immediate question is what is responsible for Indonesia's TFP growth? In theory, several factors could be responsible, including policies on R&D and patent applications, human capital, financial system, and trade openness. Figure III juxtaposes TFP growth with R&D growth for the period 1960 to 2014. The evolution of TFP growth mirrors the patterns of R&D growth. Mean R&D growth is 0.07%, which compares favourably with mean TFP growth of 1.00% over the period 1968 to 2014.

Thus, we seek to understand what factors really matter for TFP growth in Indonesia. In particular, we narrow our inquiry to the financial system (stock markets and the banking sector) including the role of the emerging Islamic stock market and hypothesise that this market is playing an increasing role in the Indonesian TFP growth experience. To get an empirical support for this argument, we run a bi-variate predictive regression model where we regress past (one year) Islamic stock market index returns on Indonesia's R&D. We find a slope coefficient of 0.098 (with a *t*-statistic of 1.734), suggesting that the Islamic stock market has some information content that is useful for the future of R&D, and, hence, TFP. Our analysis builds on the idea that the Islamic stock market could fund R&D activities. Thus, in our framework, financial markets drive TFP growth by generating R&D funding.

III. Specification of endogenous growth models

Section II paved the way to exploring the performance of endogenous growth models using Indonesian data. This section, therefore, outlines the second-generation endogenous growth models used to explain the growth experience of Indonesia; these are the semi-endogenous and Schumpeterian models. The main distinction between these latter models is that, whereas the semi-endogenous growth models relax the assumption of constant returns to knowledge,

[6] Collins, Bosworth, and Rodrik (1996) report the share of TFP in growth in Indonesia as 0.24 for the period 1960 to 1994, while Klenow and Rodriguez-Clare (1997) report 0.49 for the period 1960 to 1985.

Schumpeterian growth models maintain this assumption and assume increasing complexity of new innovations. Following Ha and Howitt (2007) and Madsen (2008), the ideas production function below is used to distinguish among endogenous growth theories:

$$g_A = \frac{\dot{A}}{A} = \lambda \left(\frac{X}{Q}\right)^{\sigma} A^{\phi-1},\ 0 < \sigma \leq 1,\ \phi \leq 1, \tag{5}$$

$Q \propto L^{\beta}$ in steady state.

In Equation (5), $\mathrm{g_A}$ is TFP growth, A is level of TFP, X is research inputs based on either the semi-endogenous growth theory or Schumpeterian growth theory, Q is product variety (proxied by employment/labour, L, real output, Y, or the product of A and L, AL), and X/Q is research intensity. The parameters are defined as follows: λ is the R&D productivity parameter, σ is the duplication parameter, assumed to be zero if all innovations are replications of existing knowledge and 1 if none of the new innovations are replications, ϕ is returns to scale in the knowledge function, and β is the coefficient of product proliferation.

The values of ϕ and β differentiate these theories. Semi-endogenous growth theory predicts $\phi < 1$ and $\beta = 0$, implying diminishing returns of knowledge at the aggregate (country) level. Schumpeterian growth theory predicts that $\phi = 1$ and $\beta = 1$, following constant returns to scale by first-generation endogenous growth models, and the first-generation endogenous growth models assume that $\phi = 1$ and $\beta = 1$.

A log-linear approximation of Equation (5) gives:[7]

$$\Delta lnA_t = ln\,\lambda + \sigma\left[lnX_t - lnQ_t + \left(\frac{\phi-1}{\sigma}\right) lnA_t\right]. \tag{6}$$

[7] See Ang and Madsen (2011, pp. 1361).

The stationarity of ΔlnA is tested using unit root tests. A cointegrating relation between Q and A is then retrieved following a test of stationarity. Similarly, stationarity of the second-generation models can be tested in terms of the following equations.

$$\upsilon_t = lnX_t + \left(\frac{\phi - 1}{\sigma}\right) lnA_t \tag{7}$$

$$\varsigma_t = lnX_t - lnQ_t \tag{8}$$

Equations (7) and (8) are semi-endogenous growth and Schumpeterian growth models, respectively. If semi-endogenous growth theory holds, then lnX and lnA should be cointegrated, the cointegrating vector being $(1, (\phi - 1)/\sigma)$ with the second element carrying a negative sign, implying diminishing returns to knowledge function, i.e. $\phi < 1$. If the Schumpeterian growth model holds, then lnX and lnQ would be cointegrated with a vector of (1, -1).

The two equations are necessary but not sufficient to test the endogenous growth theories. Thus, an alternative specification of Equation (6) may represent a sufficient condition. Madsen, Saxena, and Ang (2010) recommend the following extended production function:

$$\Delta lnA_t = \gamma_0 + \gamma_1 \Delta\, lnX_t^d + \gamma_2\, \Delta lnX_t^f + \gamma_3 ln\left(\frac{X}{Q}\right)_t^d + \gamma_4 ln\left(\frac{X}{Q}\right)_t^f + \gamma_5 ln\left(\frac{A^{JPN}}{A_{IDN}}\right)_{t-1} + \gamma_6 FL_t + \gamma_7 ln\left(\frac{INV}{GDP}\right)_t + \gamma_8 lnTRADE_t + \gamma_9 lnHC_t + e_t, \tag{9}$$

where X is R&D expenditure, A is TFP, Q is product variety (proxied by Y, L, or AL), and JPN and IDN denote Japan and Indonesia, respectively. The superscript d and f stand for, respectively, domestic and foreign, and A^{JPN}/A^{IDN} measures the distance to the technology frontier, where A^{JPN} and A^{IDN} are the TFP levels of Japan and Indonesia, respectively. Finally, FL is an index of financial liberalisation, INV/GDP is investment to GDP, $TRADE$ is trade openness, HC is human capital, ln is the natural logarithm operator, and e is a stochastic error term.[8]

The semi-endogenous growth theory predicts that $\gamma_1, \gamma_2 > 0$ and $\gamma_3, \gamma_4, \gamma_5 = 0$, and the Schumpeterian growth theory predicts that $\gamma_3, \gamma_4, \gamma_5 > 0$ and $\gamma_1, \gamma_2 = 0$. We expect financial liberalisation or openness to boost TFP growth.[9] Thus, it is expected that $\gamma_6 > 0$. We also expect investment or capital deepening to induce TFP productivity.[10] Accordingly, it is expected that $\gamma_7 > 0$. Similarly, we expect trade openness and human capital to enhance TFP growth (i.e. $\gamma_8, \gamma_9 > 0$).[11]

However, for countries like Indonesia where Islamic banking and stock market activity have become a prominent part of the economy, models represented by Equation (9) may not fully capture their growth story. There is ample evidence suggesting that the financial system is instrumental in shaping productivity. Better functioning and developed banks and equity markets help firm growth (Demirgüç-Kunt and Maksimovic, 1996). Levine and Zervos (1998) show that stock market liquidity determines productivity growth. Rajan and Zingales (1998) show that financial markets are important in countries where firms depend on external finance. Arguably, the most stimulating work motivating the role of financial markets in economic growth and productivity is Levine (1991). In Levine's model, the need for stock markets has roots in liquidity and productivity risks. The main thesis of Levine's argument is that

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[8] Investments have been found to be important in endogenous growth models for emerging markets, such as Taiwan (See Bende-Nabende and Ford, 1998).

[9] Financial liberalization enhances the functioning of financial institutions and markets, which facilitates growth in two ways (King and Levine, 1993; Levine, 2001; Bekaert, Harvey, and Lundblad, 2005; Ang, and McKibbin, 2007). First, removal of restrictions on external portfolio flows improves the liquidity of domestic stock markets, thereby facilitating the funding of innovative projects (King and Levine, 1993; Levine, 1997, 2001). Second, the presence of foreign banks promotes competition in the domestic banking system by creating an alternative borrowing channel for domestic investors (King and Levine, 1993; Levine, 1997, 2001; Bekaert, Harvey, and Lundblad, 2005).

[10] Howitt (2000) shows that capital deepening enhances R&D by reducing the interest rate on innovation and raising the returns to innovation. The sign could be different since investment plays different roles of transitional dynamics in endogenous and neoclassical growth models (see Madsen, Ang, and Banerjee, 2010).

[11] Trade openness may induce skill and technical transfer (see Grossman and Helpman, 1990). Higher human capital development is associated with enhancement of innovative activities (see e.g. Pritchett, 2001; Madsen, Saxena, and Ang, 2010).

‘[p]roductivity lowers welfare and discourages agents from investing in firms’ (p. 1453). Further, Levine argues that idiosyncratic productivity shocks are diversified away because stock markets allow investors to hold a diversified portfolio of stocks. The net result, he argues, is one of welfare enhancement, more resources for firms, and an increase in the economy’s steady-state growth rate (p. 1453).

We proxy the financial system with three variables, the Islamic financial market (Islamic stock price index), the conventional financial market (Jakarta Stock Exchange Composite Index), and the banking sector (bank assets to GDP). The choice of conventional financial market and the banking sector are motivated by the literature cited above. On the other hand, the Islamic financial market has not been considered in the endogenous growth literature. It is important to do so because Islamic financial activity is expected to influence Indonesia’s growth path going forward. The motivation for this, as alluded to in Section I, is that Islamic finance offers an alternative source for financing investments compared to conventional finance. This is because Islamic financial markets function on the principle of Islamic law, and risk-sharing is one of the key features of this market. Innovation is risky (Hitt, Hoskisson, and Ireland, 1994; Aboody and Lev, 2000; Greve, 2003; Lee and O’Neill, 2003; Merton, 2013). The risk-sharing aspect of Islamic financing offers a pathway for investors to engage in innovative activity. In other words, it is a means of attracting investors. Moreover, since the mid-1990s, with the advent of technological innovation, the Islamic finance industry has grown and now supports new growth areas, such as green, ethical and environmentally friendly projects, international risk management through Shariah-complaint hedging instruments, funding international infrastructure projects, and enhancing liquidity management and capitalisation of Islamic financial institutions consistent with new regulatory standards, such as Basel III.[12] The Islamic finance industry, therefore, has a role to play in productivity and growth.

To accommodate the role of the Islamic finance industry, we extend the baseline TFP growth regression by incorporating the Islamic financial market. We proxy the Islamic market using the Islamic stock price return. We hypothesise that R&D expenditure growth (ΔlnX_t^d) is a function of one-period lagged R&D expenditure growth (ΔlnX_{t-1}^d) and the current and previous period growth of Islamic stock price returns (ΔlnP_t and ΔlnP_{t-1}). Replacing these in Equation (9), we obtain the following augmented version of the TFP growth regression:

$$\Delta lnA_t = \gamma_0 + \gamma_1 \Delta\, lnX_{t-1}^d + \gamma_2 \Delta lnP_t + \gamma_3 \Delta lnP_{t-1} + \gamma_4\, \Delta lnX_t^f + \gamma_5 ln\left(\frac{X}{Q}\right)_t^d + \gamma_6 ln\left(\frac{X}{Q}\right)_t^f + \gamma_7 ln\left(\frac{A^{JPN}}{A^{IDN}}\right)_{t-1} + \gamma_8 FL_t + \gamma_9 DUM_t + e_t, \quad (10)$$

where DUM is a dummy variable used as an indicator of structural breaks which are obtained using the Narayan and Popp (NP, 2010) test. This extended regression implies that the semi-endogenous growth theory holds if $\gamma_1, \gamma_2, \gamma_3, \gamma_4 > 0$ and $\gamma_5, \gamma_6, \gamma_7 = 0$, and the Schumpeterian growth theory holds if $\gamma_5, \gamma_6, \gamma_7 > 0$ and $\gamma_1, \gamma_2, \gamma_3, \gamma_4 = 0$. Based on the prediction that financial liberalisation boosts TFP growth, we expect that $\gamma_8 > 0$. Investment to GDP, trade openness, and human capital are excluded from this regression because they are highly correlated to Islamic stock price change.[13]

[12] This information is obtained from an online publication found at: www.mifc.com (downloaded July 26, 2018).
[13] The correlation is 0.661 between Islamic stock price and investment to GDP, 0.566 between Islamic stock price and trade openness, and 0.906 between Islamic stock price and human capital.

IV. Data

Our empirical work is based on multiple data sources. These include the Penn World Tables (PWT) 9.0, the World Intellectual Property Organization (WIPO), the Indonesian Institute of Sciences (LIPI), Japan Statistical Yearbook (various issues), Ang and Madsen (2011), and World Development Indicators. Specifically, data on employment, TFP, and human capital are from PWT 9.0. Data on patents are sourced from WIPO. Data on R&D for Indonesia are obtained from LIPI, while those for Japan are from the Japan Statistical Yearbook (various issues).[14] Our measure of financial openness is from the Ito-Chinn (2006) database. Data on trade openness are sourced from World Development Indicators. Data on investment to GDP are from PWT 9.0. Islamic stock price data, as in Narayan, Narayan, Phan, Thuraisamy and Tran (2017), are sourced from Datastream. A summary of all variables is provided in Table A.2 of the appendix.

Labour (L) and real output (Y) are, respectively, the number of persons engaged (in millions) and real GDP at constant 2011 national prices (in million 2011 US$). Real output and labour are used as measures of product variety, consistent with the literature (Zachariadis, 2003; Griffith, Redding, and Reenen, 2004; Ha and Howitt, 2007; Madsen, 2008). In alternative models, we also employ data on university-level graduates as a proxy for labour. Variable A is TFP at constant national prices (2011 = 100). We measure R&D input (X) as government R&D expenditure (RD) and the number of patent applications by domestic residents ($PATENT$). Indonesia has limited or no data on the number of scientists and engineers engaged in R&D. Hence, we do not use this alternative measure. Following Madsen, Saxena, and Ang (2010) and Schumpeterian growth models, we measure research intensity (X/Q) as RD/Y, RD/AL, and $PATENT/L$. We adjust RD/L by TFP (i.e. RD/AL) to account for the increasing

[14] Specifically, observations on Japan R&D for the period 1968–2006 are from Ang and Madsen (2011), and from 2007 to 2018 they are from the Japan Statistical Yearbook (various issues).

complexity of new innovations associated with economic advances (Aghion and Howitt, 1992; Madsen, Saxena, and Ang, 2010).

Figure IV displays TFP and R&D trends for the period 1968 to 2018. R&D expenditure in Indonesia has experienced an upward trend, even though the growth rate has been slow. The period 1968 to 1983 saw a significant increase in R&D expenditure. During this period, the number of patent applications saw mixed growth, while TFP experienced upward movement. Following this period, the number of patent applications rose steadily. The period 1995 to 2000 saw a sharp fall in TFP, coinciding with the AFC. Between 2000 to 2018, TFP has consistently experienced an upward trajectory.

Figure V is the analogous graph for the R&D intensity measures and TFP trends. Two measures of R&D intensity – the logarithm of real R&D expenditures scaled by the logarithm of product variety, $ln(RD/Y)$, and the logarithm of real R&D expenditures scaled by the logarithm of the product of TFP and labour (AL), which we denote $ln(RD/AL)$ – experienced increasing or decreasing trends together with TFP between 1968 and 1993. From 2000 to 2018, the logarithm of $PATENT$ scaled by the logarithm of labour, $ln(PATENT/L)$, and $ln(RD/AL)$ exhibit a positive correlation with TFP. On the other hand, $ln(RD/Y)$ saw a gradual decline during this period.

Thus, from both graphs, we are unable to judge which theory is supported by the data. On the one hand, Figure IV suggests that the period following 2000 supports the innovation-driven TFP growth hypothesis of semi-endogenous growth theory, while the earlier period does not. On the other hand, Figure V shows that the two measures of R&D intensity are positively correlated with TFP during the periods 1968 to 1993 and 2000 to 2018, thus supporting the Schumpeterian theory. Hence, both graphs are inconclusive. Both graphs suggest a sharp decline in TFP, which implies a structural change in the relationship. This type of behaviour is consistent with previous studies showing that non-linearities exist in macroeconomic relationships in Indonesia. Juhro (2004), for example, notes that structural changes in the Indonesian economy, particularly after the AFC, led to a nonlinear Phillips curve. A key contribution of our paper is to model such structural change, including the advent of the Islamic financial market, in testing endogenous growth theories; thus far, this is absent from the literature.

To capture the role of Islamic financial markets, we follow Narayan, Narayan, Phan, Thuraisamy and Tran (2017) and compile data on Islamic stock prices available in the Datastream universe. The Islamic stock market in Indonesia is relatively young. Hence, we employ data on all Islamic stocks to construct an equal-weighted stock price index at constant US prices (2011=100) for our empirical analysis. For instance, the value of the index in 1968 is the simple arithmetic average of the prices of all stocks available in 1968 relative to the 2011 value. Figure VI shows a graph of the Islamic stock price index and the number of Islamic stocks each year from 1968 to 2018. The minimum number of stocks available is 34 (in 1968), while the maximum is 2,437 (in 2018). Similarly, the maximum stock price index was recorded in 1968 and the minimum in 2018.

V. Empirical results

A. Stationarity tests

A simple test of endogenous growth models is carried out via stationarity or unit root tests. That is, the semi-endogenous models imply that TFP or (lnA) follows an I(1) or a unit root process, meaning that the indicators of R&D ($lnRD$ and $lnPATENT$) also follow an I(1) process or have a unit root. For Schumpeterian models to hold, the natural logs of the R&D intensity measures RD/Y, RD/AL, and $PATENT/L$ and TFP are expected to follow an I(0) process or should be free of a unit root (Ang and Madsen, 2011). Since plots of the data (such as those depicted by Figures III and IV) suggest possible breaks, we use the Caner and Hansen (CH) (2001) test for threshold effects and unit roots to formally examine possible structural breaks or threshold effects. The results, reported in Table I, suggest that we can reject the null of no threshold effects for lnA, $lnRD$, $ln(RD/AL)$, and $ln(PATENT/L)$. Hence, we can reject the linear autoregressive (AR) model in favour of the threshold autoregressive (TAR) model when considering these variables. The unit root results are split. The unit root null is rejected for lnA, $ln(RD/AL)$, and $lnPATENT/L$. The remaining variables, $lnRD$, $lnPATENT$, and $ln(RD/Y)$ have unit roots.

We further examine the presence of unit roots using the Perron (1989) and NP tests, which account for possible structural breaks. The Perron test accommodates only a single structural break, while the NP test accommodates two endogenous breaks. Table I reports results from these tests. Both the Perron and NP tests support evidence of unit roots in TFP. For the R&D activity and intensity measures, the Perron test supports evidence of unit roots, while the NP test generates mixed conclusions. However, since the NP statistic shows that TFP has a unit root, the evidence from the NP test statistic appears to favour the semi-endogenous theory. Overall, the semi-endogenous growth models are largely supported by the stationarity tests.

B. Cointegration results

B1. Linear cointegration tests of endogenous growth models

Existing studies use linear econometric techniques to examine endogenous growth models (Madsen, Saxena, and Ang, 2010; Ang and Madsen, 2011). However, various structural changes, such as the 1997 AFC and the 2007 GFC, may have led to time-variation in the relationship between TFP growth and innovation. As we document in Section B2 below, nonlinear behaviour is present in the data. Therefore, a contribution of our paper is to account for possible regime shifts or structural changes in the relationship between TFP growth and innovation. This amounts to taking a nonlinear approach to testing the validity of growth models.

We begin by first testing the models using linear cointegration techniques and comparing results to those generated using nonlinear cointegration techniques. Table II reports results obtained using linear techniques. The results in Panel A are based on the Johansen (1991) approach, while those in Panel B are based on the autoregressive distributed lag (ARDL) bounds approach of Pesaran, Shin, and Smith (2001). The linear cointegration tests largely reject the evidence of cointegration and thus both growth models are refuted.

B2. Nonlinear cointegration tests of endogenous growth models

Are results obtained in Section B1 sensitive to nonlinear behaviour of data? Figures IV and V show a clear and sharp decline in TFP during the period 1995 to 2000. This decline is not followed by similar declines in R&D activity and intensity measures, indicating a nonlinear relationship between these variables. This nonlinear behaviour is supported by the CH test results reported in Table I. Madsen, Saxena, and Ang (2010) address this issue by estimating models for both pre-reform and full samples of data. Their approach does not explicitly model the inherent structural changes. We do so by using nonlinear cointegration techniques.

The results based on nonlinear cointegration techniques are reported in Table III. In Panel A, we report results from the Gregory and Hansen (1996) test, while those in Panel B are based on the nonlinear ARDL (NARDL) bounds testing procedure proposed by Shin, Yu, and Greenwood-Nimmo (2014). Nonlinear cointegration tests, in contrast to linear tests, largely support evidence of cointegration, and thus corroborate both growth models. The necessary condition for Schumpeterian and semi-endogenous growth theory are satisfied within a nonlinear framework. The key implication of this finding is that the validity of growth models depends on correctly modelling data features, such as non-linearities, as we show.

B3. Estimation of long-run elasticities

Equations (7) and (8) imply that $lnX_t = \mu lnQ_t + \kappa lnA_t + e_t$, where $\kappa = (1 - \phi)/\sigma$ and ln is the natural logarithm operator. Schumpeterian theory hypothesises that $\kappa = 0$ and $\mu = 1$, whereas $\kappa > 0$ and $\mu = 0$ under semi-endogenous growth theory, and e_t is a stationary error term. This relationship can be used to test endogenous growth theories, as in Zachariadis (2003, 2004).

We estimate this relationship using dynamic least squares (DOLS). The results are shown in Panel A of Table IV. The long-run elasticities show that product variety and TFP are both important predictors of R&D expenditure. Thus, the joint hypothesis under both the Schumpeterian and semi-endogenous growth theories does not appear to hold. By carefully reading our results, the condition that $\mu = 1$ and $\kappa > 0$ under the Schumpeterian and semi-endogenous theory, respectively, are satisfied. The failed conditions are $\kappa = 0$ and $\mu = 0$ under Schumpeterian and semi-endogenous theory, respectively.

Since the joint hypothesis under both the Schumpeterian and semi-endogenous growth theories do not appear to hold using the combined specification, we return to estimating the piecewise regressions in Equations (7) and (8). Panel B of Table IV reports piecewise DOLS estimates of long-run elasticities. Here, the evidence in support of the Schumpeterian theory is mixed, since the hypothesis that $\mu = 1$ is rejected whether product variety is measured by $lnAL$ or lnY and the hypothesis that $\kappa = 0$ is accepted. We are able to reject the hypothesis that $\kappa > 0$, although the estimated statistic is actually higher than zero. Thus, we cannot clearly identify the theory that holds.

C. Estimates of TFP growth regressions

This section reports estimates of the baseline TFP growth regression as represented by Equation (9). Recall that the semi-endogenous growth theory predicts that $\gamma_1, \gamma_2 > 0$ and $\gamma_3, \gamma_4, \gamma_5 = 0$, while Schumpeterian growth theory predicts that $\gamma_3, \gamma_4, \gamma_5 > 0$ and $\gamma_1, \gamma_2 = 0$. Estimates of this equation are based on ordinary least squares with standard errors obtained using the Newey–West procedure to account for any possible heteroscedasticity and autocorrelation. Note that whether or not a variable enters into the model in level form or in first differences is dictated by theory and the stationarity test results in Table A.3.

The results are reported in Table V. In Panel A, we do not control for structural breaks, while in Panel B we do so. In both regressions, the dependent variable is TFP growth, ΔlnA. Reading results from Panel A, we see that if R&D intensity is measured by RD/Y, only two variables, namely, distance to the technology frontier and investment to GDP are statistically significant. On the other hand, when R&D intensity is measured as RD/AL, the significant variables are domestic and foreign R&D growth, domestic and foreign R&D intensities, investment to GDP, and trade openness. Further, when R&D intensity is measured as $PATENT/L$, foreign R&D growth, foreign R&D intensity, investment to GDP, and trade openness are significant. When we control for human capital (in Panel A), the results suggest that domestic R&D intensity, financial liberalisation, investment to GDP, and human capital growth are statistically significant if R&D intensity is measured as RD/Y. Also, when R&D intensity is measured as RD/AL, the significant variables are domestic R&D growth, domestic R&D intensity, foreign R&D intensity, investment to GDP, financial liberalisation, human capital growth (see Panel A). In addition, when R&D intensity is measured as $PATENT/L$, foreign R&D growth, domestic R&D intensity, foreign R&D intensity, financial liberalisation, investment to GDP, trade openness, and human capital growth are significant (see Panel A). Hence, it is unclear which model best fits the data.

There is potential nonlinearity in the relationship between TFP growth and its predictors, owing to structural changes. Thus, estimates in Panel A may be inconsistent and unreliable. In Panel B, results are based on a model that accommodates structural changes. Note that when R&D intensity is measured as RD/Y, only distance to the technology frontier and investment to GDP are statistically significant. If R&D intensity is measured as RD/AL, foreign R&D growth, foreign R&D intensity, distance to the technology frontier, and investment to GDP are significant. If R&D intensity is measured as $PATENT/L$, foreign R&D growth, foreign R&D intensity, financial liberalisation, investment to GDP, and trade openness are statistically significant. Controlling for human capital in Panel B, we see that when R&D intensity is measured as RD/Y, financial liberalisation, investment to GDP, trade openness, and human capital growth are statistically significant. If R&D intensity is measured as RD/AL, financial liberalisation, investment to GDP, trade openness, and human capital growth are significant. If R&D intensity is measured as $PATENT/L$, foreign R&D growth, foreign R&D intensity, financial liberalisation, investment to GDP, trade openness, and human capital growth are statistically significant.

Thus, whether or not we control for structural changes, the complementary regression does not clearly distinguish the endogenous growth theories. However, a common pattern emerges from these estimations. R&D intensity, both domestic and foreign R&D, investment to GDP, distance to the technology frontier, financial liberalisation, trade openness, and human capital appear to be the key drivers of TFP growth in Indonesia, as they are significant in almost all specifications.

Before formally examining the role played by finance in TFP growth through R&D and innovation, we analyse the bivariate causal relations between the finance, TFP growth, R&D, and patent indicators. These basic results are reported in Table A.4 of the Appendix. The results show that the financial system can induce R&D expenditures and patents. For example, there is a causal flow from bank assets ratio ($lnBA$) to R&D expenditures (lnX), and from market capitalisation ratio ($lnCAP$) to patents ($lnPATENT$). The direction of causality also reverses, flowing from R&D expenditures or patents to the financial system. For example, lnX and $lnPATENT$ Granger cause Islamic stock prices (lnP). Besides, financial systems may directly Granger cause TFP growth, as evidenced by a causal flow from $lnCAP$ to lnA. Thus, these preliminary results suggest that plausible relationships exist among these variables, and confirm our hypothesis. However, the tests are based on bivariate models, and do not sufficiently reveal our hypothesised transmission mechanism that financial systems (particularly, the Islamic finance) foster R&D and innovation, which, in turn, foster TFP growth.

We, therefore, turn to our main (extended) endogenous growth model (Equation (10)) to properly evaluate the transmission mechanism. The results are reported in Table VI. The correlation between Islamic stock price and investment to GDP is 0.661; it is 0.566 for trade openness and 0.906 for human capital. Thus, we exclude investment to GDP, trade openness, and human capital from this estimation to avoid multicollinearity issues. Panel A reports the estimates of Equation (10) based on the full sample period (i.e. 1968–2018). As a robustness check, we restrict the sample period to 1981–2018. This is because the total number of Islamic stocks was very limited (34) but became significant by 1981 (i.e. 357 Islamic stocks were listed as of 1981). Previous studies also employ samples starting from 1981 (see Narayan, Narayan, Phan, Thuraisamy and Tran, 2017). The resulting estimates are in Panel B. We find that the role of Islamic stocks in TFP growth is relevant in all three specifications. It appears that the estimates based on the 1981–2018 sample provide relatively concrete support for the role of the Islamic stock market when compared to those based on the 1968–2018 sample (as indicated by the improvement in *t*-statistics). That is, in two of the three regressions, Islamic stock price return is significant at the 1% level using the 1981–2018 sample. Our conviction is that the Islamic stock market in Indonesia will continue to gain significant influence in TFP given policy initiatives (see Section I) aimed at bringing Islamic finance to the mainstream as a way of doing business. Aside from these results, we find that lags of domestic R&D and patent growth may also induce TFP growth, as evidenced by the statistical significance of ΔlnX_{t-1}^{d} in two of the regressions.

We further examine our results by proxying product variety with the total labour force characterised by university-level education. Labour force with university-level education is more likely to create varied and valued products as compared to using a general measure of labour. Estimates based on this measure are reported in columns 5 and 6 of Table VI. Our main results still hold in this context, particularly for the $PATENT/AL^{*}$ specification. The evidence in support of Islamic stock price return is stronger if we limit the sample period to 1981–2018, since it is significant in both the RD/AL^{*} and $PATENT/AL^{*}$ specifications. A unique finding is that the Islamic market is prominent in Indonesian TFP growth. This is evident in the significance of the current growth of Islamic stock prices in at least four of the five regressions. The slope coefficients on ΔlnP_t fall in the 0.017 to 0.049 range with a minimum t-statistic of 1.857. Economically, these statistics imply that a one standard deviation increase in stock price returns leads to an increase in TFP growth of between 0.48% and 1.38%. Thus, economically, the slope coefficients imply that a one standard deviation increase in stock price returns increases the TFP growth by between 1.04% and 3.00% of its sample mean. Domestic R&D activities also seem to be relevant in some specifications. In particular, the estimates show that a one standard deviation increase in lag domestic R&D activity growth will increase TFP growth by between 1.44% and 2.24%. This means that a one standard deviation increase in lag domestic R&D activity growth will increase TFP growth by between 3.13% and 4.87% of its sample mean. The overall message is that domestic R&D and the role of Islamic markets are not only statistically relevant, but they are economically meaningful as well.

Furthermore, we examine whether the overall stock market and banking sector generally foster innovative activity and thus TFP growth in Indonesia.[15] To do this, we re-

[15] In our analysis, we attempted to examine the roles of other financial markets (such as insurance and bonds) in TFP growth; however, we could not do so due to data limitation. Specifically, the sample periods are 2011 to 2017 and 2006 to 2018, respectively, for the insurance and bond market indicators, which are insufficient to generate any meaningful estimates.

estimate Equation (10) by replacing the Islamic stock return with either the two indicators of stock market or the banking sector growth. For the stock market growth, we use the Jakarta Stock Exchange Composite Index return and market capitalisation growth. For the banking sector growth, we use bank assets to GDP growth and bank loans to GDP growth. These estimates are shown in Table VII. We find that the current and previous levels of stock return do influence subsequent TFP growth in at least two out of five regressions. We find similar evidence for the banking sector—both current and past banking sector growth exert statistically significant effects on TFP growth in at least two out of five regressions.

Our results suggest that a positive growth in both the stock market and the banking sector enhances TFP growth. In terms of economic significance, the slope coefficients on the Jakarta stock market growth (i.e. composite index return and market capitalisation growth) are in the 0.011 to 0.036 range, with a minimum *t*-statistic of 1.834. The implication here is that a one standard deviation increase in stock market growth leads to an increase in TFP growth by between 0.57% and 0.76%. Economically, a one standard deviation increase in the Jakarta stock market growth increases the TFP growth by between 1.24% and 1.65% of its sample mean. With respect to the banking sector, the estimates show that a one standard deviation increase in banking sector assets and loans to GDP growth will increase TFP growth by between 0.82% and 1.50%. The implication is that a one standard deviation increase in banking sector growth will increase TFP growth by between 1.78% and 3.26% of its sample mean. These estimates generally support a finance-led TFP growth hypothesis. Taken together, these results also imply support for second-generation endogenous growth models.

In our final analysis, we examine the overall influence of the financial sector (stock markets and banks) on TFP growth. We use the principal component analysis to create a composite financial sector indicator (FIN) based on all five financial market indicators, namely Islamic stock price return, Jakarta stock price return, market capitalisation to GDP, bank assets to GDP, and bank loans to GDP. We re-estimate Equation (10) by replacing the Islamic stock return with FIN. Table VIII reports these estimates. The overall financial sector growth significantly influences TFP growth; the effect is positive and statistically different from zero in four out of the five regressions. The economic interpretation of these coefficients is that a one standard deviation increase in financial sector growth will increase TFP growth by between 1.11% and 1.65%. Thus, a one standard deviation increase in financial sector growth will increase TFP growth by between 2.41% and 3.59% of its sample mean.

Our finding that financial markets, and the Islamic stock markets in particular, may help fund R&D activities, and consequently TFP growth demands a careful interpretation. We observe, from Tables V and VI, that after controlling for the role of financial markets, the adjusted R-squared falls from around 90% to 30%. This may imply statistically that the growth model for Indonesia is a better fit without financial markets, which is actually consistent with the observed characteristics of developing economies in that their financial markets are underdeveloped. However, from an economic perspective, both the traditional and the Islamic financial markets in the country have grown substantially during the past two decades. Hence, their contributions to R&D funding and thus TFP growth would only increase over time. Overall, both models (the one with and the other without financial markets) have unique attributes that could be relevant to the policymaker. While the model without financial markets may have a powerful forecasting potential, the model with financial markets indicates the need to enhance the financial market as an integral component of the overall economic system.

VI. Concluding remarks

The Indonesian economy has experienced sustained growth for multiple decades. The country has undergone a structural transformation towards a services sector–oriented economy and a rise in the importance of Islamic finance as a way of conducting business and economic activity. Despite this progress and transformation, issues related to the productivity of the financial sector, particularly the country's sustained growth, are not well understood. The literature highlights several bottlenecks to Indonesia's economic growth, including the quality of infrastructure, human capital, and education, that inhibit the country from moving to a higher growth trajectory. In this regard, understanding growth models that best explain the evolution of the Indonesian economy is imperative.

Moreover, despite increasing evidence that second-generation endogenous models better explain Indonesia's growth experience, few studies examine these models in developing and emerging economies. The existing studies, however, ignore the role of developments in Islamic financial markets and structural shocks, which can potentially influence TFP growth. Islamic financial activities have increased tremendously during the past decades. The Islamic financial system is guided by principles that are different from the conventional financial system. Hence, understanding how Islamic finance influences growth appears to be appealing. A possibility is that the underlying relationship between financial systems and growth becomes nonlinear when faced with structural shocks over the sequence of economic development. If so, using linear models will not provide the ideal setting to evaluate the validity of growth models. Motivated by these issues, we test whether second-generation endogenous growth theories explain Indonesia's growth experience. Using time series data for the period 1968 to 2018, we find that while our estimates are not clear-cut, semi-endogenous models appear to better explain the growth experience of Indonesia. When we extend the growth model to account for the role of the financial system, consistent with our expectation, we find that growth in the Islamic stock market, the conventional stock market, and the banking sector spurs Indonesia's TFP growth. Based on an overall financial sector index, we show that the financial sector as a whole fosters TFP growth by boosting investment in R&D and patents. These findings suggest that policymakers should encourage and promote innovative activities (which will be reflected in increasing R&D expenditure). From our results, a boost to R&D and growth of the Islamic and conventional stock markets as well as the banking sector as alternative ways of conducting business will help spur economic growth.

An additional advantage of our study is that it opens opportunities for additional work on endogenous growth theories in Indonesia. Two lines of inquiry are already clear. First, Indonesia is a culturally rich and religious country. Cultural capital can naturally contribute to development of ideas. In other words, cultural capital can enhance the value of R&D. High quality, innovative output resulting from R&D is likely to boost economic growth. Second, Indonesia is a diverse country with 34 provinces. These provinces have different challenges for growth and development. A provincial-level test of endogenous growth theories will provide detailed insight on the relevance of growth models conditional on provincial characteristics. Both these issues will add new perspectives on understanding the relevance of endogenous growth theories.

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Figure I: Trend in real GDP growth (in percentage)

The figure presents the trends in real GDP growth (in percentage). The data come from the World Bank.

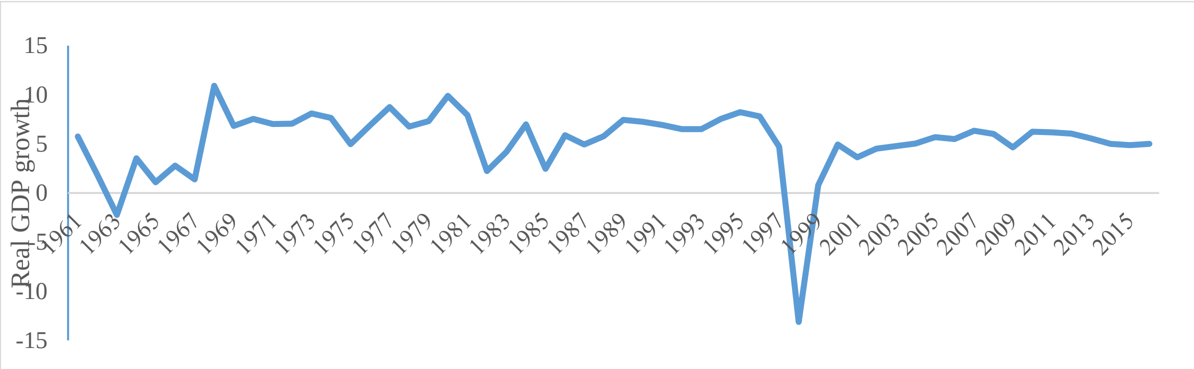

Figure II: Decadal average GDP growth (in percentage)

The figure presents the decadal average of GDP growth (in percentage). The data come from World Bank.

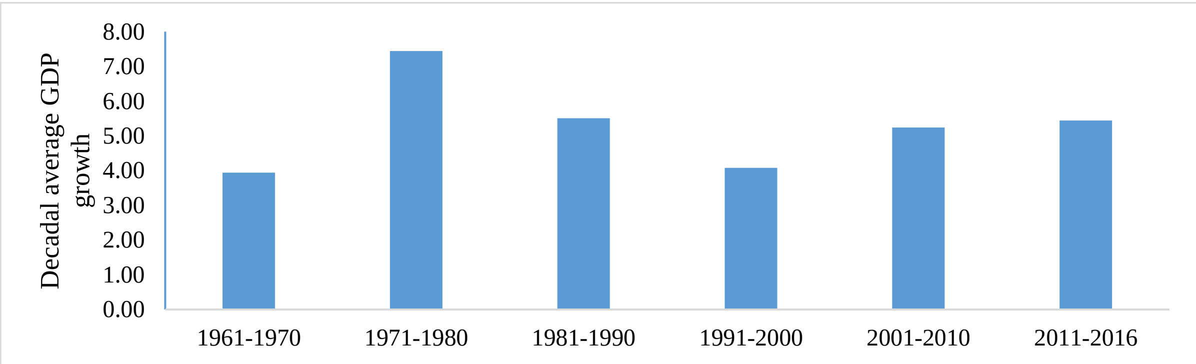

Figure III: Indonesian TFP and R&D growth from 1960 to 2014

The figure shows the trends in TFP growth from 1960 to 2014 and R&D growth from 1968 to 2014 for Indonesia. TFP is measured in constant national prices (2011=1). R&D growth is the natural logarithm changes in government R&D expenditure. The TFP and R&D data come from Penn World Tables version 9.0 and Indonesian Institute of Sciences, respectively.

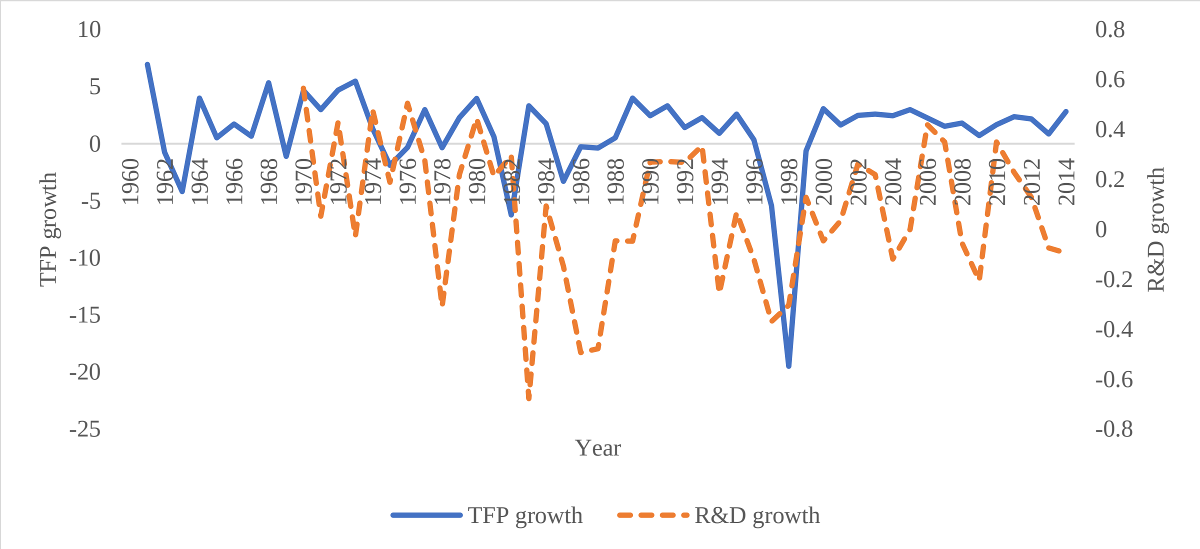

Figure IV: Trends in TFP and R&D activity measures

The figure presents trends in TFP and R&D activity measures. lnA is the logarithm of TFP, $lnRD$ is the logarithm of real R&D expenditures, and $lnPATENT$ is the logarithm of patent applications from residents. The right axis is TFP, while the left axis is the R&D. ln is the natural logarithm operator. The sample period used is from 1968 to 2018.

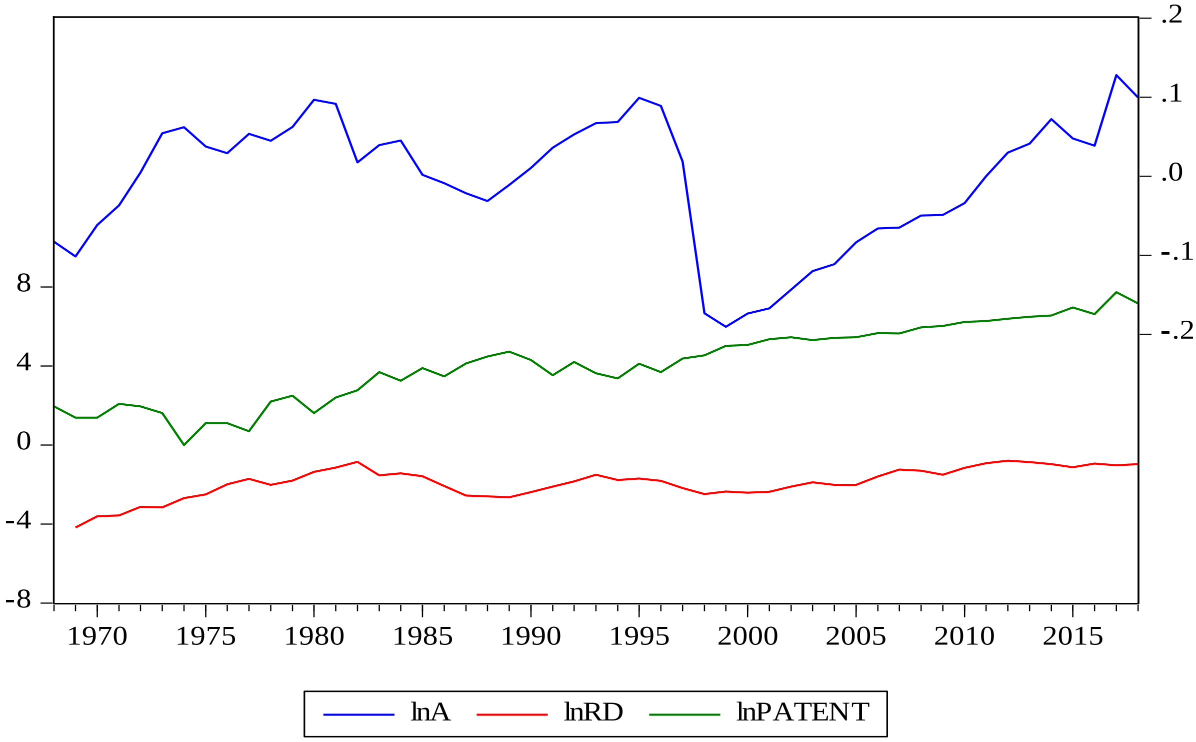

Figure V: Trends in TFP and R&D intensity measures

The figure presents trends in TFP and R&D intensity measures. lnA is the logarithm of TFP, $lnRD/Y$ is the logarithm of real R&D expenditures scaled by real GDP or product variety, $lnRD/AL$ is the logarithm of real R&D expenditures scaled by the product of TFP and labour, $lnPATENT/L$ is the logarithm of patent applications from residents scaled by labour. The right axis is TFP, while the left axis is the R&D intensity. ln is the natural logarithm operator. The sample period used is from 1968 to 2018.

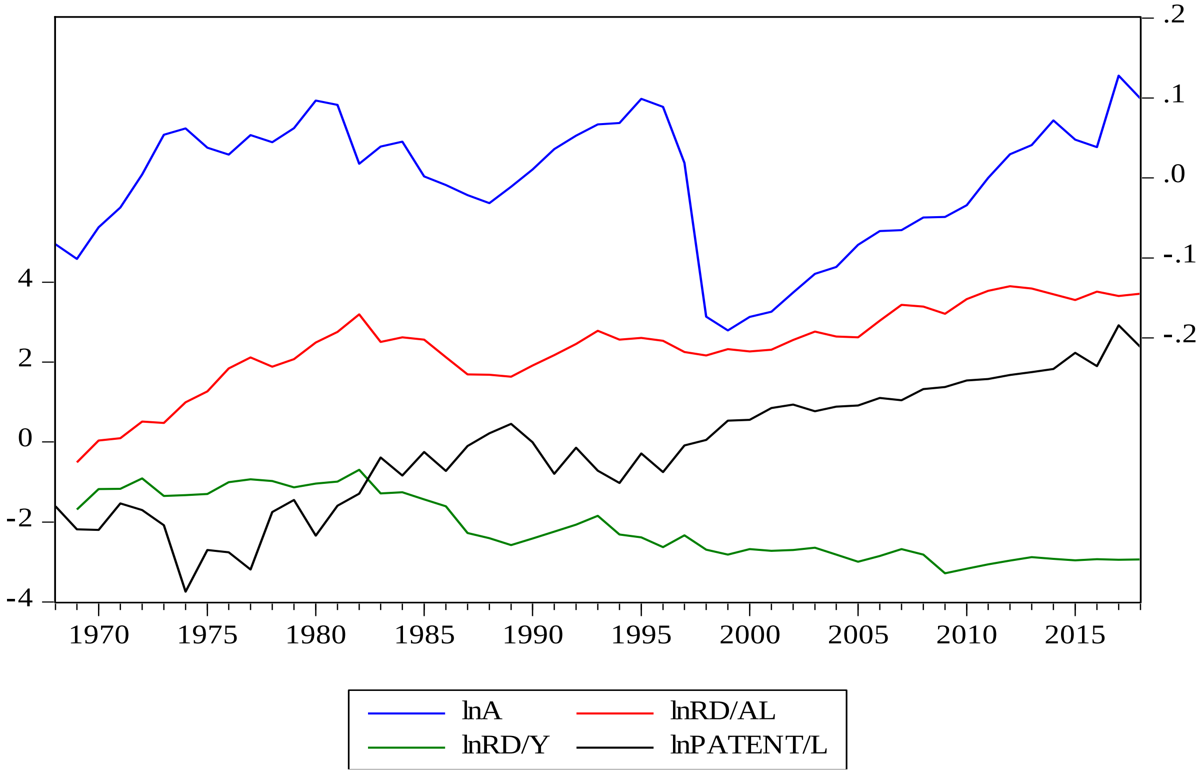

Figure VI: Trends in the Islamic stock price index and the number of stocks

The figure shows the trends in the Islamic stock price index and the number of stocks per year. We employ data on all Islamic stock prices in order to construct an equal-weighted stock price index at constant US prices (2011=100) for our empirical analysis. Note that in the empirical analysis, we take the natural logarithm of the index and difference it in order to obtain our measure of Islamic stock price return. The data are obtained from Datastream. The sample period is 1968–2018.

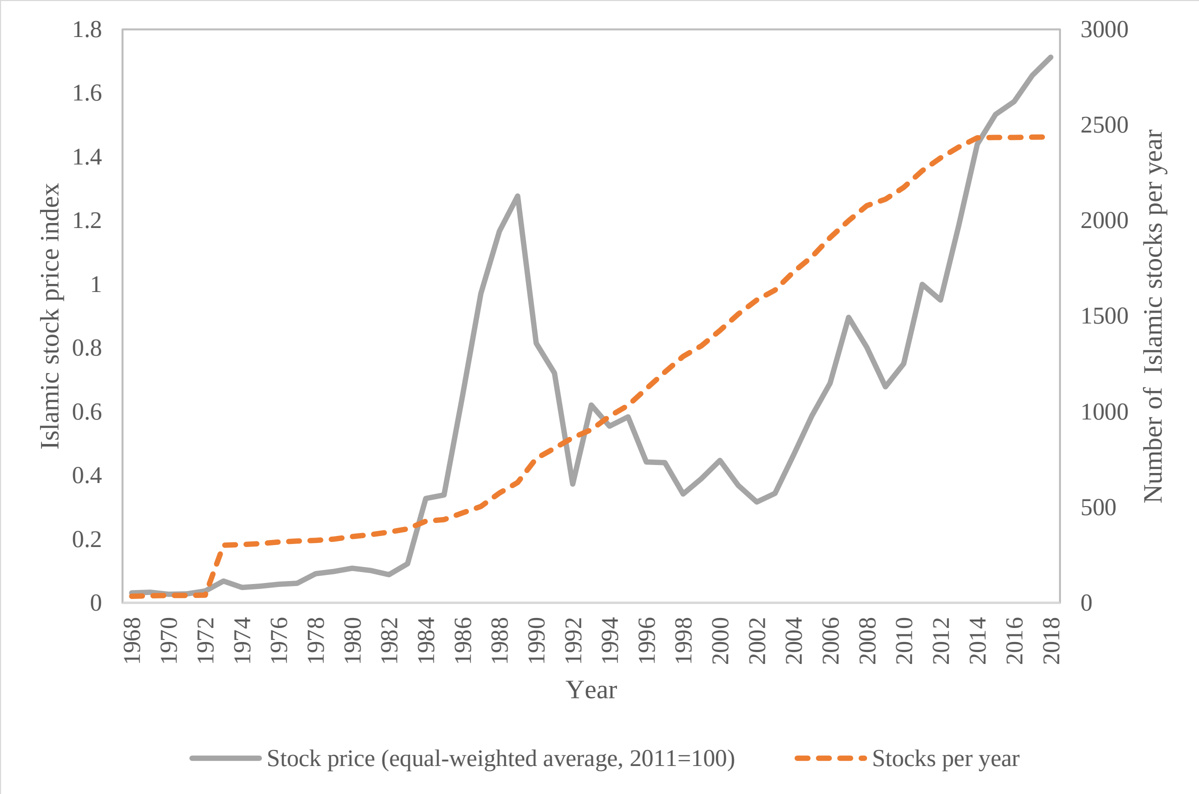

Table I: Stationarity tests of endogenous growth models

The table shows threshold and stationarity tests of endogenous growth models. The Wald statistic (W_T), and the one-sided threshold unit root test statistic ($R_{1,T}$) for the chosen delay parameter between 1 and 3 are compared with the bootstrap *p*-values. The bootstrap *p*-values are calculated from 1,000 replications. The delay parameter is restricted to a maximum of three due the small sample size and because the data frequency is annual. The *t*-statistic, and M1 and M2 statistics are compared with critical values tabulated in Perron (1989), and Narayan and Popp (2010), respectively. Lags are selected automatically using Akaike information criterion (AIC) for the Perron test. Lags for the Narayan and Popp (2010) test are based on the procedure suggested by Hall (1994). Perron (1989) takes into account a structural break, Caner and Hansen (2001) test accounts for threshold effects and unit roots, and Narayan and Popp (2010) account for two structural breaks. In all three cases, we include only the intercept. *ln* denotes the natural logarithm operator. TB1, TB2, and k denote, respectively, the first and second structural break dates, and the optimal lag. The sample period used is from 1968 to 2018.

	Caner-Hansen (2001) test									
Variable	W_T	*p*-values (lags)			$R_{1,T}$		*p*-values			
lnA	54.303	0.031(3)			17.370		0.033			
$lnRD$	27.906	0.034(1)			7.300		0.460			
$lnPATENT$	13.521	0.451(3)			6.400		0.590			
$ln(RD/Y)$	14.412	0.640(1)			3.860		0.790			
$ln(RD/AL)$	20.489	0.091(3)			11.538		0.086			
$ln(PATENT/L)$	29.514	0.084(2)			31.001		0.011			
	Perron (1989) test									
Variable	*t*-statistic			Lags			Integration property			
lnA	-3.999			1			I(1)			
$lnRD$	-3.432			1			I(1)			
$lnPATENT$	-4.879			0			I(1)			
$ln(RD/Y)$	-5.567			0			I(0)			
$ln(RD/AL)$	-3.647			0			I(1)			
$ln(PATENT/L)$	-4.708			0			I(1)			
	Narayan-Popp (2010) test									
	M1					M2				
Variable	Test statistic	TB1	TB2	k	Status	Test statistic	TB1	TB2	k	Status
lnA	-2.629	1981	1997	3	I(1)	-3.871	1981	1997	3	I(1)
$lnRD$	-3.117	1982	1996	0	I(1)	-4.746	1982	2006	4	I(0)
$lnPATENT$	-6.717	1982	1990	4	I(0)	-5.033	1979	1990	5	I(0)
$ln(RD/Y)$	-2.685	1982	1986	0	I(1)	-3.373	1982	1993	2	I(1)
$ln(RD/AL)$	-2.619	1982	1985	0	I(1)	-4.262	1982	2006	4	I(0)
$ln(PATENT/L)$	-7.438	1982	1990	4	I(0)	-4.985	1979	1990	5	I(0)

Table II: Results for linear cointegration tests

The table reports the results for linear cointegration tests. Panel A contains the results of the Johansen test. The null hypothesis of no cointegration is tested against alternatives of at least one cointegration. A maximum lag of two is included in the model. Panel B contains the results for the ARDL bounds test. The null hypothesis of no cointegration is tested against an alternative of cointegration. k is the number of predictors in the equation. I(0) and I(1) are the critical values for the lower and upper bounds, respectively. A maximum lag of two is included in the model. The lags are selected using the Akaike information criterion. In both panels, we test the semi-endogenous growth theory: $\nu_t = lnX_t + ((\phi - 1)/\sigma)lnA_t$, where X is R&D expenditure, and A is TFP for Indonesia; and the Schumpeterian growth theory: $\varsigma_t = lnX_t - lnQ_t$, where Q is product quality, Y or AL. ln is the natural logarithm. The sample period used is from 1968 to 2018.

	Panel A: Johansen test				
Equation 1a	Number of CE(s)		Trace statistic		Critical value (5%)
$lnX = f(lnY, lnA)$	None		21.833		29.797
	At most 1		10.528		15.495
	At most 2		3.763		3.841
	Number of CE(s)		Maximum-eigen value statistic		Critical value (5%)
	None		11.305		21.132
	At most 1		6.765		14.265
	At most 2		3.763		3.841
Equation 1b	Number of CE(s)		Trace statistic		Critical value (5%)
$lnX = f(lnAL, lnA)$	None		23.939		29.797
	At most 1		10.347		15.495
	At most 2		3.665		3.841
	Number of CE(s)		Maximum-eigen value statistic		Critical value (5%)
	None		13.593		21.132
	At most 1		6.682		14.265
	At most 2		3.665		3.841
	Panel B: ARDL bounds test				
Equation 2a	Test statistic	Value	Significance	I(0)	I(1)
$lnX = f(lnY, lnA)$	F-statistic	2.949	10%	3.17	4.14
	k	2	5%	3.79	4.85
			1%	5.15	6.36
Equation 2b					
$lnX = f(lnAL, lnA)$	F-statistic	2.770			
	k	2			

Table III: Results for nonlinear cointegration tests

The table reports the results for nonlinear cointegration tests. Panel A reports the results from the Gregory-Hansen (1996) test for cointegration with regime shifts. The null hypothesis of no cointegration is test against the alternative there is cointegration with regime shifts. The lag level is chosen using the Akaike information criterion. The regime shift occurred on 1984. Panel B reports the results for nonlinear ARDL (NARDL) bounds testing procedure of Shin et al. (2014). The null hypothesis of no cointegration is tested against an alternative of cointegration with negative and positive changes in a predictor being asymmetric. k is the number of predictors in the equation. I(0) and I(1) are the critical values for the lower and upper bounds, respectively. A maximum lag of one is included in the model. We test the semi-endogenous growth theory: $\nu_t = lnX_t + ((\phi - 1)/\sigma)lnA_t$, where X is R&D expenditure, and A is TFP for Indonesia; and the Schumpeterian growth theory: $\varsigma_t = lnX_t - lnQ_t$, where Q is product quality, GDP (Y) or AL. ln is the natural logarithm. The sample period used is from 1968 to 2018. Finally, * and ** denote significance at 10 and 5% levels, respectively.

	Panel A: Gregory-Hansen test				
Equation	ADF (*t*-statistic)	Phillips (*Zt*-statistic)		Lag	Break
$lnX = f(lnY, lnA)$	-5.516**	-5.454*		1	1984
$lnX = f(lnAL, lnA)$	-5.212*	-5.363*		1	1984
	Panel B: NARDL bounds test				
Equation	Test statistic	Value	Significance	I(0)	I(1)
$lnX = f(lnY, lnA)$	F-statistic	4.834**	10%	2.72	3.77
	k	3	5%	3.23	4.35
			1%	4.29	5.61
$lnX = f(lnAL, lnA)$	F-statistic	3.269			
	k	3			

Table IV: Estimates of long-run elasticities

The table reports the long-run elasticities. In Panel A, we estimate the specification $lnX_t = \mu lnQ_t + \kappa lnA_t + e_t$, where $\kappa = (1 - \phi)/\sigma$. Schumpeterian theory hypothesises $\kappa = 0$ and $\mu = 1$, whereas $\kappa > 0$ and $\mu = 0$ under semi-endogenous growth theory, and e_t is a stationary error term (Ha and Howitt, 2007; Zachariadis, 2003, 2004). X is R&D expenditure, and A is TFP for Indonesia, Q is product quality, Y or AL. In Panel B, we estimate $\nu_t = lnX_t + ((\phi - 1)/\sigma)lnA_t$ and $\varsigma_t = lnX_t - lnQ_t$. lnX_t is the dependent variable. The predictor is either lnY or $lnAL$ in the Schumpeterian model and lnA in the semi-endogenous model. Fixed leads and lags of one are used. Long-run variance estimate are based on Newey-West fixed bandwidth. The sample period used is from 1968 to 2018. Coefficients and t-statistics are outside and inside the parenthesis, respectively. Finally, *, **, and *** denote significance at 10, 5, and 1% levels, respectively.

	Panel A: DOLS estimates of long-run elasticities		
Variable	Coefficient (*t*-statistic)	Variable	Coefficient (*t*-statistic)
lnY	0.839***(4.506)	*lnAL*	1.860***(4.865)
lnA	5.389***(3.092)	*lnA*	3.207*(1.793)
Constant	-13.573***(-4.981)	*Constant*	-10.166***(-5.599)
R^2	0.660	Adjusted R^2	0.677

	Panel B: Piecewise DOLS estimates of long-run elasticities		
Variable	Coefficient (*t*-statistic)		
lnA	4.197(1.489)	---	---
lnY	---	0.759***(3.459)	---
lnAL	---	---	1.738***(4.444)
Constant	-1.895***(-9.694)	-12.568***(-3.975)	-9.488***(-5.495)
R^2	0.083	0.446	0.557

Table V: OLS estimates of TFP growth regressions

The table reports the OLS estimates of TFP growth regressions. Panel A reports estimates of the TFP growth regression without controlling for structural breaks. Panel B reports estimates of the TFP growth regression controlling for structural breaks. X or RD is R&D expenditure; A is TFP for Indonesia; Q is product variety (i.e. Y or AL); L is labour force or employment; $PATENT$ is number of patent applications. FL is financial liberalisation; INV/GDP is investment to GDP; $TRADE$ is trade openness; and HC is human capital. The dependent variable is TFP growth (ΔlnA). ln is the natural logarithm operator. d, f, JPN, and IDN denote, respectively, domestic, foreign, Japan, and Indonesia. X/Q denotes the R&D intensity measure. For instance, RD/Y means that X is RD and Q is Y in the model. Where applicable, the remaining non-difference variables are differenced in line with the stationarity test in Table A.3. The sample period used is 1968 to 2018. The longest sample period used is 1968 to 2018. The dummy variable, DUM, takes into consideration a potential shift in the parameters due to structural changes in the economy around 1984. We test our hypothesis using a heteroskedasticity and serial correlation robust covariance matrix. Coefficients and t-statistics are outside and inside the parenthesis, respectively. Finally, *, **, and *** denote significance at 10, 5, and 1% levels, respectively.

Panel A: TFP growth regression without structural breaks						
X/Q	RD/Y		RD/AL		$PATENT/L$	
ΔlnX^d	0.003(0.299)	-0.000(-0.015)	0.436***(8.214)	0.344***(7.279)	-0.001(-0.137)	0.002(0.562)
ΔlnX^f	0.075(1.093)	0.142(1.364)	-0.299*(-1.832)	-0.116(-1.364)	1.267***(6.022)	0.725***(3.514)
$ln(X/Q)^d$	-0.002(-0.829)	0.009**(2.669)	-0.433***(-8.115)	-0.337***(-7.093)	-0.001(-0.466)	-0.004**(-2.471)
$ln(X/Q)^f$	-0.019(-0.297)	-0.123(-1.210)	0.325*(1.842)	0.178*(2.007)	-1.292***(-6.122)	-0.736***(-3.534)
$ln(A^{JPN}/A^{IDN})_{t-1}$	0.094**(2.699)	0.030(0.898)	0.002(0.046)	-0.013(-0.328)	0.038(1.102)	0.031(1.111)
FL	-0.003(-0.711)	0.016***(3.461)	0.002(0.827)	0.015**(2.169)	-0.004(-1.287)	0.009**(2.559)
$\Delta ln(INV/GDP)$	-0.974***(-15.115)	-0.905***(-9.785)	-0.450***(-5.974)	-0.505***(-6.558)	-0.889***(-11.289)	-0.897***(-14.052)
$lnTRADE$	0.008(0.547)	0.029(1.443)	-0.019**(-2.107)	-0.017(-1.838)	0.028*(1.959)	0.025**(2.098)
$\Delta lnHC$		-2.776***(-5.388)		-1.711**(-2.323)		-1.768***(-4.674)
R^2	0.769	0.893	0.868	0.932	0.865	0.911
Panel B: TFP growth regression with structural breaks						
X/Q	RD/Y		RD/AL		$PATENT/L$	
ΔlnX^d	0.003(0.257)	0.000(0.025)	0.004(0.314)	0.003(0.363)	0.002(0.450)	0.001(0.249)
ΔlnX^f	0.079(0.529)	0.150(1.499)	-0.432**(-2.345)	0.008(0.058)	1.306**(4.023)	0.691**(2.697)
$ln(X/Q)^d$	-0.005(-0.484)	0.004(0.519)	-0.003(-0.435)	-0.004(-0.837)	-0.005(-1.354)	-0.003(-1.178)
$ln(X/Q)^f$	-0.022(-0.149)	-0.129(-1.311)	0.492***(2.776)	0.031(0.216)	-1.323***(-4.094)	-0.704***(-2.744)
$ln(A^{JPN}/A^{IDN})_{t-1}$	0.096**(2.045)	0.036(1.157)	0.052***(2.683)	0.059(1.218)	0.043(1.234)	0.029(1.122)
FL	-0.002(-0.327)	0.018***(4.546)	-0.004(-0.895)	0.018**(4.034)	-0.007**(-2.369)	0.011*(1.885)
$\Delta ln(INV/GDP)$	-0.973***(-9.572)	-0.901***(-13.210)	-0.951***(-8.446)	-0.932***(-11.829)	-0.913***(-16.744)	-0.890***(-18.270)
$lnTRADE$	0.008(0.367)	0.028*(1.969)	0.002(0.101)	0.024(1.502)	0.028**(2.197)	0.024*(1.995)
$\Delta lnHC$		-2.793***(-7.837)		-2.649***(-6.474)		-1.838***(-3.453)
DUM	-0.005(-0.299)	-0.010(-0.959)	0.011(1.148)	-0.013(-1.673)	0.014(1.335)	-0.004(-0.516)
R^2	0.764	0.893	0.772	0.889	0.866	0.909

Table VI: OLS estimates of extended TFP growth regression

The table reports the OLS estimates of the extended TFP growth regressions. Here, we extend the simple TFP growth regression to account for the role of Islamic stocks in R&D expenditure. Panel A reports estimates of the TFP growth regression when lag R&D expenditure growth, ΔlnX^d_{t-1}, Islamic stock price growth (return), ΔlnP_t, and lag of Islamic stock price growth (return), ΔlnP_{t-1}, are used as predictors of domestic R&D expenditure growth, ΔlnX^d_t for the period 1968–2018. Panel B reports estimates of the TFP growth regression by restricting the sample period to 1981–2018 period (when Islamic stocks became relevant). In both panels, we excluded investment to GDP, INV/GDP, trade openness, $TRADE$, and human capital, HC, because they are highly correlated with the Islamic stock price return. X or RD is R&D expenditure; A is TFP for Indonesia; Q is product variety (i.e. Y or AL); L (L^*) is labour force or employment (university labour force with university education); $PATENT$ is number of patent applications. The dependent variable is TFP growth (ΔlnA). ln is the natural logarithm operator. d, f, JPN, and IDN denote, respectively, domestic, foreign, Japan, and Indonesia. X/Q denotes the R&D intensity measure included in the TFP growth regression. For instance, RD/Y means that X is RD and Q is Y in the model. Where applicable, the remaining non-difference variables are differenced in line with the stationarity test in Table A.3. The longest sample period used is 1968 to 2018. The longest sample period used is 1968 to 2018. The dummy variable, DUM, takes into consideration a potential shift in the parameters due to structural changes in the economy around 1984. We test our hypothesis using a heteroskedasticity and serial correlation robust covariance matrix. Coefficients and *t*-statistics are outside and inside the parenthesis, respectively. Finally, *, **, and *** denote significance at 10, 5, and 1% levels, respectively.

	Panel A: R&D expenditure growth replaced by predictors ΔlnX^d_{t-1}, ΔlnP_t and ΔlnP_{t-1}				
	(1968-2018)			(1976-2018)	
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^*	$PATENT/L^*$
ΔlnX^d_{t-1}	0.051***(3.517)	0.037(1.262)	-0.004(-1.076)	0.046(1.292)	-0.014(-1.319)
ΔlnP_t	0.035***(6.161)	0.037*(1.857)	0.017**(2.050)	0.042(1.675)	0.026***(3.174)
ΔlnP_{t-1}	0.006(0.310)	0.013(0.827)	0.000(0.029)	0.015(0.620)	-0.009(-0.921)
ΔlnX^f	0.035(0.254)	-0.594(-1.617)	1.709***(5.199)	-0.782(-1.380)	-0.037(-0.150)
$ln(X/Q)^d$	-0.023***(-5.360)	0.011(0.848)	0.003(1.555)	0.017(1.187)	0.012(1.659)
$ln(X/Q)^f$	-0.144***(-7.528)	0.547(1.472)	-1.764***(-5.014)	0.765(1.567)	-0.154***(-5.641)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.173***(-4.140)	-0.222***(-3.116)	-0.186**(-2.425)	-0.154***(-3.646)	-0.119***(-6.457)
FL	0.003(0.376)	-0.001(-0.099)	-0.007(-1.250)	-0.007(-1.222)	-0.003(-0.259)
DUM	0.015(0.412)	0.002(0.091)	-0.004(-0.755)	0.018*(1.769)	-0.021(-1.761)
R^2	0.311	0.303	0.429	0.289	0.260
	Panel B: R&D expenditure growth replaced by predictors ΔlnX^d_{t-1}, ΔlnP_t and ΔlnP_{t-1}				
	(1981-2018)				
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^*	$PATENT/L^*$
ΔlnX^d_{t-1}	0.079**(2.644)	0.062(1.059)	-0.014***(-3.718)	0.060*(1.935)	-0.029***(-5.742)
ΔlnP_t	0.049***(3.479)	0.047*(1.998)	0.031***(4.820)	0.048*(1.946)	0.035***(3.245)
ΔlnP_{t-1}	-0.012(-1.596)	0.008(0.322)	-0.014**(-2.554)	0.011(0.402)	-0.028(-1.594)
ΔlnX^f	0.569(1.512)	-0.594(-0.294)	1.355***(12.826)	-0.628(-1.124)	-0.066(-0.603)
$ln(X/Q)^d$	-0.034***(-5.443)	0.014(0.474)	0.017*(1.815)	0.025(0.818)	0.024**(2.681)
$ln(X/Q)^f$	-0.576(-1.228)	0.586(0.275)	-1.472***(-11.450)	0.625(1.187)	-0.114***(-2.969)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.058**(-2.618)	-0.132(-1.694)	-0.137***(-8.628)	-0.134(-1.451)	-0.081**(-2.386)
FL	0.004(0.920)	-0.005(-0.158)	0.010(0.688)	-0.005(-0.650)	-0.001(-0.141)
DUM	0.001(0.055)	0.034***(3.148)	-0.011(-0.419)	0.032(1.039)	0.004(0.4211)
R^2	0.373	0.313	0.492	0.322	0.339

Table VII: OLS estimates of extended TFP growth regression with alternative finance indicators

The table reports the OLS estimates of the extended TFP growth regressions with alternative finance indicators. Here, we extend the simple TFP growth regression to account for the role of the general stock market and banks in R&D expenditure. Panel A1 reports estimates of the TFP growth regression when lag R&D expenditure growth, ΔlnX_{t-1}^{d}, Jakarta stock price growth (return), $\Delta lnJP_t$, and lag of Jakarta stock price growth (return), $\Delta lnJP_{t-1}$, are used as predictors of domestic R&D expenditure growth, ΔlnX_t^d for the period 1977–2018. Panel A2 does the same thing but replaces R&D expenditure growth by predictors ΔlnX_{t-1}^{d}, growth in market capitalization to GDP, $\Delta lnCAP_t$, and lag of $\Delta lnCAP_t$ ($\Delta lnCAP_{t-1}$). Panel B2 reports estimates of the TFP growth regression when lag R&D expenditure growth, ΔlnX_{t-1}^{d}, bank assets to GDP growth, $\Delta lnBA_t$, and lag of bank assets to GDP growth, $\Delta lnBA_{t-1}$, are used as predictors of domestic R&D expenditure growth, ΔlnX_t^d for the period 1977–2018. Panel B2 does the same thing but replaces R&D expenditure growth by predictors ΔlnX_{t-1}^{d}, bank loans to GDP growth, $\Delta lnBL_t$, and lag of $\Delta lnBL_t$ ($\Delta lnBL_{t-1}$). In both panels, we excluded investment to GDP, INV/GDP, trade openness, $TRADE$, and human capital, HC, because they are highly correlated with the stock and bank indicators. X or RD is R&D expenditure; A is TFP for Indonesia; Q is product variety (i.e. Y or AL); L (L^*) is labour force or employment (university labour force with university education); $PATENT$ is number of patent applications. The dependent variable is TFP growth (ΔlnA). ln is the natural logarithm operator. d, f, JPN, and IDN denote, respectively, domestic, foreign, Japan, and Indonesia. X/Q denotes the R&D intensity measure included in the TFP growth regression. For instance, RD/Y means that X is RD and Q is Y in the model. Where applicable, the remaining non-difference variables are differenced in line with the stationarity test in Table A.3. The longest sample period used is 1968 to 2018. The dummy variable, DUM, takes into consideration a potential shift in the parameters due to structural changes in the economy around 1984. We test our hypothesis using a heteroskedasticity and serial correlation robust covariance matrix. Coefficients and *t*-statistics are outside and inside the parenthesis, respectively. Finally, *, **, and *** denote significance at 10, 5, and 1% levels, respectively.

	Panel A1: R&D expenditure growth replaced by predictors ΔlnX_{t-1}^{d}, $\Delta lnJP_t$ and $\Delta lnJP_{t-1}$				
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^*	$PATENT/L^*$
ΔlnX_{t-1}^{d}	0.051*(1.897)	-0.005(-0.879)	-0.001(-0.093)	0.026(1.505)	-0.013(-0.584)
$\Delta lnJP_t$	0.012(0.637)	0.015**(2.223)	-0.001(-0.084)	0.016*(1.834)	0.004(0.206)
$\Delta lnJP_{t-1}$	0.013(0.631)	0.035**(2.529)	0.016**(2.217)	0.031**(2.608)	0.028**(2.389)
ΔlnX^f	0.086(0.476)	-0.953**(-2.239)	1.625***(9.914)	-0.749**(-2.287)	-0.037(-0.291)
$ln(X/Q)^d$	-0.006(-0.233)	0.044(1.633)	0.001(0.198)	0.015(0.576)	0.009(0.969)
$ln(X/Q)^f$	-0.222*(-1.993)	1.049**(2.190)	-1.777***(-10.531)	0.763*(1.920)	-0.158***(-9.326)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.264**(-2.347)	-0.285***(-3.599)	-0.169***(-12.332)	-0.143***(-4.579)	-0.113***(-2.972)
FL	-0.004(-0.401)	0.010(0.502)	-0.005(-0.626)	-0.008(-1.046)	-0.003(-0.371)
DUM	0.032(0.821)	-0.001(-0.027)	-0.014(-1.003)	0.004(0.343)	-0.029(-1.175)
R^2	0.314	0.369	0.439	0.281	0.285
	Panel A2: R&D expenditure growth replaced by predictors ΔlnX_{t-1}^{d}, $\Delta lnCAP_t$ and $\Delta lnCAP_{t-1}$				
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^*	$PATENT/L^*$
ΔlnX_{t-1}^{d}	0.043(1.695)	-0.004(-0.474)	-0.003(-0.282)	0.030***(4.602)	-0.012(-1.342)
$\Delta lnCAP_t$	0.010(0.906)	0.011***(3.258)	0.004(0.550)	0.011***(6.450)	0.006(0.631)
$\Delta lnCAP_{t-1}$	0.023**(2.207)	0.029**(2.109)	0.023*(1.860)	0.027***(7.724)	0.029***(5.159)
ΔlnX^f	0.035(0.209)	-0.737***(-4.217)	1.285***(5.563)	-0.538***(-3.545)	-0.009(-0.039)
$ln(X/Q)^d$	0.007(0.279)	0.046**(2.089)	0.005(0.529)	-0.003(-0.258)	0.011*(1.948)
$ln(X/Q)^f$	-0.109(-0.917)	0.867***(3.778)	-1.424***(-6.409)	0.561***(3.227)	-0.148***(-4.577)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.195*(-1.747)	-0.278***(-5.038)	-0.148***(-3.809)	-0.134***(-2.911)	-0.100(-1.192)
FL	-0.014(-1.230)	0.004(0.275)	-0.007(-0.756)	-0.015***(-5.154)	-0.010(-1.131)
DUM	0.039(1.025)	0.015(1.269)	-0.013(-0.741)	0.018**(2.657)	-0.015(-0.620)
R^2	0.401	0.515	0.539	0.409	0.441

	Panel B1: R&D expenditure growth replaced by predictors ΔlnX_{t-1}^d, $\Delta lnBA_t$ and $\Delta lnBA_{t-1}$				
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^*	$PATENT/L^*$
ΔlnX_{t-1}^d	0.038*(1.758)	0.014(0.387)	0.001(0.212)	0.033(1.058)	-0.008(-0.569)
$\Delta lnBA_t$	0.121*(1.718)	0.185***(3.508)	0.112**(2.574)	0.191***(3.671)	0.153***(2.958)
$\Delta lnBA_{t-1}$	-0.094(-1.497)	-0.030(-0.669)	-0.092**(-2.487)	-0.122**(-2.579)	-0.089**(-2.185)
ΔlnX^f	0.016(0.114)	-0.661(-1.531)	1.873***(3.946)	-0.647(-1.665)	-0.013(-0.083)
$ln(X/Q)^d$	-0.012(-0.640)	0.019(1.529)	-0.001(-0.400)	-0.010(-0.796)	0.008(1.080)
$ln(X/Q)^f$	-0.157*(-1.726)	0.583(1.290)	-1.920***(-3.931)	0.636(1.504)	-0.159***(-7.651)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.218***(-2.842)	-0.323***(-6.277)	-0.211***(-9.517)	-0.198***(-5.494)	-0.157***(-3.743)
FL	-0.002(-0.189)	-0.005(-0.357)	-0.011*(-1.755)	-0.010(-0.925)	-0.006(-0.795)
DUM	0.029(0.793)	-0.008(-0.467)	0.006(0.899)	0.012(0.757)	-0.018(-1.223)
R^2	0.336	0.362	0.483	0.348	0.323
	Panel B2: R&D expenditure growth replaced by predictors ΔlnX_{t-1}^d, $\Delta lnBL_t$ and $\Delta lnBL_{t-1}$				
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^*	$PATENT/L^*$
ΔlnX_{t-1}^d	0.033(1.507)	0.012(0.779)	0.000(0.083)	0.023*(1.735)	-0.006(-0.467)
$\Delta lnBL_t$	0.046(1.147)	0.065***(4.419)	0.043**(2.316)	0.065***(7.312)	0.075***(3.751)
$\Delta lnBL_{t-1}$	-0.032(-0.827)	-0.018(-1.680)	-0.044**(-2.419)	-0.036***(-9.262)	-0.057**(-2.078)
ΔlnX^f	0.011(0.098)	-0.531*(-1.899)	1.828***(4.782)	-0.670***(-2.894)	-0.009(-0.049)
$ln(X/Q)^d$	-0.014(-1.146)	0.015(1.373)	0.002(0.386)	0.007(0.573)	0.010(1.403)
$ln(X/Q)^f$	-0.159*(-1.919)	0.474*(1.800)	-1.887***(-4.645)	0.661**(2.487)	-0.204***(-5.239)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.210***(-3.065)	-0.278***(-6.194)	-0.198***(-10.663)	-0.188***(-6.387)	-0.131**(-2.557)
FL	0.000(-0.001)	-0.002(-0.140)	-0.007(-0.797)	-0.008(-1.437)	-0.002(-0.175)
DUM	0.027(1.013)	-0.009(-0.594)	-0.003(-0.243)	0.009(1.000)	-0.022(-1.525)
R^2	0.286	0.282	0.451	0.259	0.306

Table VIII: OLS estimates of extended TFP growth regression with our composite finance indicator

The table reports the OLS estimates of the extended TFP growth regressions with our composite finance indicator. We construct the composite finance indicator by combining Islamic stock price return, Jakarta composite index return, market capitalisation to GDP, and bank assets and loans to GDP ratios using principal component analysis. Here, we extend the simple TFP growth regression to account for the role of the general financial market (i.e. the stock market and banks) in R&D expenditure. We report estimates of the TFP growth regression when lag R&D expenditure growth, ΔlnX_{t-1}^{d}, growth in the financial market, $\Delta lnFIN_{t}$, and lag of growth in the financial market, $\Delta lnFIN_{t-1}$, are used as predictors of domestic R&D expenditure growth, ΔlnX_{t}^{d} for the period 1977–2018. We excluded investment to GDP, INV/GDP, trade openness, $TRADE$, and human capital, HC, because they are highly correlated with the stock and bank indicators, and by extension, the composite finance indicator. X or RD is R&D expenditure; A is TFP for Indonesia; Q is product variety (i.e. Y or AL); L (L^{*}) is labour force or employment (university labour force with university education); $PATENT$ is number of patent applications. The dependent variable is TFP growth (ΔlnA). ln is the natural logarithm operator. d, f, JPN, and IDN denote, respectively, domestic, foreign, Japan, and Indonesia. X/Q denotes the R&D intensity measure included in the TFP growth regression. For instance, RD/Y means that X is RD and Q is Y in the model. Where applicable, the remaining non-difference variables are differenced in line with the stationarity test in Table A.3. The longest sample period used is 1968 to 2018. The dummy variable, DUM, takes into consideration a potential shift in the parameters due to structural changes in the economy around 1984. We test our hypothesis using a heteroskedasticity and serial correlation robust covariance matrix. Coefficients and t-statistics are outside and inside the parenthesis, respectively. Finally, *, **, and *** denote significance at 10, 5, and 1% levels, respectively.

Variable	Coefficient (t-statistic)				
X/Q	RD/Y	RD/AL	$PATENT/L$	RD/AL^{*}	$PATENT/L^{*}$
ΔlnX_{t-1}^{d}	0.061*(1.950)	0.021(1.129)	-0.006(-0.648)	0.041*(2.019)	-0.019(-1.665)
$\Delta lnFIN_{t}$	0.046*(2.016)	0.041**(2.351)	0.033*(2.006)	0.049**(2.313)	0.046(1.646)
$\Delta lnFIN_{t-1}$	-0.020(-1.434)	0.006(0.493)	-0.017(-1.390)	0.002(0.186)	-0.001(-0.079)
ΔlnX^{f}	0.143(1.136)	-0.739(-1.478)	1.642***(5.414)	-0.633*(-1.748)	-0.038(-0.258)
$ln(X/Q)^{d}$	-0.022(-1.608)	0.030(1.328)	0.000(-0.011)	0.013(0.562)	-0.001(-0.168)
$ln(X/Q)^{f}$	-0.232**(-2.154)	0.801(1.457)	-1.771***(-5.654)	0.644(1.676)	-0.131***(-4.548)
$ln(A^{JPN}/A^{IDN})_{t-1}$	-0.274***(-3.126)	-0.296**(-2.655)	-0.189***(-5.207)	-0.201***(-3.048)	-0.186**(-2.352)
FL	-0.002(-0.202)	0.001(0.037)	-0.009(-1.254)	-0.013(-1.570)	-0.009(-1.456)
DUM	0.018(0.785)	0.004(0.176)	-0.012(-1.471)	0.008(0.578)	-0.028**(-2.328)
R^2	0.393	0.381	0.470	0.345	0.321

Appendix

Table A.1: Summary of the literature

The table summarises the empirical literature on semi-endogenous and Schumpeterian growth models. Panel A summarises single country studies, while Panel B summarises multi-country studies.

Panel A: single country studies				
Authors	Sample & data	Models/theory tested	methods	findings
Zachariadis (2003)	US (1963–1988)	Schumpeterian growth	System of linear equation; Three-stage least squares	Support
Laincz and Peretto (2006)	US (1964–2001)	Schumpeterian growth	Linear cointegration model (Johansen test)	Support
Ha and Howitt (2007)	US (1953–2000)	Semi-endogenous growth; Schumpeterian growth	Linear cointegration model (Johansen test)	No support; Support
Madsen, Ang and Banerjee (2010)	Britain (1620-2006)	Schumpeterian growth	Linear unit roots and cointegration tests	No support; Support
Madsen, Saxena, and Ang (2010)	India (1950–2005)	Semi-endogenous growth; Schumpeterian growth	Linear unit roots and cointegration tests	No support; Support
Venturini (2012)	US (1973-1996)	Schumpeterian growth	Simultaneous equations	Support
Panel B: Multi-country studies				
Authors	Sample & data	Models/theory tested	methods	findings
Griffith, Redding and Van Reenen (2003)	12 OECD countries (1974-1990)	Schumpeterian growth	Linear dynamic panel models	Support
Griffith, Redding and Van Reenen (2004)	12 OECD countries (1970-1992)	Schumpeterian growth	Linear dynamic panel models	Support
Zachariadis (2004)	10 OECD countries (1971-1995)	Schumpeterian growth	Seemingly unrelated regression models	Support
Ulku (2007a)	26 OECD and 15 non-OECD countries (1981-1997)	Schumpeterian growth	Fixed effects and difference GMM	Support
Ulku (2007b)	17 OECD countries (1960-1997)	Schumpeterian endogenous growth	Linear dynamic panel models (system GMM and difference GMM)	Support
Madsen (2008)	21 OECD countries (varying time periods but mostly between 1965-2004)	Semi-endogenous growth; Schumpeterian growth	Linear panel cointegration models	No support; Support

Ang and Madsen (2011)	China, India, Japan, Korea, Singapore, and Taiwan (1953-2006)	Semi-endogenous growth; Schumpeterian growth	Linear panel unit roots and cointegration tests	Limited support; Support
Barcenilla-Visús, López-Pueyo, and Sanaú-Villarroya (2014)	Finland, France, Italy, USA, Canada and Spain (1979–2001)	Semi-endogenous growth; Schumpeterian growth	Linear panel unit roots and cointegration tests	Support; Support

Table A.2: Variables, definitions, and sources

This table describes each variable, its calculation (where applicable) and its source. These variables are used in testing the endogenous growth models.

Variable name	**Variable definition**	**Source & calculation**
L	Labour or employment. This the number of persons engaged (in millions)	Penn World Tables version 9.0.
L^*	Total labour force with university level education (1976–2018)	Statistics Indonesia
HC	Human capital index based on the average years of schooling from Barro and Lee (2013) database.	Penn World Tables version 9.0
$LABSH$	Share of labour compensation in GDP at current national prices	Penn World Tables version 9.0
Y	Real GDP at constant 2011 national prices (in mil. 2011US$)	Penn World Tables version 9.0
A	Total factor productivity (TFP) at constant national prices (2011=1)	Penn World Tables version
FL	Financial openness index, available from 1970	Ito-Chinn (2006) database
$PATENT$	Patent applications, residents	World Intellectual Property Organization (WIPO) (https://www3.wipo.int/ipstats)
RD	R&D expenditure by government	Indonesian Institute of Sciences (LIPI); Japan Statistical Yearbook (various issues; www.stat.go.jp/english/data) (observations for 1968–2006 are taken from Ang and Madsen, 2011). For Indonesia, we used a simple average of adjacent observations, if an observation is missing in-between. We converted observations from local currency to US$ using rupiah–US$ exchange rate. Our treatment of the remaining observation for Japan follows Madsen and Ang.
RD/Y	R&D expenditure as a percentage of GDP	Indonesian Institute of Sciences (LIPI); Japan Statistical Yearbook (various issues; www.stat.go.jp/english/data) (observations for 1968–2006 are taken from Ang and Madsen, 2011). For Indonesia, we used a simple average of adjacent observations, if an observation is missing in-between. Observations for Japan from 2007 to 2018 are computed using R&D and GDP data from the same source.
RD/AL	Government R&D Expenditure as a percentage of TFP adjusted product variety.	R&D data comes from Indonesian Institute of Sciences (LIPI) and Japan Statistical Yearbook (various issues; www.stat.go.jp/english/data) (observations for 1968–2006 are taken from Ang and Madsen, 2011); data on TFP (A) and labour (L) are from Penn World Tables version 9.0
$PATENT/L$	Patent applications, residents divided by product variety	Data on patent applications are from World Intellectual Property Organization (WIPO); data

		on product variety or labour (L) are from Penn World Tables version 9.0
A^{JPN}/A^{IDN}	Distance to frontier or Indonesia TFP at constant national prices (2011=1) divided Japan TFP at constant national prices (2011=1)	TFP for Indonesia and Japan are both from Penn World Tables version 9.0
P	Equal-weighted annual Islamic stock prices (2011 = 1).	Narayan, Narayan, Phan, Thuraisamy, and Tran (2017); Datastream. The index is computed as the simple arithmetic average of the prices of all the stocks each year relative to the 2011 value.
JP	Jakarta Stock Exchange composite index	Global Financial Database
CAP	Jakarta Stock Exchange market capitalization to GDP	Global Financial Database
BA	Bank assets to GDP	Observations for the period 1977–1986 is from Statistik Ekonomi dan Keuangan Indonesia and for 1987–2018 is from Statistik Perbankan Indonesia.
BL	Bank loans to GDP	Observations for the period 1977–1986 is from Statistik Ekonomi dan Keuangan Indonesia and for 1987–2018 is from Statistik Perbankan Indonesia.
FIN	Composite finance indicator	We compute the composite finance indicator using principal component analysis. The indicator is composed of the logarithm of P, JP, CAP, BA, and BL.
INV/GDP	Capital stock (investment) to GDP.	Penn World Tables version 9.0. This is computed as capital stock at constant 2011 national prices (in mil. 2011US$) divided by real GDP at constant 2011 national prices (in mil. 2011US$)
$TRADE$	Trade openness, measured by the sum of exports and imports over GDP	World Development Indicators. They measured it as "Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product."

Table A.3: Stationarity test of the remaining variables

The table shows the stationarity test of the remaining variables in complementary TFP regressions. For this exercise, we use the Narayan-Popp (NP, 2010) test. The M1 and M2 statistics are compared with critical values tabulated in NP. Lags for the test are based on the procedure suggested by Hall (1994). The NP test accounts for two structural breaks. We include only the intercept. *ln* denotes the natural logarithm operator. TB1, TB2, and k denote, respectively, the first and second structural break dates, and optimal lag selected. The variables are as defined in Table A.2. ln is the natural logarithm operator. JPN, IDN, and f denote, respectively, Japan, Indonesia, and foreign. The sample period used is from 1968 to 2018.

	Narayan-Popp (2010) test									
	M1					M2				
Variable	Test statistic	TB1	TB2	k	Status	Test statistic	TB1	TB2	k	Status
lnP	-3.020	1983	1991	0	I(1)	-2.251	1983	1991	0	I(1)
$lnJP$	-2.379	1987	2002	0	I(1)	-1.469	1987	1990	0	I(1)
$lnCAP$	-2.107	1988	2008	0	I(1)	-2.313	1990	1996	0	I(1)
$lnBA$	-2.408	1978	1997	5	I(1)	-2.210	1991	1997	1	I(1)
$lnBL$	-4.323	1986	1998	0	I(0)	-2.442	1981	1998	0	I(1)
$lnFIN$	-2.199	1987	1992	0	I(1)	-2.175	1990	1993	0	I(1)
$lnHC$	2.214	1980	1990	4	I(1)	1.707	1980	1983	4	I(1)
$lnPATENT^f$	-2.555	1981	1983	0	I(1)	-2.174	1981	1984	0	I(1)
$ln(RD/Y)^f$	-3.126	2000	2006	0	I(1)	-2.464	2000	2006	0	I(1)
$ln(RD/AL)^f$	-2.344	2001	2006	0	I(1)	-1.447	2001	2006	0	I(1)
$ln(PATENT/L)^f$	-2.282	1981	1983	0	I(1)	-1.742	1981	1984	0	I(1)
$ln(RD/AL^*)^d$	-2.005	1992	2005	0	I(1)	-3.779	1992	2009	1	I(1)
$ln(PATENT/L^*)^d$	-4.398	1990	1995	0	I(0)	-3.849	1990	1994	0	I(1)
$\ln(INV/GDP)$	1.006	1981	1997	0	I(1)	-0.3135	1981	1997	0	I(1)
$lnTRADE$	-2.501	1997	1999	5	I(1)	-5.988	1984	1997	3	I(0)
$ln(A^{JPN}/A^{IDN})$	-4.417	1984	1997	3	I(0)	-4.091	1981	1997	3	I(0)

Table A.4: Bivariate causality test results

The table shows the bivariate causality test results between variables. We include two lags in each bivariate model. The sample period used is from 1968 to 2018.

Null Hypothesis:	*F*-Statistic	*p*-value
lnX does not Granger Cause lnA	1.307	0.281
lnA does not Granger Cause lnX	1.204	0.310
$lnPATENT$ does not Granger Cause lnA	0.311	0.735
lnA does not Granger Cause $lnPATENT$	2.761	0.073
lnP does not Granger Cause lnA	0.120	0.887
lnA does not Granger Cause lnP	0.387	0.681
$lnJP$ does not Granger Cause lnA	0.969	0.390
lnA does not Granger Cause $lnJP$	0.692	0.507
$lnCAP$ does not Granger Cause lnA	4.084	0.026
lnA does not Granger Cause $lnCAP$	0.421	0.660
$lnBA$ does not Granger Cause lnA	0.864	0.428
lnA does not Granger Cause $lnBA$	0.044	0.957
$lnBL$ does not Granger Cause lnA	0.322	0.727
lnA does not Granger Cause $lnBL$	15.597	0.000
$lnFIN$ does not Granger Cause lnA	0.148	0.863
lnA does not Granger Cause $lnFIN$	0.493	0.615
$lnPATENT$ does not Granger Cause lnX	1.632	0.207
lnX does not Granger Cause $lnPATENT$	2.332	0.109
lnP does not Granger Cause lnX	0.247	0.783
lnX does not Granger Cause lnP	3.788	0.031
$lnJP$ does not Granger Cause lnX	1.467	0.244
lnX does not Granger Cause $lnJP$	1.208	0.311
$lnCAP$ does not Granger Cause lnX	0.942	0.399
lnX does not Granger Cause $lnCAP$	1.422	0.255
$lnBA$ does not Granger Cause lnX	2.648	0.082
lnX does not Granger Cause $lnBA$	0.131	0.877
$lnBL$ does not Granger Cause lnX	0.555	0.578
lnX does not Granger Cause $lnBL$	1.258	0.294
$lnFIN$ does not Granger Cause lnX	0.737	0.486
lnX does not Granger Cause $lnFIN$	0.787	0.463
lnP does not Granger Cause $lnPATENT$	1.199	0.311
$lnPATENT$ does not Granger Cause lnP	2.547	0.089
lnP does not Granger Cause $lnPATENT$	0.406	0.669
$lnPATENT$ does not Granger Cause $lnJP$	3.650	0.036
$lnCAP$ does not Granger Cause $lnPATENT$	3.936	0.029
$lnPATENT$ does not Granger Cause $lnCAP$	1.231	0.305
$lnBA$ does not Granger Cause $lnPATENT$	1.097	0.342
$lnPATENT$ does not Granger Cause $lnBA$	0.891	0.417
$lnBL$ does not Granger Cause $lnPATENT$	0.724	0.490
$lnPATENT$ does not Granger Cause $lnBL$	1.546	0.224
$lnFIN$ does not Granger Cause $lnPATENT$	0.197	0.822
$lnPATENT$ does not Granger Cause $lnFIN$	1.345	0.274