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GOVERNMENT SPENDING ON TERTIARY EDUCATION, KNOWLEDGE, TECHNOLOGY, AND ECONOMIC GROWTH *

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This study examines the role of government spending on tertiary education in promoting economic growth through knowledge creation and technology for panel data from 71 countries (1998-2014). This transmission channel is supported by Granger non-causality tests on high-income groups only. Both all panels (all countries) and upper-middle-income groups demonstrated direct causation from the government's support of tertiary education to economic growth and vice versa. Additionally, the lower-middle-income group acknowledged the importance of government spending on tertiary education to stimulate output via interaction between knowledge and technology. These findings remain feasible with the inclusion of the governance variable. This study adds new findings and offers relevant policy insights, especially in the era of a knowledge-based economy.

Keywords: Economic Growth, Government Spending, Knowledge, Technology, Tertiary Education
JEL Classification: C33, H52, I28, O11

1. INTRODUCTION

"Higher education is an important form of investment in human capital. It can be regarded as a high level or a specialised form of human capital, the contribution of which to economic growth is very significant." (Tilak, 2003, p.152)

Tertiary education is considered a *necessary and sufficient* condition 'for the effective creation, dissemination, and application of knowledge for building technical and professional capacity' (Taylor, 2008, p.89). Indeed, new knowledge is a major

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source of competitive advantage, and it has been adopted as the most powerful driver of social and economic progress. Mueller (2006) adds that "*knowledge is recognised as a crucial element of economic growth in addition to physical capital and labour*" given that it can be commercially transformed into products and processes (i.e., value-added). Conversely, the long-run economic benefits of industrial innovation and university research are largely channeled to the public and consumers worldwide in the form of lower prices and the availability of a greater variety of goods (Hoffman and Hill, 2009, p. 11). Accordingly, "*…research activities of universities produce knowledge… that advances science and technology and results in innovation*" (Hoffman and Hill, 2009, p.1 and p.10). Universities are public entities that contribute to technological advance through the production and dissemination of knowledge, as well as the education of students (Feldman and Kogler, 2007, p.15).[1] It eventually outlines the connectedness among tertiary education, knowledge, innovation, and economic growth. Thus, this study aims to ascertain their possible directions of causation, that is which appears (comes) first before other(s).

This study is motivated by a need to ascertain the role of government spending on tertiary education on economic growth by considering a transmission mechanism. Government spending on tertiary education creates new knowledge and accelerates innovation and technology advancement that spurs economic growth. The findings from this study will answer the question, "*What do we know about government spending on tertiary education and economic growth?*" This research question has not been succinctly answered in past studies as the possible transmission channels (i.e., the creation of knowledge and technology) are ignored as discussed in Section 2. Information from prior research is either insufficient (i.e weak support) or inconclusive to answer this question based on *ad hoc* bivariate or multivariate frameworks. This study adds to the existing literature by primarily looking at government spending on tertiary education in spurring economic growth with the mediating role of knowledge creation that invents new technology. Hence, this study contributes to the existing literature with new findings and inspires further research. The inter-linkages among these variables have been tested more systematically by employing Granger non-causality tests for a panel data of 71 countries spanning between 1998 and 2014, including four income groups as classified by the World Bank. This study shows that the hypothesis holds only for the high-income group. The lower-middle-income group reflects the importance of government spending on tertiary education to stimulate output indirectly via knowledge creation which interacts with technology. Indeed, this study considers the institution (institutional quality) in mediating the association between government spending on tertiary education and economic growth. Overall, governance does not alter these findings.

The interest of this study is two-edged. Firstly, it discovers more generalised

[1] They have reviewed a large number of studies on the contribution of universities, in particular the relationships between scientific research, technological innovation, and economic growth creation (p.15-16).

findings instead of the country- or regional-specified in past studies. Secondly, it is a cross-discipline study among macroeconomics, education economics and growth economics that may interest the respective economists, researchers, and policymakers. This study has important policy implications, especially regarding fiscal policy to tertiary education expenditure, intellectual property rights protection to new knowledge created and technology invented, and transmission of technology growth.

This study is structured as follows. Section 2 gives a brief review of the selected past studies on the related topics. Section 3 presents the conceptual framework, variables, data, and testing methods. Section 4 reports the empirical results and discussion. Section 5 covers the conclusions and policy implications.

2. LITERATURE REVIEW

Research on the impact of government spending on [tertiary] education in spurring economic growth via knowledge creation and technology development remains exploratory. Most studies considered only a pairwise association between government spending on tertiary education, knowledge, technology, and economic growth, and omitted knowledge and technology transmission channels. Hence, this study fills the research gaps.

2.1. Government Spending on Education and Economic Growth

Keynes (1936) acknowledged the role of government spending in promoting economic growth and development. Blankenau et al. (2007) found a robust positive relationship between government education expenditures and per capita output growth for high-income countries between 1960 and 2000, but not for poor-and middle-income countries. Meanwhile, the general equilibrium model from a study conducted by Van Heerden et al. (2007) revealed that government spending on higher education increases the supply of professionals, thereby leading to higher total factor productivity and contributing to economic growth. Chakraborty and Krishnankutty (2012) found that education expenditures positively explain the economic growth of the states in India (2004-2010). However, a negative implication was observed for the percentage of expenditure on education with aggregate data and non-special category states, except for Northeastern states. Grdinic (2014) concluded that public expenditures on education, including the size of the tertiary-educated workforce and the number of researchers, positively impact economic growth for selected EU members and former Soviet Union countries between 2000 and 2011. Using a panel data of 22 high and 19 upper-middle-income countries (1970-2010), Dufrechou (2016) posited that higher education does promote economic growth but varies from the prevailing “tertiary tilt” in public education spending. Scientific and technological skills produced by the education system increase productivity and improve the ability of the countries to increase their income.

2.2. Education and Economic Growth

Education has long been considered as input for human capital that contributes to productivity and economic growth. Tilak (2003) found that higher education contributed positively to economic growth in 49 Asia and Pacific countries. Ozsoy (2008) documented that education is a widely accepted instrument to spur economic development, and it is significantly interrelated with income to generate public and private benefits. Huang and Li (2010) found that the number of enrolments at education institutions and GDP are cointegrated (i.e., having a long-run relationship) - both variables are interdependent. In other words, education generates China's economic growth and *vice versa* for the period between 1952 and 2004. Masayuki (2012) discovered that highly-educated workers in Japan contributed to innovation while tertiary education is critical to vitalise the country's economy. Using the West Virginia data from 2000 to 2010, Bashir et al. (2013) reported a positive relationship between educational development and income growth. Ada and Acaroglu (2014) employed an augmented Solow model and observed that improvement in human capital quality (proxied by health and education) increases per capita GDP for 15 the Middle East and North African countries from 1990 to 2011. Likewise, Sbaouelgi (2016) confirmed that higher education (human capital) and economic growth (per capita GDP) are cointegrated for South Korea but not for Tunisia and Morocco. South Korea has a high level of human capital and high economic development for the period between 1960 and 2011. Oancea et al. (2017) reported that higher education is positively associated with economic growth for the Czech Republic and Romania from the 1980 to 2013 period.

2.3. R&D - Innovation and Economic Growth

Bilbao-Osorio and Rodriguez-Pose (2004) found that R&D investment and higher education in peripheral regions of the European Union (EU) are positively associated with innovation (number of patent applications), and in turn allow the transformation of innovation into economic growth. Zachariadis (2004) concluded that aggregate R&D intensity (than of manufacturing sector) has a positive influence on productivity, including the output of 10 OECD countries for the period between 1971 and 1995. Goel et al. (2008) observed a larger role of federal R&D (relative to non-federal R&D) in generating growth, whereas the defence R&D has a stronger impact than that of non-defence R&D for the 1953 to 2000 period. Surprisingly, a study by Samimi and Alerasoul (2009) based on a simplified Cobb-Douglas production function rejects that R&D (share of government spending on research in GDP, number of researchers per one million population, and scientific output) has a positive implication on economic growth for 30 developing countries for the period of 2000 to 2006. Bayarcelik and Tasel (2012) found that R&D expenditure and researchers employed in R&D departments positively affected Turkey's economic growth for the period of 1998 to 2010. However, a reversed impact was demonstrated by the patent proxy. Gumus and Celikay (2015) concluded that R&D expenditure positively explained the long-run economic growth based on panel data of 52 countries (1996-2010), but weak support is observed for developing countries in the short-run than in the long-run. Sahin (2015) confirmed a positive relationship between innovation (R&D expenditures) and economic growth for a panel data of 15 OECD countries (1990-2013) in which the production of advanced technology increases their ability to compete internationally both in production level and quality. As Xia et al. (2016) reported, Sichuan province's economic growth is impacted the most by college test and development R&D funds, then the application of R&D funds, and the least influential is the basic R&D funding during the 2004 to 2012 period. Other studies on R&D (innovation) and economic growths are Glomm and Ravikumar (1992), Zhang (1996), Brauninger and Vidal (2000), and Blankenau (2005).

3. CONCEPTUAL FRAMEWORK, DATA AND TESTING METHODS

3.1. Conceptual Framework

The conceptual framework employed in this study is compromised by two fundamental hypotheses. The first is the Keynesian theory (Keynes, 1936) which advocates that government spending is an exogenous (fiscal) policy that can impact growth and development in the short run. The second is Wagner's law (Wagner, 1890) which considers government spending as an outcome of economic growth to meet the increased protective, administrative and education functions of the state. These two hypotheses have been generally acknowledged by their causation patterns through non-causality tests in a bivariate framework, but their possible transmission channels are ignored, in which knowledge creates technology and subsequently promotes economic growth. Unidirectional causation from knowledge to technology is hypothesised as technology is about "know-how", which cannot be achieved without knowledge. As noted, "*if basic science is the source of all new technical knowledge, then technology itself produces no new knowledge, and the technologist's role becomes that of applying knowledge generated elsewhere*" (Layton, 1974, p.34).[2] Indeed, knowledge is an increasingly important determinant of the wealth of nations Taylor, 2008, p.89). Similarly, as a proxy to knowledge, ideas improve the technology of production which allows a given bundle of inputs to produce either more or better output (Jones, 2002, p.72). Lucas (1988) adds that acceleration of economic growth can be attained through

[2] Scientists generate new knowledge which technologists then apply (Layton, 1974, p.31). Similarly, as quoted, "*Knowledge was generated by technologists…*" (Layton, 1974, pp.40).

formal schooling, physical capital accumulation, and technological change. Additionally, Romer (1990) acknowledges that public spending on research and development promotes human capital, which in effect might accelerate economic growth.

The conceptual framework of this study focuses on the possible directions of causation from government spending on tertiary education to economic growth via knowledge creation by the education which then inverts new technology.[3] The latter variable, technology, is a key driver of (that causes) economic growth as postulated in the Solow growth model (Solow, 1956). It also captures the government spending and economic growth nexus as the so-called Wagner's law and Keynesian hypothesis

3.2. Data

This study uses the World Development Indicators (WDI) database from the World Bank (http://data.worldbank.org). The available data of researchers in R&D, scientific and technical journal articles, and technicians in R&D are the 'common' proxy variables for 'knowledge'.[4] However, only one variable is selected for the knowledge given data availability (country-wise) for at least five years between 1960 and 2014. The patent application about a new way of doing things or a new technical solution to a problem is employed to represent technology.[5] The government spending on education at the tertiary level is available for education staff compensation, current education expenditure, expenditure on tertiary education, and government spending per student (tertiary level). The data filtering exercise delivers a short panel data of 71 countries with at most 17 annual observations spanning between 1998 and 2014. Table A1 shows the data used in this study, sorted by four income groups.[6,7]

More precisely, the underlying variables are described as follows. *Technology*: Patent applications ($\ln PAR$) is the worldwide patent applications filed through the Patent

[3] The basic activity variables (Hoffman and Hill, 2009, relate to universities payroll, employment, university spending on goods and services, and the customers (i.e., students) in the local economy are also being considered. From the empirical perspective, the baseline empirical Equation (1) of Dufrechou (2016, p.6) considers real per capita GDP growth in responded to initial level of real GDP, share of tertiary educated people and a vector of other factors (i.e., investment ratio, trade openness, tropical areas, size of government, and so on).

[4] It [knowledge] can be measured by patents, hyperlinks, citations, and so on (Leydesdorff, 2003).

[5] According to Veugelers and Rey (2014, pp.21-22), knowledge transfers from academia can be proxied by licensing of university, academic spin-off activities, citation to academic patents, and citations in corporate patents to scientific literature. As quoted by Layton (1974, p.31) technology is "*how things are commonly done or made*" and "*what things are done or made*" i.e., imitating technology as a technique, and technologist as technician.

[6] The countries were grouped by their income as classified by the World Bank.

[7] Only one country, Madagascar is considered from the low-income group because the data available for a reasonable sample size for at most, a simple test of correlation.

Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention. For example, a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent protects the invention to the owner of the patent for a limited period, generally 20 years. *Knowledge*: Scientific and technical journal articles ($\ln STJA$), measures the number of scientific and engineering articles published in the fields of physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. *Expenditure on tertiary education* (ETE) is expressed as a percentage of total general government spending on education. *Economic growth* ($\ln Y$) is measured by per capita GDP (in real prices) which is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.

Table 1 depicts the average statistics (i.e., median) of the underlying variables. The high-income group (countries) has the highest technology creation ($\ln PAR$), which is above the world's average. It is consistently followed by other income groups, viz. upper-middle, lower-middle, and low. A similar observation holds for the knowledge ($\ln STJA$), as well as the government spending on tertiary education (ETE). These crude observations tentatively acknowledge that government spending on tertiary education is positively correlated with income groups in creating knowledge and technology.

The unit root tests are first conducted for the panel data, including their respective income groups, namely high-income, upper-middle, and lower-middle to ensure that the underlying variables are stationary, $I(0)$, as presumed in computing the Granger non-causality tests. The panel unit root tests of Im et al. (2003), Fisher-type ADF and PP tests (Maddala and Wu, 1999), and Choi (2001) are employed. Their test statistics are illustrated in Table A2. It is found that $\ln STJA$ is stationary, $I(0)$, for all panels. Similarly, both $\ln PAR$ and ETE are in the $I(0)$ process, except for the lower-middle-income panel where both variables are non-stationary, $I(1)$. The per capita GDP is non-stationary $I(1)$ for all panels, except for the lower-middle-income panel which is stationary, $I(0)$. Hence, for the non-stationary, $I(1)$ variables of the respective panels, they have been differenced once (i.e., $\Delta x_{i,t} = x_{i,t} - x_{i,t-1}$) to ensure stationary, $I(0)$ in panel Granger non-causality testing.

Table 1. Summary Statistics (Measured by Median)

	Government spending on tertiary education, ETE_{it}	Knowledge, $\ln STJA_{it}$	Technology, $\ln PAR_{it}$	Per capita GDP, $\ln Y_{it}$
All	0.20	8.31	6.538	10.50
Income Group:				
High	0.22	9.09	7.24	10.50
Upper-Middle	0.19	7.71	6.46	11.22
Lower-Middle	0.17	5.74	4.92	9.53
Low (Madagascar)	0.14	4.10	1.78	10.26

3.3. Panel Granger Non-Causality Tests

According to Granger (2003, p.70) "*Various causality definitions have been used with panel data, which could be considered as a vector of time series, at least theoretically. When using G-causality, the test usually asks if some variable, say X_t, causes another variable, say Y_t, everywhere in the panel, in notation $X_{j,t-1} \Longrightarrow Y_{j,t}$,* for every j ["country" in the panel]" in which "$\Longrightarrow$" stands for "Granger-cause". Note that the definition leans heavily on the basic idea that *the cause occurs before the effect*. This study employs Granger non-causality test (Granger, 1969; 2003) to ascertain the possible directions of causation among the endogenous variables, which hypothesises the role of government spending on tertiary education (ETE) in promoting economic growth ($\ln Y$) via knowledge ($\ln STJA$) and technology ($\ln PAR$) creation. More technically, it is written as $ETE \Longrightarrow \ln STJA \Longrightarrow \ln PAR \Longrightarrow \ln Y$. The Granger non-causality test is simply based on a bivariate panel VAR (Vector Autoregressive) framework that is standard pairwise Granger non-causality regressions (least squares) for each cross-section individually as presented in equations (1) and (2).

$$y_{i,t} = \alpha_{0,i} + \alpha_{1,i} y_{i,t-1} + \cdots + \alpha_{l,i} y_{i,t-l} + \beta_{1,i} x_{i,t-1} + \cdots + \beta_{l,i} x_{i,t-l} + \varepsilon_{i,t}, \quad (1)$$

$$x_{i,t} = \alpha'_{0,i} + \alpha'_{1,i} x_{i,t-1} + \cdots + \alpha'_{l,i} x_{i,t-l} + \beta'_{1,i} y_{i,t-1} + \cdots + \beta'_{l,i} y_{i,t-l} + \varepsilon_{it}, \quad (2)$$

where i denotes country sample, t is time dimension, and l is maximum lag length, or VAR(l). It is assumed that common coefficients across cross-section for possibly causality across all countries as a whole, $\alpha_{0,i} = \alpha_{0,j}, \alpha_{1,i} = \alpha_{1,j}, \cdots, \alpha_{l,i} = \alpha_{l,j}, \forall i, j$ and $\beta_{1,i} = \beta_{1,j}, \cdots, \beta_{l,i} = \beta_{lj}, \forall i, j$ as in the y regression, as well as x regression, by the average of the test statistics, $\bar{W}$ statistic.

The test treats the panel data as one large stacked set of data and then performs the Granger non-causality test in the standard way, with an exception of not letting data from one cross-section enter the lagged values of data from the next cross-section. More formally, the panel Granger non-causality tests follow a [standard] *Wald*-test procedure to test the null hypothesis of "x does not Granger-cause y" for y regression (i.e., $H_0 : \beta_{1,i} = \beta_{2,i} = \cdots = \beta_{l,i} = 0$, against H_1: at least one $\beta_{l,i} \neq 0$), while "y does not Granger-cause x" for x regression (i.e., $H_0 : \beta'_{1,i} = \beta'_{2,i} = \cdots = \beta'_{l,i} = 0$ against $H_1 : at\ least\ one\ of\ \beta'_{l,i} \neq 0$). If the null hypothesis of y regression is rejected (at least) at 0.10 level, causality from x to y can be inference and *vice versa* for x regression. This statistic is appropriately weighted in unbalanced panels and follows a standard normal distribution, $\bar{Z}$ statistic.

For comprehensiveness, this study also estimates the effects (i.e., coefficients) of the underlying variables on economic growth, that is to compute the panel least squares estimates of the *ad hoc* growth equation i.e., $\ln Y_{i,t} = f(ETE_{i,t}, \ln STJA_{i,t}, \ln PAR_{i,t})$ including the interaction between $nSTJA_{i,t}$ and $\ln PAR_{i,t}$. This additional insight is in line with Granger (1969) that a cause occurs before its effect, and knowledge of a cause improves the prediction of its effect.

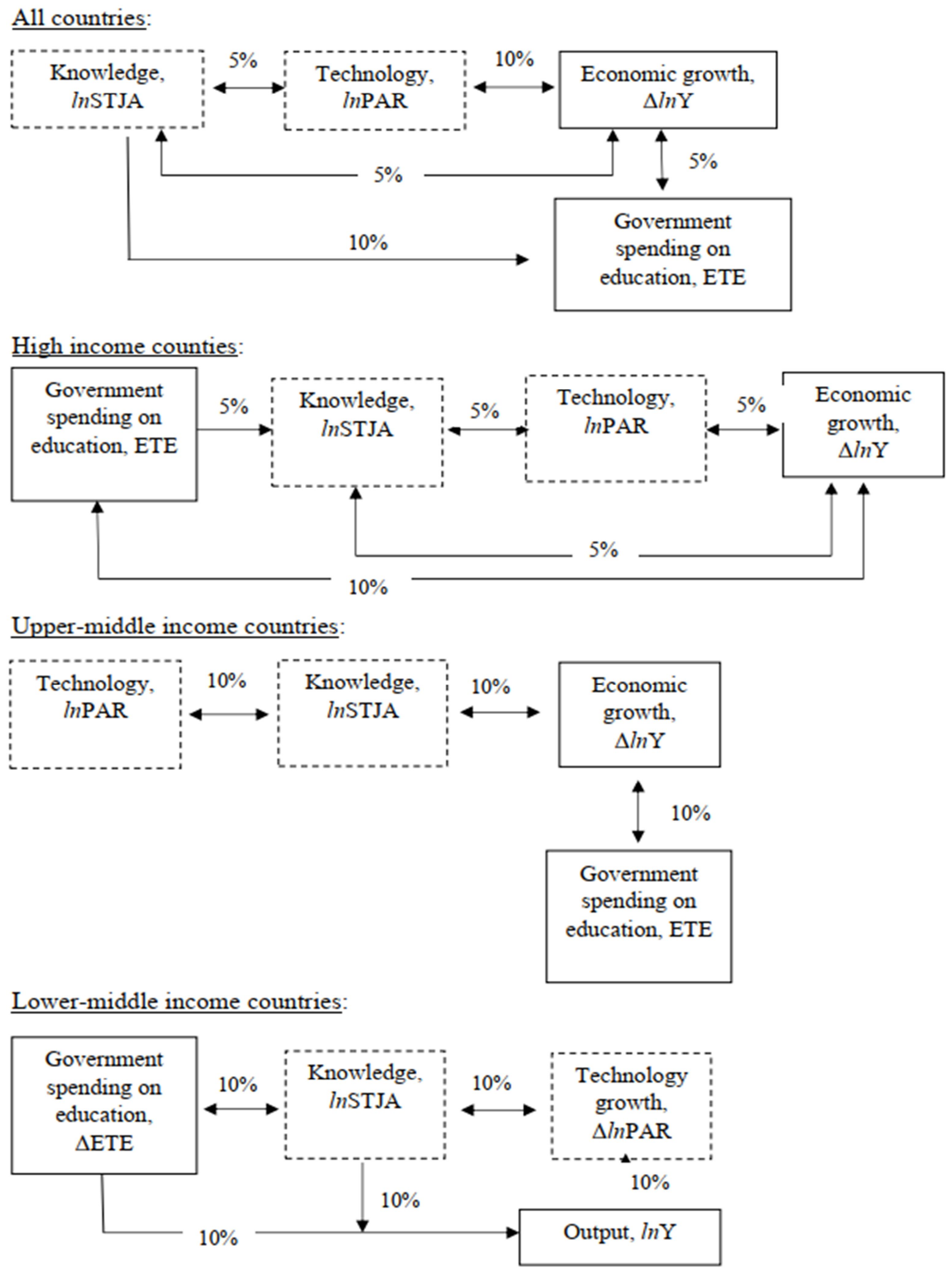
4. EMPIRICAL RESULTS

This section reports and discusses the empirical results. First of all, this section considers the core results of the Granger non-causality tests reported in Table A3 and their computed test [F-] statistics for VAR(l) of 1, 2 and 3. A rule of thumb is that a maximum lag length of 3 is reasonable for annual data. Different variables may require different time lag(s) to deliver their causes. For visual convenience, the patterns of causation among the variables, $\ln PAR$, $\ln STJA$, ETE, and $\ln Y$ are presented in Figure 1 - for both the all-countries panel and the three income groups, with at least one of the [three] lag structures being statistically significant at 10% level.

As shown in Figure 1, the high-income group is the only case that validates the underlying hypothesis that government spending on tertiary assists to spur innovation - knowledge creates technology, and [technology] produces more outputs (per capita GDP), regardless of their reverse causal effect. This hypothesis does not hold for all countries - full panel, and other income groups (i.e., upper- and lower-middle-income). Government spending on tertiary education does Granger-cause knowledge at a 5% significant level, that new knowledge is created and extended by education, which further invents new and innovative technology as a crucial driver to economic growth. This finding is in line with the nature of some high-income countries. For example, Norway spent 6.4% as a percentage of GDP in 2015 while New Zealand was at 6.3%, the United Kingdom at 6.2%), and the United States at 6.1%.[8] Hence, high-income countries should consider priorities for fiscal spending on education, especially tertiary and R&D-related education.

For the high-income group, bidirectional causation is observed between government spending on tertiary education and economic growth, which is explained by both Wagner's law and Keynesian hypothesis at a 10% significance level. Government matters for growth! It suggests that government should continue to spend even more on tertiary education to facilitate economic growth. The role of government spending on tertiary education has both direct and indirect effects (via knowledge and technology), causing economic growth in high-income countries. Bidirectional causation is evidenced at a 5% level, between knowledge and economic growth that the new growth theories acknowledge the role of accumulation of knowledge in spurring economic growth. Indeed, high-income countries require knowledge accumulation for continuing [long-run] growth. Furthermore, bidirectional causation between knowledge and technology reflects that both variables are interdependent, i.e., without new knowledge creation, no invention occurs in technology. In such a case, amended and existing regulations are crucial to protect both knowledge and technology, including those relating to intellectual property rights, patents, and so on.

[8] Education Expenditures by Country, https://nces.ed.gov/programs/coe/indicator/cmd



Note: The figures illustrate the direction of causation among the underlying variables, at least at 10% level of significant.

Figure 1. Plots of Non-Causality Results

The all-countries panel's results demonstrate that the world economic growth is driven (caused) directly by government spending on tertiary education, knowledge, and technology, respectively at a 10% significance level. This finding fails to support the proposed framework that government spending on tertiary education causes economic growth via knowledge creation and advancement in technology. However, reverse causation is observed between these variables and economic growth. Given the current growth rate, further government spending on tertiary education is necessary (Wagner's law). Technology (Solow growth model) and accumulation of knowledge (endogenous growth theory) are also crucial in promoting further growth. Interestingly, government spending on tertiary education does not create knowledge but a reverse direction from knowledge to government spending on tertiary education. This finding indicates a requirement for government spending on tertiary education to 'finance' the existing accumulation of knowledge. Bidirectional causation occurs between knowledge and technology at a 5% significance level, further enhancing the interdependence between these variables. Hence, country-wise policy (such as intellectual property rights) should simultaneously target both knowledge creation and advancement in technology.

Table 2. Correlation – Low Income Country, Madagascar

	Government spending on tertiary education, ETE_t	Technology, $\ln PAR_t$	Knowledge, $\ln STJA_t$	Per capita GDP, $\ln Y_t$
ETE_t	1.00			
$\ln PAR_t$	0.04	1.00		
$\ln STJA_t$	-0.36	-0.43	1.00	
$\ln Y_t$	0.15	0.42	0.18	1.00

For the upper-middle-income group, the proposed framework is not supported by the data. A bidirectional causality is found between the variables - technology and knowledge, knowledge and economic growth, and economic growth and government spending on tertiary education, at a 10% significance level. This finding aligns with the results from all the countries. The drivers of economic growth are government spending on tertiary education (Keynesian hypothesis), accumulation of knowledge, and technology (via. knowledge channel). These findings imply that the upper-middle-income countries are necessary to 'catch up' quickly with the transfer of advanced technology from developed countries to facilitate economic growth through its transmission channel of knowledge. Government spending on tertiary education plays a critical role in creating knowledge in which the existing education and policy should be reviewed and revised accordingly.

Lastly, the lower-middle-income group supports the Keynesian hypothesis that government spending on tertiary education directly causes output at a 10% significance level. The government spending on tertiary education does Granger-cause knowledge then technology, but there is no causation from technology to output event at a 10% significance level. Furthermore, knowledge causes output that reflects the proposed framework, except for the technology that is '*by-passed'*. Both knowledge and technology are consistently in bidirectional causation for other income groups and all countries. Hence, a sound fiscal policy emphasising tertiary education is a 'necessary and sufficient' condition for the lower-middle-income countries to achieve a higher output caused by the accumulation of knowledge.

For low-income countries, only Madagascar is chosen because of data unavailability for more countries. Given a small sample size of eight observations, a simple correlation analysis reported in Table 2[9] depicts that technology and per capita GDP are moderately correlated, (0.42), whereas knowledge and technology are negatively correlated (-0.43). Meanwhile, the correlation between government spending on tertiary education and knowledge is negative, (-0.36), and its correlation with technology (0.04) and per capita GDP (0.15) is weak. These findings eventually suggest *inefficiency* in the low-income group, in the case of Madagascar, either to finance growth directly (i.e., Keynesian hypothesis) or to generate knowledge, in which it creates technology for promoting growth as hypothesised *a prior*. The 1997-2019 statistics from the World Bank reveal that Madagascar's government spending on tertiary education was only 1.5% in 1997 and 1.8% in 2013, while the highest was 3.3% in 2005 with the recent (2019) is only 2.9%. It is impossible to consider the expansion of government spending on tertiary education in this content, but the policy of technology transfer or importation via foreign direct investment inflows spur the nation's per capita GDP.

For comprehensiveness, this study offers the panel least squares (OLS) estimates as reported in Tables 3 and 4, which is the conventional way *the cause occurs prior to its effect*. Conversely, the results of [panel] Granger non-causality tests provide no information about the effect of the independent variables, i.e., government spending on tertiary education, knowledge, and technology on economic growth. Table 3 presents the baseline estimates of the growth equation and government spending equation of $\Delta lnY_{i,t}i$ and $ETE_{i,t}$. The empirical results indicated that both hypotheses are supported by the panel data of all countries at a 10% significance level, and the high-income group at a 1% significance level. It acknowledges the role of government spending on tertiary education in spurring economic growth (Wagner's law) while economic growth requires government supports via spending on tertiary education. However, both panel data of upper-middle and lower-middle-income groups have their right-hand side variables statistically insignificant at a 10% level. One of the possible explanations is the omission of their potential transmission variables such as knowledge ($\ln STJA_{i,t}$) and technology ($\ln PAR_{i,t}$).

Table 4 has incorporated these variables, i.e., knowledge, and technology, as well as their interaction term, $\ln STJA_{i,t} \times \ln PAR_{i,t}$ to explain economic growth. For all countries' panel data, the role of government spending on tertiary education in economic growth surprisingly disappears in which the variable ETE is statistically insignificant at a 10% level. Both knowledge and technology are statistically insignificant at a 10%

[9] Due to insufficient observations for Madagascar, higher level of time series methods such as non-causality, and least squares estimation are infeasible. Also, the reported results of simple correlation analysis may be interpreted with caution.

level (see, the first column). Nevertheless, the interaction term $\ln STJA_{i,t} \times \ln PAR_{i,t}$ is statistically significant at a 5% level with a positive marginal effect on economic growth (i.e., 0.012 and 0.016 of knowledge and technology, respectively). Increasing knowledge through education can spur the economy after interacting with technology. A similar result is observed for technology as it interacts with knowledge before spurring economic growth. Overall, a variety of policy instruments to promote university-industry knowledge transfer is necessary to achieve sustainable global economic growth.

Table 3. Real per Capita GDP and Government Expenditure on Tertiary Education

	All		Income Group					
			High		Upper-Middle		Lower-Middle[a]	
Regressor:	$\Delta\ln Y_{i,t}$	$ETE_{i,t}$	$\Delta\ln Y_{i,t}$	$ETE_{i,t}$	$\Delta\ln Y_{i,t}$	$ETE_{i,t}$	$\Delta\ln Y_{i,t}$	$ETE_{i,t}$
$ETE_{i,t}$	0.08*		0.25***		-0.11			
	(0.05)		(0.00)		(0.13)			
$\Delta ETE_{i,t}$							-0.17	
							(0.63)	
$\ln Y_{i,t}$								-0.02
								(0.63)
$\Delta\ln Y_{i,t}$		0.07*		0.18***		-0.11		
		(0.05)		(0.00)		(0.13)		
Constant	0.01	0.21***	-0.04***	0.22***	0.06***	0.20***	9.81***	0.21
	(0.35)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.62)
Adjusted R^2	0.48	0.84	0.55	0.86	0.51	0.76	0.99	-0.04
F-statistic	9.32	48.91	11.36	51.63	7.79	21.21	9397.13	0.89
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.63)
Cross-sections	71	71	37	37	21	21	12	12

Notes: Specification assumes cross-section fixed, and period fixed. Sample (adjusted) is between 1999 and 2014. The value in (.) is p-value. ***, **, and * denote significant at 1%, 5%, and 10%, respectively. [a] $\Delta\ln Y_{i,t}$ and $ETE_{i,t}$ are statistically insignificant at 10% level, for cross-checking.

For the high-income countries, the interaction term is statistically insignificant at a 10% level. However, government spending on tertiary education directly promotes economic growth with an estimated coefficient of 0.3, which outweighs the unfavourable effect of knowledge (-0.02) and technology (-0.02). It strengthens the hypothesis that government spending on tertiary education increases economic growth via knowledge creation by education and technology innovation by knowledge. Consistent with the Keynesian hypothesis, high-income countries should continue to support tertiary education in their government spending. As the statistics reported by the World Bank, the expenditure on tertiary education was 23% of government expenditure on education in 2016 for high-income countries, 19% for upper-middle-income, and 16% for lower-middle-income groups (2013).[10]

[10] Expenditure on tertiary education, https://data.worldbank.org/indicator/SE.XPD.TERT.ZS?most_recent_value_desc=true

The estimated coefficients as reported for the upper-middle-income group are in a reverse sign to those for the high-income group. The estimated coefficient of government spending on tertiary education is with a negative sign, -0.21 and statistically significant at a 5% level. It may be explained that the government spending on tertiary education indirectly affects economic growth via its transmission channels – knowledge and technology, which are statistically significant at a 10% level with a positive sign. The interaction between knowledge and technology is statistically significant at a 10% level with a positive marginal effect (of 0.03) on economic growth. Therefore, upper-middle-income countries should strengthen their tertiary education in order to accelerate both knowledge transfer and technology advancement.

Table 4. Estimates of Economic Growth (Real per Capita GDP)

Regressor	All, $\Delta\ln Y_{i,t}$		Income group: High, $\Delta\ln Y_{i,t}$		Upper-Middle, $\Delta\ln Y_{i,t}$		Lower-Middle[a] $\ln Y_{i,t}$	
$ETE_{i,t}$	0.07	0.07	0.34***	0.34***	-0.20**	-0.21**		
	(0.18)	(0.13)	(0.00)	(0.00)	(0.03)	(0.02)		
$\Delta ETE_{i,t}$							-0.17	-0.04
							(0.69)	(0.94)
$\ln PAR_{i,t}$	0.00	0.02**	-0.01***	-0.02	0.00	0.042**		
	(0.36)	(0.01)	(0.01)	(0.19)	(0.74)	(0.01)		
$\Delta\ln PAR_{i,t}$							-0.00	-0.12
							(0.88)	(0.11)
$\ln STJA_{i,t}$	0.00	0.01*	-0.02***	-0.02**	0.00	0.04**	-0.00	0.01
	(0.86)	(0.07)	(0.00)	(0.02)	(0.79)	(0.02)	(0.91)	(0.84)
$\ln STJA_{i,t} \times \ln PAR_{i,t}$		-0.00**		-0.00		-0.01***		
		(0.02)		(0.95)		(0.00)		
$\ln STJA_{i,t} \times \Delta\ln PAR_{i,t}$								0.02
								(0.11)
Constant	-0.02	-0.10*	0.26***	0.26***	0.04	-0.24**	9.78***	9.72***
	(0.67)	(0.06)	(0.00)	(0.00)	(0.54)	(0.04)	(0.00)	(0.00)
Adjusted R^2	0.48	0.49	0.58	0.58	0.52	0.53	0.99	0.99
F-statistic	9.07	9.09	11.88	11.63	7.31	7.58	6368.50	6335.5
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cross-sections	71	71	37	37	21	21	12	12

Notes: Specification assumes cross-section fixed, and period fixed. Sample (adjusted) is between 1999 and 2013. The value in (.) is p-value. ***, **, and * denote significant at 1%, 5%, and 10%, respectively. [a]$\Delta\ln Y_{i,t}$, $ETE_{i,t}$, and $\ln PAR_{i,t}$ statistically insignificant at 10% level, for cross-checking. Their adjusted R^2 is 0.25.

Surprisingly, for the lower-middle-income group, none of the right-hand variables including government spending on tertiary education, knowledge, and technology as well as the interaction term, are statistically significant at a 10% level. This finding intuitively reflects the resource inefficiency of lower-middle-income countries when governance (institutional quality) is weak. After taking the governance into account, the interaction term, $\ln STJA_{i,t} \times \Delta\ln PAR_{i,t}$ is statistically significant at a 10% level with a marginal effect of 0.1 on output when knowledge is created. Both indicators of governance, namely government effectiveness and voice and accountability are statistically and positively significant at 5% (see, Table A6). Hence, good governance does matter for economic growth in lower-middle-income countries.

Resultantly, this study further considers a research question "*Do governance [institutional quality matter for the role of government spending on tertiary education in promoting economic growth?"* Government spending on tertiary education offers other outcomes - *strengthening governance* (Ozsoy, 2008). The 'economics of ideas' postulate the patents and copyrights as legal mechanisms that grant inventors monopoly power for a time to allow them to reap a return from their inventions (Jones, 2002, p.79) - "*An economy in which the rules and institutions are changing frequently may be a risky place in which to invest [the returns to investing]"* (Jones, 2002, p.133). The country that attracts investments, institutions and laws favours production over diversion; and the economy is open to international trade and competition in the global marketplace and characterised by stable economic institutions (Jones, 2002, p.133). Furthermore, the process of economic growth was sporadic and inconsistent over the vast course of history as institutions (such as property rights) were not sufficiently developed and discoveries and inventions were infrequent (Jones, 2022, p.163).

The complementary results as documented in Figure A4 and Tables A5-A6 consider the World Governance Indicators (WGI) data (Kaufmann et al., 2010).[11] Overall, the empirical results reaffirm the early findings that are relatively consistent and offer additional insights into WGI are discovered. Firstly, for the panel Granger non-causality tests as illustrated in their findings graphically in Figure A1, Wagner's law and Keynesian hypothesis remain to be supported at least at a 10% level, except for the lower-middle-income group in which only the direction of causality is from government spending on tertiary education growth to output. It reflects the crucial role of government spending on territory education as fiscal policy to sustain economic growth. More precisely, good governance (i.e., worldwide governance) does Granger-cause economic growth in all countries including other income groups, except for the lower-middle-income group in which it is from output to governance. Of the results, only the high-income group discloses that government spending on tertiary education causes good governance (Ozsoy, 2008), thereby inducing economic growth at a 10% level without considering both knowledge and technology. The governance variable is exogenous in nature and only causes government spending on tertiary education and knowledge, respectively, but no other causal linkages. Bi-directional causation between knowledge and technology occurs at an earlier period.

[11] It is available from www.govindicators.org. The Worldwide Governance Indicators (WGI) project reports aggregate and individual governance indicators for over 200 countries and territories over the period 1996–2016, including the methodology employed. A single WGI variable used in this study is based on the averaged value of the six dimensions of governance, namely voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption.

The estimated panel regressions of the growth equation (Table A6) in this study are relatively robust in terms of estimated size and sign of the underlying variables as depicted in Table 4. An exemption is that the knowledge variable becomes insignificant at a 10% level for all countries' estimates. Meanwhile, the variable becomes statistically significant for the lower-middle-income group. The empirical results have answered the early research question that *governance does matter for economic growth*. In general, the estimated panel regressions reveal that the control of corruption, political stability and absence of violence/terrorism, and the rule of law are consistently important (i.e., statistically significant at least 10%) for all countries and the high-income groups. Furthermore, the government effectiveness, voice and accountability are statistically significant at least at a 10% level for upper-and lower-middle-income groups (including the rule of law for the upper-middle-income group). All the estimated coefficients are in expected sign (positive) that good governance promotes economic growth. Two exemptions are for regulatory quality (upper-middle-income group) and the rule of law (all, high and upper-middle-income groups) which reflected negative implications for economic growth, between -0.07 and -0.05. Overall, the core variables – government spending on tertiary education, knowledge, and technology, as well as the interaction term among them remain crucial in promoting economic growth directly as robust with the early findings. The governance plays a role in mediating these variables in spurring economic growth. Policy for developing and ensuring good governance is essential, which requires a fair legal framework and to be enforced impartially.

5. CONCLUSION

This study offers fresh empirical evidence that government spending on tertiary education plays a crucial role in promoting economic growth by creating knowledge and inventing technology for only the high-income group. First, this finding is consistent with the conventional information that high-income countries allocate more budget - government spending on education (including R&D as a share per GDP) with the establishment of intellectual and patents protections that allow technology and human capital to efficiently transfer inputs into outputs (i.e., higher growth) compared to poorer countries. Second, both Wagner’s law and Keynesian hypothesis have been observed for the all countries panel of 71 countries (1998-2014) and the high-income group that the directions of causation are from government spending on tertiary education to economic growth and *vice versa*. Thirdly, the government spending on tertiary education has *indirectly* stimulated output via interaction between knowledge and technology in the lower-middle-income group. Lastly, these findings remain relatively robust after introducing governance variables obtained from the World Governance Indicators, while good governance does matter for economic growth.

In the era of a knowledge-based economy, this study highlights several aspects of policy implications. For the way fiscal policy is being conducted, government spending should be focused on tertiary education including R&D at universities with sound education plans. The role of government spending on tertiary education on growth cannot be ignored regardless of their income groups as postulated by the Keynesian hypothesis. Moreover, the spending on tertiary education can be offset or even contribute to economic growth by transferring knowledge and technology to other countries. Additionally, it is necessary to promote good governance such as a well-protected intellectual property right on knowledge created (i.e., patent protection) to invent new technology, especially for the middle and low-income groups. In fact, the lower-income countries may fail to achieve a prospective growth without new technology either by home-invented or transferred from advanced countries where relevant policies have to ensure new technology, including human capital to be utilised for higher productivity (more outputs) such as policies on industrialisation.

One of the limitations of this study is the omission of other relevant variables given the simplicity of the assumption. The four core variables, namely government spending on tertiary education, knowledge, technology, and economic growth, including governance for robustness check, are *necessary but insufficient* to comprehensively analyse the present research question. Further studies might be designed by considering the era of financial globalisation such as the inclusion of financial (capital) openness and financial development indicators. Another suggestion is to consider the possible thresholds of the respective variables that allow government spending on tertiary education to impact economic growth. It partially explains why only the high-income group supports the testable hypotheses in this study. High-income countries are most likely above the required thresholds with a higher share of government spending on tertiary education, new knowledge created, and technology invented, perhaps with good governance, and more open financial markets (well-regulated) than lower-income countries.

APPENDIX

Table A1. List of 71 Countries

- High income group (37 countries): Australia, Austria, Belgium, Canada, Chile, Cyprus, Czech Rep., Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea Rep., Latvia, Lithuania, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, Slovak Rep., Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States, and Uruguay.
- Upper-middle income group (21 countries): Argentina, Azerbaijan, Belarus, Brazil, Bulgaria, Colombia, Croatia, Cuba, Iran, Jamaica, Kazakhstan, Malaysia, Mexico, Paraguay, Peru, Romania, Russian Federation, Serbia, South Africa, Thailand, and Turkey.
- Lower-middle income group (12 countries): Armenia, Bangladesh, Guatemala, India, Indonesia, Kyrgyz Rep., Moldova, the Philippines, Syrian Arab Rep., Tajikistan, Tunisia, and Ukraine.
- Low income group (1 country): Madagascar.

Table A2. Panel Unit

	All countries			High-income countries		
Variable	Im, et al.	ADF-Fisher	PP-Fisher	Im, et al.	ADF-Fisher	PP-Fisher
$ETE_{i,t}$	-0.90	179.56**	219.0***	-1.515*	96.90**	116.35***
	(0.19)	(0.01)	(0.00)	(0.07)	(0.03)	(0.00)
$\Delta ETE_{i,t}$	-104.90***					
	(0.00)					
$\boldsymbol{I(d)}$	I(1)	I(0)	I(0)	I(0)	I(0)	I(0)
$\ln PAR_{i,t}$	-3.62***	236.71***	310.60***	-2.77**	121.70***	156.57***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta\ln PAR_{i,t}$						
$\boldsymbol{I(d)}$	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
$\ln STJA_{i,t}$	-8.94***	315.65***	284.10***	-13.76***	139.12***	120.32***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\boldsymbol{I(d)}$	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
$\ln Y_{i,t}$	0.93	143.95	156.02	1.21	57.59	57.10
	(0.83)	(0.44)	(0.20)	(0.89)	(0.92)	(0.93)
$\Delta\ln Y_{i,t}$	-13.74***	493.82***	513.40***	-8.97***	208.03***	229.80***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\boldsymbol{I(d)}$	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
	Upper-middle-income countries			Lower-middle-income countries		
Variable	Im, et al.	ADF-Fisher	PP-Fisher	Im, et al.	ADF-Fisher	PP-Fisher
$ETE_{i,t}$	-0.56	61.17**	78.07***	0.54	20.48	21.91
	(0.29)	(0.03)	(0.00)	(0.71)	(0.67)	(0.59)
$\Delta ETE_{i,t}$	-13.18***			-3.29***	53.38***	59.62***
	(0.00)			(0.00)	(0.00)	(0.00)
$\boldsymbol{I(d)}$	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)
$\ln PAR_{i,t}$	-1.65*	73.30***	101.40***	-0.96	31.39	33.00
	(0.05)	(0.00)	(0.00)	(0.17)	(0.14)	(0.10)
$\Delta\ln PAR_{i,t}$				-8.80***	113.90***	138.80***
				(0.00)	(0.00)	(0.00)
$\boldsymbol{I(d)}$	I(0)	I(0)	I(0)	I(1)	I(1)	I(1)
$\ln STJA_{i,t}$	-5.19***	100.14***	74.53***	-7.61***	71.46***	84.32***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\boldsymbol{I(d)}$	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
$\ln Y_{i,t}$	1.46	40.25	45.63	-1.46*	43.56***	50.74***
	(0.93)	(0.55)	(0.32)	(0.07)	(0.01)	(0.00)
$\Delta\ln Y_{i,t}$	-7.34***	129.01***	156.26***			
	(0.00)	(0.00)	(0.00)			
$\boldsymbol{I(d)}$	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)

Notes: The reported value is their respective test statistics, while the value in (.) is p-value. ***, **, and * denote significant at 1%, 5%, and 10%, respectively. Automatic lag length selection based on SIC: 0 to 2. Exogenous variables: Individual effects. Newey-West automatic bandwidth selection and Bartlett kernel. Null: Unit root (assumes individual unit root process) for low-income group Madagascar.

Table A3. Pairwise Panel Granger Non-Causality Tests

	All countries			High-income countries		
Null Hypothesis:	Lag 1	Lag 2	Lag 3	Lag 1	Lag 2	Lag 3
$ETE =/\Rightarrow \Delta\ln Y$	8.27***	5.83***	3.39**	1.30	2.58*	1.84
	(0.00)	(0.00)	(0.02)	(0.26)	(0.08)	(0.14)
$\Delta\ln Y =/\Rightarrow ETE$	0.03	1.55	3.28**	2.73*	6.23***	3.65**
	(0.87)	(0.21)	(0.02)	(0.09)	(0.00)	(0.01)
$\ln PAR =/\Rightarrow \Delta\ln Y$	6.14**	3.00*	2.05	5.04**	8.46***	4.46***
	(0.01)	(0.05)	(0.11)	(0.03)	(0.00)	(0.00)
$\Delta\ln Y =/\Rightarrow lnPAR$	0.24	0.02	2.24*	1.07	5.33***	9.38***
	(0.62)	(0.98)	(0.08)	(0.30)	(0.01)	(0.00)
$\ln STJA =/\Rightarrow \Delta\ln Y$	23.67***	14.29***	6.64***	12.04***	9.40***	6.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta\ln Y =/\Rightarrow \ln STJA$	0.06	3.09**	3.32**	5.99**	5.25***	5.47***
	(0.81)	(0.05)	(0.02)	(0.02)	(0.01)	(0.00)
$\ln PAR =/\Rightarrow ETE$	1.24	0.71	0.54	0.10	0.78	1.58
	(0.27)	(0.49)	(0.66)	(0.76)	(0.46)	(0.19)
$ETE =/\Rightarrow \ln PAR$	0.30	0.74	2.07	1.01	1.18	0.93
	(0.58)	(0.48)	(0.10)	(0.32)	(0.31)	(0.43)
$\ln STJA =/\Rightarrow ETE$	2.83*	1.11	0.24	0.08	0.40	0.09
	(0.09)	(0.33)	(0.87)	(0.78)	(0.67)	(0.96)
$ETE =/\Rightarrow \ln STJA$	0.70	1.53	0.77	4.91**	1.76	0.90
	(0.40)	(0.22)	(0.51)	(0.03)	(0.17)	(0.44)
$\ln STJA =/\Rightarrow \ln PAR$	10.80***	11.15***	10.48***	0.35	0.05	3.44**
	(0.00)	(0.00)	(0.00)	(0.55)	(0.95)	(0.02)
$\ln PAR =/\Rightarrow \ln STJA$	0.84	1.60	2.69**	15.24***	14.82***	1.38
	(0.36)	(0.20)	(0.05)	(0.00)	(0.00)	(0.25)
	Upper-middle-income countries			Lower-middle-income countries		
Null Hypothesis:	Lag 1	Lag 2	Lag 3	Lag 1	Lag 2	Lag 3
$ETE =/\Rightarrow \Delta\ln Y$	3.25*	2.51*	0.57	2.91*	1.10	1.67
	(0.07)	(0.09)	(0.64)	(0.09)	(0.34)	(0.19)
$\Delta\ln Y =/\Rightarrow ETE$	2.87*	1.62	2.77**	1.36	0.62	0.04
	(0.09)	(0.20)	(0.05)	(0.25)	(0.54)	(0.99)
$\ln PAR =/\Rightarrow \Delta\ln Y$	0.07	0.13	0.49	0.04	0.20	0.51
	(0.79)	(0.88)	(0.69)	(0.84)	(0.82)	(0.68)
$\Delta\ln Y =/\Rightarrow lnPAR$	0.03	0.21	0.46	2.83*	2.09	1.71
	(0.86)	(0.81)	(0.71)	(0.09)	(0.13)	(0.17)
$\ln STJA =/\Rightarrow \Delta\ln Y$	4.18**	5.79***	2.23*	3.07*	0.31	0.22
	(0.04)	(0.00)	(0.09)	(0.08)	(0.74)	(0.88)
$\Delta\ln Y =/\Rightarrow \ln STJA$	1.84	1.65	3.22**	1.93	2.32	1.51
	(0.18)	(0.20)	(0.02)	(0.17)	(0.10)	(0.22)
$\ln PAR =/\Rightarrow ETE$	0.14	1.33	0.79	1.43	0.37	0.06
	(0.71)	(0.27)	(0.50)	(0.24)	(0.69)	(0.98)
$ETE =/\Rightarrow \ln PAR$	0.27	0.29	1.56	0.04	1.50	1.33
	(0.60)	(0.75)	(0.20)	(0.84)	(0.24)	(0.29)
$\ln STJA =/\Rightarrow ETE$	0.17	0.25	0.03	0.25	0.33	0.31
	(0.69)	(0.78)	(0.99)	(0.62)	(0.72)	(0.817)
$ETE =/\Rightarrow \ln STJA$	0.28	0.46	0.06	3.90*	2.39	2.89**
	(0.60)	(0.63)	(0.98)	(0.05)	(0.10)	(0.05)
$\ln STJA =/\Rightarrow \ln PAR$	3.37*	3.96**	3.02**	2.02	3.08*	2.64*
	(0.07)	(0.02)	(0.03)	(0.16)	(0.05)	(0.05)
$\ln PAR =/\Rightarrow \ln STJA$	0.78	1.00	2.63*	0.02	3.72**	1.17
	(0.38)	(0.37)	(0.05)	(0.88)	(0.03)	(0.32)

Notes: $=/\Rightarrow$ stands for "does not Granger cause". ***, **, and * denote significant at 1%, 5%, and 10%, respectively. The reported value is *F*-statistic, while the value in (.) is *p*-value.

Table A5. Low Income Country (Madagascar) Correlation with WGI

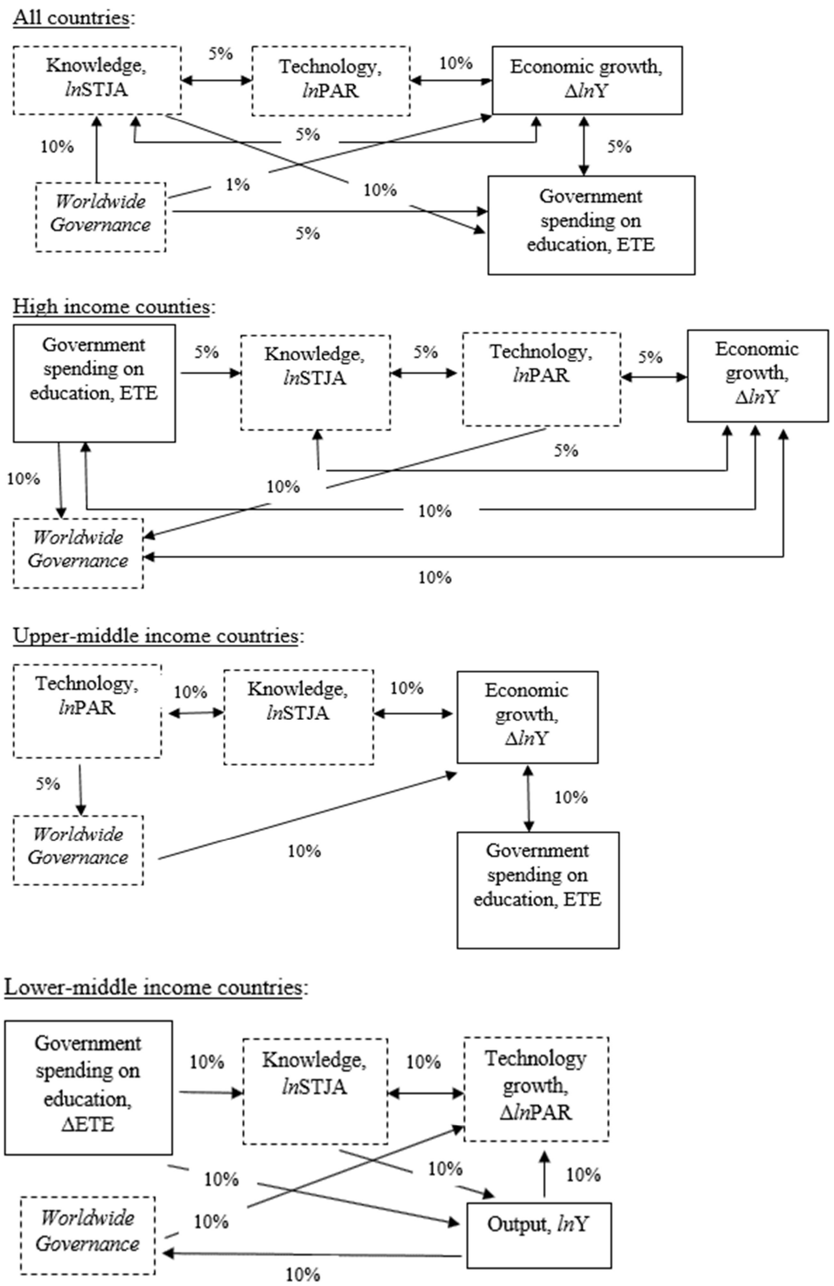
	Government spending on tertiary education, ETE	Technology, $\ln PAR$	Knowledge, $\ln STJA$	Per capita GDP, $\ln Y$
WGI	-0.51	0.54	-0.26	0.41

Note: Low-income country consist only one country as above, here correlation analysis has been used.

Table A6. Estimates of Panel Least Squares on Real per Capita GDP with WGI

	Income group:							
Regressor:	All, $\Delta\ln Y_{i,t}$		High, $\Delta\ln Y_{i,t}$		Upper-Middle, $\Delta\ln Y_{i,t}$		Lower-Middle, $\ln Y_{i,t}$	
$ETE_{i,t}$	0.06 (0.25)	0.07 (0.18)	0.30^{***} (0.00)	0.30^{***} (0.00)	-0.22^{**} (0.04)	-0.21^{**} (0.04)		
$\Delta ETE_{i,t}$							0.01 (0.80)	0.21 (0.60)
$\ln PAR_{i,t}$	0.00 (0.75)	0.02^{*} (0.05)	-0.02^{***} (0.00)	-0.03^{*} (0.05)	0.00 (0.86)	0.04^{*} (0.073)		
$\Delta\ln PAR_{i,t}$							0.02 (0.42)	-0.10 (0.13)
$\ln STJA_{i,t}$	-0.00 (0.91)	0.01 (0.15)	-0.02^{*} (0.05)	-0.03^{**} (0.05)	0.01 (0.69)	0.04^{*} (0.079)	0.07^{**} (0.03)	0.08^{**} (0.01)
$\ln STJA_{i,t} \times \ln PAR_{i,t}$		-0.00^{**} (0.05)		0.00 (0.41)		-0.00^{*} (0.06)		
$\ln STJA_{i,t} \times \Delta\ln PAR_{i,t}$								0.02^{*} (0.07)
Constant	0.01 (0.78)	-0.08 (0.23)	0.29^{***} (0.00)	0.34^{***} (0.00)	0.03 (0.68)	-0.21 (0.15)	9.45^{***} (0.00)	9.34^{***} (0.00)
Government Effectiveness	0.01 (0.38)	0.01 (0.38)	0.01 (0.67)	0.01 (0.61)	0.05^{**} (0.04)	0.04 (0.14)	0.16^{**} (0.02)	0.14^{**} (0.04)
Control of Corruption	0.03^{***} (0.00)	0.03^{**} (0.01)	0.03^{***} (0.00)	0.03^{***} (0.00)	0.02 (0.38)	0.02 (0.48)	0.04 (0.50)	0.03 (0.54)
Political Stability & Absence of Violence/ Terrorism	0.01^{**} (0.03)	0.01^{**} (0.02)	0.03^{***} (0.00)	0.03^{***} (0.00)	0.01 (0.57)	0.00 (0.92)	0.05 (0.14)	0.04 (0.19)
Regulatory Quality	-0.01 (0.43)	-0.01 (0.39)	-0.00 (0.72)	-0.01 (0.69)	-0.03 (0.15)	-0.04^{*} (0.08)	-0.09 (0.37)	-0.12 (0.24)
Rule of Law	-0.05^{***} (0.00)	-0.06^{***} (0.00)	-0.07^{***} (0.00)	-0.07^{***} (0.00)	-0.06^{**} (0.02)	-0.05^{*} (0.08)	-0.08 (0.17)	-0.07 (0.25)
Voice & Accountability	0.01 (0.18)	0.01 (0.27)	-0.01 (0.58)	-0.01 (0.64)	0.07^{***} (0.01)	0.05^{**} (0.03)	0.08^{**} (0.04)	0.08^{**} (0.03)
Adjusted R^2	0.52	0.53	0.62	0.62	0.54	0.55	0.99	0.99
F-statistic	9.05 (0.00)	9.04 (0.00)	11.64 (0.00)	11.44 (0.00)	6.55 (0.00)	6.59 (0.00)	7563.5 (0.00)	7750 (0.00)
Cross-sections	71	71	37	37	21	21	12	12

Notes: Specification assumes cross-section fixed, and period fixed. Sample (adjusted) is between 2000 and 2013. The value in (.) is p-value. ***, **, and * denote significant at 1%, 5%, and 10%, respectively.



Note: The figures illustrate the direction of causation among the underlying variables, at least at 10% level of significant.

Figure A4. Pairwise panel Granger non-causality tests with World Governance Indicators (WGI).

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