STUDY ON THE ROLE AND CONTRIBUTION OF SCIENCE, TECHNOLOGY, AND INNOVATION (STI) AS DRIVING FACTORS FOR THE THAI ECONOMY IN THE 21ST CENTURY: AN EMPIRICAL OBSERVATION

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Abstract - This paper explores the characteristics, movements and determinants of Total Factor Productivity (TFP) in Thailand within the past two decades, with the study being organized into two main parts which are 1.) the correlation of TFP and economic growth (for both the overall economy and on the sectoral levels), in comparison with other factors of production, based on growth models with technology parameter (A) as the augmenting factor complimenting the traditional factors of production, which are capital (K) and labor (L), and, 2.) the determinants of TFP for the case of Thailand between 2000 and 2021. It is observed that, from the available data for Thailand between 1991 – 2021, technology (represented by TFP) correlates rather strongly with growth, both at the overall level and that of the industrial and service sectors, in line with previous studies. Furthermore, the econometric regression analysis at the determinant level - examining numerous factors that have theoretical or empirical influences on TFP in other countries and studies - suggests that for the case of Thailand within the period examined, domestic private RDI, industrial value added, and government expenditure have significant and positive correlation with TFP. Thus, while further in-depth examination and discussion will prove useful as the next phase of addressing the issue of TFP in Thailand, it can be observed that, for the past few decades, TFP in Thailand have been an active component in the growth of the Thai economy, where it is likely that changes in Thai TFP are most heavily influenced by private and government spendings, as well as value-added in the industrial sector. We acknowledge the results of the various studies prior which suggested that TFP in different economies across different time periods are influenced differently by a diverse mix of factors.

Keywords - Total Factor Productivity (TFP), Economic Growth, R&D, Science, Technology, and Innovation (STI).

I. INTRODUCTION

There has been a long-standing debate on the relationship between technology and economic growth; factors of production, labor L and capital K, by themselves, cannot maintain sustainable growth in the long run, and many countries' hope in pushing economic growth via supply of capital would prove to be unsustainable and costly in the absence of technological growth.

Aiming to examine the issues surrounding technology and economic growth in several facets for the purpose of acquiring potentially useful policy insights and information, this paper sets out to examine the issue from two main analyses: 1.) the "contribution rate" of the technology parameter (A) in the Solow Growth model – to what extent does changes in Thailand's total factor productivity (TFP), representing technology, correlate with changes in economic growth during the past 30 years, and, 2.) econometric analysis using regression model to assess the determinant(s) of TFP in Thailand between 1991 – 2021. The methodology and findings are as follows:

II. METHODOLOGY & DATA

This study employs two main methodologies to address the issues concerning TFP in Thailand. The first methodology is to employ the analysis of "contribution rate" of technology and TFP, based on the rationale of the Solow Growth Model, in line with prior research done by Zheng and Wang (2020). The second methodology is an econometric regression based on various literatures and prior works, where the selection of the independent variables (Xs) becomes the focal issue. Jointly, these analytical methods provide information and basic insights on the landscape of TFP in Thailand.

2.1. Contribution Analysis / Correlation Analysis

As there have been many methods to study the relationship between TFP and economic growth, we select a method employed by Zheng and Wang (2020), which focuses on the "contribution rate" of each of the factors – labor, capital and technology.

This method, which we would like to consider as "correlation analysis" or the examination of the movements of the three factors along with economic growth over time, yields a summary plot which displays such movements, which can then be compared and examined. In such a manner, one can grasp the patterns of how the country's economic growth is influenced by, or at least coherent with, changes in each of the factors, L, K and A.

Zheng and Wang (2020) uses the following formula to assess the movement of technology in relation to Y, or the technology contribution rate:

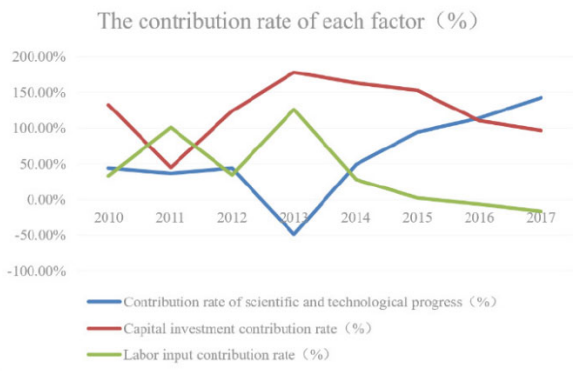
$$\text{Technology contribution rate} = \frac{\frac{\Delta A}{A}}{\frac{\Delta Y}{Y}} \times 100$$

Similar formulas are used for the other two factors, L and K. In so doing, the movements of the other two factors are outlined as:

$$\text{Labor contribution rate} = \frac{\frac{\Delta L}{L}}{\frac{\Delta Y}{Y}} \times 100$$

$$\text{Capital contribution rate} = \frac{\frac{\Delta K}{K}}{\frac{\Delta Y}{Y}} \times 100$$

In Zheng and Wang (ibid.), the authors obtained the following diagram for the case of Chongqing, China:



Source: Zheng and Wang (2020)

In this vein, we can adopt this aforementioned methodology to assess the case of Thailand. We draw on the dataset of NESDB for the past few decades. Data description and usage will be discussed later in the upcoming section. In so doing, the benefit to be had is that we can, comparatively to the Chinese cases, examine how much technology has played its contribution in the development of the Thai economy, while the second part will take a look at how TFP is influenced by other factors in the domestic economy, hoping to gain insights on how to promote or stimulate TFP growth, and thus technology-led growth, in the Thai economy. The results will be presented in the findings section.

2.2. Regression Analysis of Determinants of TFP

In the second part, after examining the situation of economic growth and the contribution rates of the factors, we now turn to a second important issue – "What determines changes in the TFP of Thailand?". In this part, we treat TFP or the parameter representing technology as the dependent variable. Instead of considering TFP as a determinant of the dependent variable (economic growth) in the previous section, here we aim to examine what affects TFP itself. For the purpose of this study, we have chosen to follow the economic regression specified in Zeng, Shu and Ye (2022).

Noteworthily, the issue of determinants of TFP have been the focus of many studies. Literature review shows that the choices of determinants examined in econometric models can vary to great extents – each author or study can focus on wildly diverse mix of variables. Nevertheless, for the purpose of practicality, Zeng, Shu and Ye (ibid.) have selected only the most popular and practical variables that are straightforward and well-known, and do not go into too much specific details.

Zeng, Shu and Ye (ibid.) employed the following variables.

- TRADE: Dependency ratio on international trade (trade openness index), being the ratio of total imports and exports to GDP
- FDI: Foreign direct investment, the ratio of FDI to GDP
- TECH: R&D expenditure, R&D spending as a percentage of GDP
- IS: Industrial structure, being the value added of tertiary industry as percentage of GDP
- M: Government expenditure, the general budget spending as share of GDP
- HC: Human capital, represented by total high school and higher education graduates

All these variables are expected to have positive relationship with the dependent variable TFP, as positive elements in the economy.

Our model employed in this study, however, added a few elements into the base modelbefore we adopt it to the Thai economy for our analysis. We add two more variables of our interest, which are 1.) market complexity, and, 2.) ease of doing business. Both variables are expected to have positive relationship with the dependent TFP variable.

In our study, we employ data from the period between 2000-2021, during which the detailed data for Thailand are available (we acknowledge the limitation that working with detailed time-series data for Thailand faces a constraint in terms of data availability, as many specific or detailed variables and statistics were not always collected prior to the 2000s period). Ideally, the more data on our hands, the better, but this appears to be the limitation facing many similar research works. This is discussed in 2.3.

2.3. Data Employed in the Study

Given the methodology and the model addressed above, we perform the analyses with available data in

Thailand as of first half of 2023. Data requirement for each of the methodology stages were different, but compatible. Some in-depth variables were not readily available in Thailand, especially for longer periods of time, which suggests that it is ultimately a good thing that the econometric model selects the relatively popular and mainstream economic and technological variables, rather than ones that are too specific or detailed.

The contribution rate analysis or the correlation analysis is straightforward; it requires the data for the stock amount of the factors labor L and capital K, coupled with data on economic growth and changes in TFP. While surveying for said data is costly in terms of both time and financial costs, all of the data required in this first step is readily available at the Office of the National Economic and Social Development Council (NESDC – formerly known as NESDB) upon formal request. Furthermore, the data for the factors, TFP, and economic growth are also available for the sectoral level (agriculture, industrial and service sectors), albeit not sub-sectoral levels. The detailed nature of the data in the first part is helpful in assessing sectoral characteristics, which will be addressed soon in the upcoming part.

For the second part employing the econometric model, data were acquired from several sources, most importantly the World Bank World Development Indicators (WDI) Database, where the majority of the variables come from.

The list of the variables employed in our model is as follows:

Variable name	Source	Expected signs
TFP	NESDC	+
OPEN	WDI WB	+
FDI_NET	WDI WB	+
RDI	NXPO Thailand	+
IVALD	WDI WB	+
GOV_E	WDI WB	+
HDI	UNDP	+
MKTCOM	OEC	+

The variable for ease of doing business, unfortunately, had to be omitted since the data for Thailand is available only for 2010-2020, which would drastically put further pressure on the year constraints that the study already face. Of the new variables, therefore, we only retain the variable for market complexity for the analysis.

We then end up with the following model specification:

$$TFP_{it} = B_0 + B_1 FDI_{t-1} + B_2 ln\, Open_t + B_3 ln\, RDI_{t-1} + B_4 ln\, IValAdd_t + B_5 ln\, GovE_{t-1} + B_6 ln\, HDI_t + B_7 ln\, MComp_t + e$$

Where TFP is total factor productivity.
FDI is foreign direct investment.
Open is trade openness.
RDI is private domestic R&D expenditure.
IValAdd is value added in industry sector (%GDP).
GovE is government expenditure.
HDI is human capital, represented by HDI index.
MComp is market complexity.

The expected signs for all variables are positive, and prior expectations anticipate that they ought to be statistically significant. Most of the variables are selected in this study such that it is as comparable as possible to the original model. However, we recognize that the significance of the variables will vastly vary between cases – across countries and regions, time periods, sectors, and so on. The objective of this stage is to examine which determinants are statistically significant for the case of Thailand during the past 2 decades, and to what extent(s).

III. RESULTS AND DISCUSSION

3.1. Findings from the Correlation Analysis

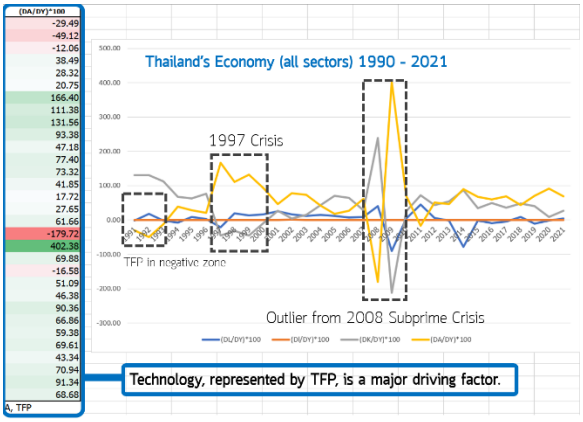


Fig.1 – Factor contributions for overall Thai economy

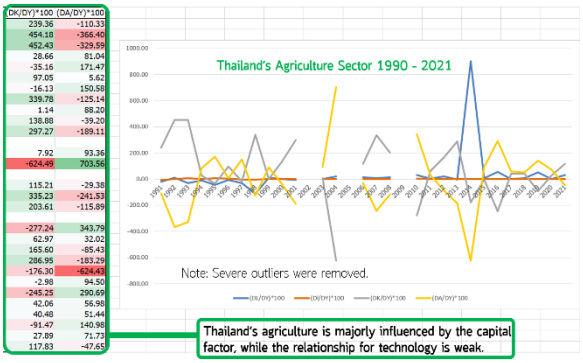


Fig.2 – Factor contributions in Thai agriculture sector

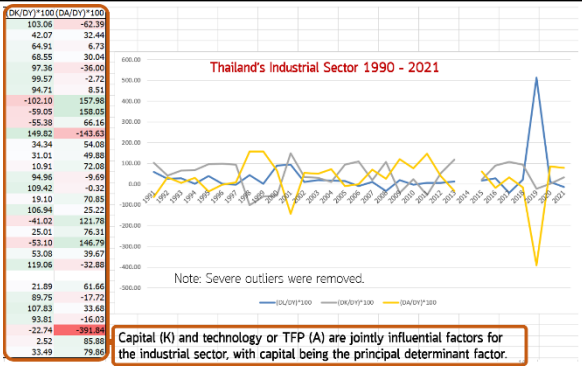


Fig.3 – Factor contributions in Thai industrial sector

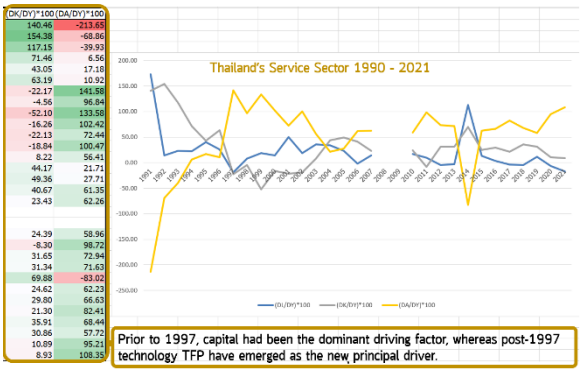


Fig.4 – Factor contributions in Thai services sector

Figures 1-4 exhibits the behaviour and contribution or correlation of the factors of production of Thailand between 1991-2021. By rationale, growth should not be reliant on the amount of labor (L) and land (l), but rather by technology, and, to a lesser extent, capital. Zheng and Wang (2020) explained in their prior research on how economic expansion via labor or even capital would prove to be unsustainable in the long run, where countries would do well to successfully make the transition to technology-driven growth.

Applying said rationale and the methodology for the case of Thailand's historical data for the recent decades, we observe that the Thai economy, for the past 30 years, have been exhibiting potential for technology-driven growth, as can be seen from the rather high contribution or correlation rates of the technology factor (A, TFP – shown in green in the corresponding side tables, and illustrated as movements in the positive zone of the diagrams). Overall, the Thai economy fares rather well in this regard, although there are rooms for improvement and reflection. One can argue that the developmental pattern of Thailand is not doing too badly in this issue.

Sector-wise, it is noteworthy that each of the three main sectors of production (agriculture, industrial, and services) display different characteristics. The agricultural sector does not appear, for the last 30 years, to be affected much by technology factor. This may coincide with, or be explained by, Thai agricultural sector's perceived failure to absorb and utilize technology in its operations – the Thai agricultural sector has long been viewed to be not of a very high-tech nature, and struggles to make the transformation into high-value, precision agriculture. A silver lining here is that the sector appears to be relying more on capital rather than labor or land (which would have been a red flag suggesting primary or extremely outdated modes of manual labor production), although there is still much exploration for future works on this matter.

The industrial sector, perhaps not counter-intuitively, is affected by both capital and technology. One can observe, also, that capital is significantly more influential. This means that the industrial sector in Thailand, while not low-tech, still has much room for improvement and enhancement towards becoming a technology-driven industrial sector. Lastly, the service sector seems to enjoy contribution from the technology factor (which captures changes in the quality of capital and labor, as opposed to the quantity or amount that are represented by K and L) in full stride. This suggests that Thailand's services sector have been absorbent of technological progress and are most adaptive to change during the past two decades, with the year 1997 being a shifting point in the time series.

These findings shed light on the landscapes of how the factors of production play their roles in Thailand's economic growth over time, and would serve as potentially useful policy inputs or insights. We, however, are not done with our exercises just yet, and are interested in taking a further look at how and to what extents Thailand's TFP are influenced, in turn, by other economic factors. We explore the determinants of Thailand's TFP and statistical significance in the second part of the study now.

3.2. Findings from the Econometric Analysis

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. reg tfp l.fdi_net_in ln_open_t l.ln_rdi ln_ivald l2.ln_gov_e ln_hdi ln_mktcom l.tfp

      Source |       SS           df       MS      Number of obs =        20
-------------+----------------------------------   F(  8,    11) =      3.53
       Model |  144.01042         8  18.0013025   Prob > F      =    0.0283
    Residual |  56.1086306        11  5.1007846   R-squared     =    0.7196
-------------+----------------------------------   Adj R-squared =    0.5157
       Total |  200.119051        19  10.5325816   Root MSE      =    2.2585

------------------------------------------------------------------------------
         tfp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  fdi_net_in |
         L1. |   1.69e-11   2.10e-10     0.08   0.937    -4.45e-10    4.79e-10
    ln_open_t |   7.340953   12.75383     0.58   0.576    -20.73004    35.41195
      ln_rdi |
         L1. |   10.14694   4.30386      2.36   0.038     .6742036    19.61967
    ln_ivald |   110.3306   48.00601     2.30   0.042     4.670045    215.9911
    ln_gov_e |
         L2. |   30.72662   13.6409      2.25   0.046     .7032008    60.75003
      ln_hdi |  -38.27286   108.8749    -0.35   0.732    -277.9049    201.3592
   ln_mktcom |  -14.46588   18.78957    -0.77   0.458    -55.82145    26.88969
             |
         tfp |
         L1. |   .0641717   .3595883     0.18   0.862    -.7272769    .8556202
             |
       _cons |  -509.4071   162.122     -3.14   0.009    -866.2353   -152.579
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Source: W. Nakawiroj - Data Center Division, NXPO (2023)

Fig.5 – Statistical significance of determinants of TFP

From the aforementioned econometric regression model discussed above, we experimented with numerous specifications and fine-tuning of the model. Eventually, the decision was made to employ and

experiment with lags for some of the variables, which are FDI, RDI, and government expenditures - the rationale being: such undertakings are, at the end of the day, investments, and investments would take some time to show their full effect, rather then working on an instantaneous manner. The results, while interesting and potentially useful, are not surprising. We observe from the regression results that, for the case of Thailand between 2000-2021, the three most influential factors affecting Thai TFP (which in turn affects the economy and promotes sustainable economic progress, as mentioned in the earlier sections) are private RDI investment (RDI) with a lag of one year or more, industrial sector value added (IVALD), and government expenditure (GOV_E) with a 2-year lag.

We acknowledge the common phenomenon that the same sets of determinants of TFP may drastically differ in terms of their influence and significance when assigned to different cases, countries, time periods, and contexts – the determinants that are highly significant or relevant in one case may be trivial or event irrelevant in another environment. As such, this observation may shed some light on what has been driving Thailand's TFP for the past few decades.

The findings are not counterintuitive. RDI investments directly add to the stock of knowledge and productivity over time and this shows that the Thai economy can absorb the gains from RDI investments rather than see them get diluted in an inefficient technological environment. This is a hopeful finding, albeit one that would benefit from further research and inquisition in the future. Secondly, industrial sector value added, following the model used by Zeng, Shu and Ye (2022), proved to be statistically significant, which means that the capacity of the Thai industrial sector may well generate spillovers into the overall economy's competitiveness, and suggest that by augmenting the strength of the industrial sector at home, TFP can be hoped to remain strong over time. Lastly, government expenditure are also significant and positive in its contribution to TFP, albeit with a lag of 2 years, meaning that government spending may exert upward pressure on TFP, despite taking some time. Of course, these are the findings for the case of Thailand during the last two decades and other countries and other time periods need not necessarily conform or be coherent with our finding.

Some notes for discussion and further works may prove useful here. Firstly, the author acknowledges the limitations of the data, particularly the number of years (observations). This has been an issue plaguing numerous similar works in the past. The agenda for future research would involve using alternative methods to bypass the year limitations, which are currently being explored along with alternative in-depth models. Also, as more in-depth and specific data become available in the near future, follow-up studies can employ such in-depth data for a more detailed analysis which would seek to answer some or most of the questions that still remain in these findings we discuss today. Nevertheless, these findings shed light on previously silent areas of the landscapes of Thailand's TFP movements and determinants, and would serve as potentially useful basis and inputs for policy dialogues, discussions and debates.

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REFERENCES

[1] Y. Zheng, and Y. Wang, "Research on the Contribution Rate of Scientific and Technological Progress to Chongqing's Economic Growth Based on the Solow Growth Model", E3S Web of Conferences 235, NETID 2020.

[2] S. Zeng, X. Shu, and W. Ye, "Total Factor Productivity and High-Quality Economic Development: A Theoretical and Empirical Analysis of the Yangtze River Economic Belt, China", International Journal of Environmental Research and Public Health, 2022.

[3] K. Promwong, "An Analysis of the Sources of Productivity Growth and Competitiveness in Thailand's Manufacturing Sector", Strathclyde University Doctoral Dissertation, 2001.

[4] Office of the National Economic and Social Development Council of Thailand, "Capital Stock of Thailand, 2021 Edition", 2021.

[5] J. Sobieraj, and D. Metelski, "Economic Determinants of Total Factor Productivity Growth: The Bayesian Modelling Averaging Approach", Entrepreneurial Business and Economics Review, 2021.

[6] N. Crafts, "Quantifying the Contribution of Technological Change to Economic Growth in Different Eras: A Review of the Evidence", 2003.

[7] A. Frija, B. Dhehibi, A. Aw-Hassan, S. Akroush, and A. Ibrahim, "Approaches to Total Factor Productivity Measurements in the Agriculture Economy", Research Program on Dryland Systems, 2015.

[8] Y. Kim, and N. Loayza, "Productivity Growth, Patterns and Determinants Across the World", World Bank Policy Research Working Paper, 2019.

[9] M. Danquah, E. Moral-Benito, and B. Ouattara, "TFP Growth and Its Determinants: A Model Averaging Approach", Empirical Economics, 2014.

[10] S. Urata, and Y. Yokota, "Trade Liberalization and Productivity Growth in Thailand", Developing Economies, 1994.

[11] T. Kaewthong, and J. Caceres, "Determinants of Total Factor Productivity Growth in Different Postal Designated Operators", Maejo University, 2022.

[12] F. Theppitupong, and J. Caceres, "Impact of Research and Development Capital on TFP Growth: The Case of ASEAN Countries", Maejo University, 2022.

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