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RESEARCH

The Role of Technology in Indonesian Economy: A System-Dynamics Model

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Abstract

It is an accepted view that technological progress is an extremely important, perhaps the most important, determinant in the growth in output per man. Therefore, the government's policies related to the R & D activities to spur the development of the technology in order to enhance economic growth in Indonesia are becoming very important to be analyzed. For this purpose, a process oriented model of technology-economy interactions (Technology-Economy Model) was developed; and through the simulation of the model a clear and distinct understanding of the role of the technology in the Indonesian economy can be obtained. In the model, the capital-labor ratio (KLR) is proposed as an indicator of the technology in an economic system. This implies that the development of technology will be strongly determined by the decisions those related to the development of capital (investment and depreciation) and the growing of labor (hire and fire). The structure of decision making process is naturally consists of the interdependent relationships among some components which constructing causal loops (feedback loops). Based on this thought, the system dynamics methodology is used in this study to de-velop the Technology-Economy Model. The growth behavior of the technology and the economy is obtained through simulating the model from year 2000 until year 2050 for some scenarios related to the R&D activities and the economic policies. The analysis of the model behavior provides some important policy directions those expected to produce the higher technology and economic growth and also the better performance of the economy, i.e.: policies to manage R&D activities becoming effective, R&D policies should have a linkage with the education and training policies (link and match), have also a linkage with the economic policies (investment, export, and import), and the development of industry (wage policies).

Keywords: technology, capital, labor, capital-labor ratio, system dynamics

1. Introduction

Since the publication of Solow's thought (1956), in a paper entitled "A Contribution to the Theory of Economic Growth", it is believed that technology (technical progress) was instrumental in promoting the economic growth of a region. Based on this belief, accompanied by factual studies of the economic growth in developed/industrial country, then technological planning (technological develop-ment and implementation) became the focus of the most important planning policy for developing countries (developing country), including the Unitary State of the Republic of Indonesia (NKRI)

The technological development and implementation in an economic system cannot be separated from the existence of policies relating to the activities of research and development (R&D). The long term implications of the policies may be different from its short-term implications (dynamic complexity). The policies related to R&D activities (among other research incentives policy of the Ministry of Research and Technology), issued by the government to encourage technological developments in Indonesia, which in turn will further enhance economic growth in Indonesia, become important to be analyzed. The analysis on the technology-economy phenomenon is expected to answer how the incentive policy, in the process-oriented context, may affect the state of the art of technology in Indonesia, that eventually enhance the economic growth in Indonesia. The most important questions that must be answered in the context of the process are:

(1) Why the dynamics of technology-economy phenomenon occurring in the past (2000-2010) in Indonesia (the historical behavior) behaves as observed based on macro data of Indonesia's economic growth in that period; and

(2) Should the historical behavior be not fit with what we expect, how do (through what policies) we make the future technology-economy phenomenon in Indonesian behave as we expect (increased technological growth and more impacts on better economic performance: better encourage economic growth, reduce imports, and reduce the level of unemployment).

The analysis to answer the aforementioned questions is conducted through a simulation process using a computer model. The simulation model provides an understanding about the cause of the technology-economy dynamics; based on this understanding, policies are designed to achieve a better technology-economy performance (policy directions). The structure of the model consists of the physical structure and the structure of the decision-making process by the actors in the technology-economy phenomenon, which describes the elements forming these phenomena and their mutual relations.

This study is intended to explain the influence of research and technology policies towards the development of technology in Indonesia and how it will impact economic growth. First, this paper will be briefly explained the existence of economic growth models, that have considered the role of technology and criticism on these models. Next this paper recommends a model of technology-economy phenomenon, capable to relatively better explain the phenomena based on a process-oriented approach. Based on this idea then a simulation model using the methodology of System Dynamics (Sysdyn) is constructed. This methodology is used since it is process-oriented, and very adequately capable to answer the questions started with why and how about a phenomenon; notably required in the process of policy analysis. The analysis of research and technology policies is then performed using the model through the development of several scenarios.

2. The Technology-Economy Model of Solow

In Solow's model of growth, in addition to being determined by the capital growth and labor growth, the rate of economic growth (income or gross domestic product/GDP) of a region is determined by the level of technical progress, considered as an exogenous scale. Solow's model uses the production function of $q = A(t)\ f(K,L)$ with q as output, K as capital, L as labor, and A(t) as the amount of technical progress that is considered as an exogenous scale. In his empirical evidence, Solow found the rate of technological progress as a residual factor of the economic growth rate reduction, with the growth rate of capital K and the growth rate of labor L. Hence, technical progress is also commonly referred to as a residual factor in the economic growth.

In the context of policy analysis, Solow's model above cannot be used. Hence the economic growth theory with technology as an endogenous variable is still widely used. The model attempts to explain the decision-makings (policies) that will determine the progress of science, through the activities of research & development (R&D), in their influence on the technological development may in turn stimulate the growth of an economy.

One of the researches using the theory is conducted by Tjahjono and Anugrah (2006), Economic Researchers at the Bureau of Economic Research (BRE), Directorate of Economic Research and Monetary Policy (DKM), of the Bank of Indonesia. This study calculates the performance of Indonesia's economic growth by using (i) the Solow-Swan model, (ii) the expansion of the Solow-Swan model by adding the human capital factor, fit to Mankiw-Romer-Weil (MRW) model, and (iii) several factors, the sources of business cycle fluctuations in Indonesia. The results of growth accounting show that the TFP growth (Total Factor Productivity, as an indicator of technology) during the period from 1985 to 2004 reached 1.35% per year.

When the technology-economy phenomenon is observed carefully, technological element is not explicitly visible in it. The production level of a product (goods or services) that can be produced by an economy is in fact only determined by the presence of two most important production factors, namely capital or capital goods (machinery/ equipment and buildings/constructions) and labor; both in terms of quantity and quality (sophisticated machines, highly skilled labors). The technological element is embedded in both production factors: capital and labor.

This means that the policies (interventions) affecting technology-economy phenomenon can only work through capital and labor, among others, research & development (R&D) policies and education & training policies. R&D activities will build the nation's ability to create (generation capacity), while the level of education will determine the nation's ability to perform repetitions (repetition capacity). In this context it can certainly be stated that, Solow's model of growth cannot be used to achieve the objectives of this study that focus on research & technology (R&D) policies. In addition, the model adequate for the purpose of policy analysis (policy model) must accommodate a number of principles that shall be described below.

3. The Model for Policy Analysis

The model, qualified and capable to be used as a means of analysis to formulate (design) the policy, must be a vehicle to find effective ways, and means of interventions in a system (phenomenon). Through this intervention, the desired system-behavior can be obtained (and the undesired system-behavior can be avoided). Thus, the model established for the purpose must meet the following requirements:

(1) Since the effect of an intervention (policy), in the form of behavior, is a subsequent occurrence; then to trace it, the time element (dynamic) is required;

(2) It must be capable of simulating various interventions and can give rise to the desired system-behavior;

(3) It allows at simulation whose effects of intervention dramatically vary: (1) in the context of time (long-term versus short-term effects, trade-offs in time), and (2) in the context of sectors (the effect of improving a sector's performance results in exacerbating of other sectors' performance, the trade-offs between sectors); referred to as dynamic complexity;

(4) The above system-behavior is an experienced and observed behavior (historical) or a never observed behavior (experienced but not observed or never experienced but is likely to occur); and

(5) It is capable to explain why a certain behavior (e.g. difficult transition) can occur.

To construct a policy model that accommodates the requirements above, Sterman (1981) proposes some principles that should exist in a dynamic model:

(1) the desired and occurring circumstances must be explicitly stated and distinguished in the model;

(2) the existence of the stock and flow structure of real life should be represented in the model;

(3) the streams that are conceptually different in characteristics must be clearly distinguished in handling them;

(4) only the information actually available to actors in the system should be used in decision modeling;

(5) the structure of decision-making rules in the model must fit with managerial practices; and

(6) the model must be robust in extreme conditions.

Furthermore, in relation to model-validity, a model must fit with existing empirical reality. The model is the result of an effort to make an artificial reality (Burger, 1966). Modeling efforts must be in accordance with scientific method. Saeed (1984) has described the scientific method based on Popper's concept of refutation (1969). This method requires that a model must have a lot of points of contact with reality (reality), and the repeated comparison between the model and the real world through the points of contact must make the model robust.

4. Methodology of System Dynamics

Speaking about a policy-making process (decision) in a social phenomenon will involve dynamic things. A dynamic phenomenon emerges due to the physical structure and decision-making structure that interact with each other. The physical structure is formed by the accumulation (stock) and flow networks of people, goods, energy, and materials, while the decision-making structure is formed by the accumulation (stock) and network of information flow used by actors (human) in the system that describe the rules of the decision-making process. It is both structures that cause the behavior of a phenomenon (system) to emerge.

In the paradigm of system dynamics (systems thinking), physical structure and decision-making structure are believed to be built by interdependent elements and form a closed-loop or feedback loop. The interdependent relationship between elements is a feedback causal one rather than unidirectional causal one (Senge, 1990). The feedback loop is the building blocks of the main model. It is the model built through a structural analysis, based on system dynamics approach (systems thinking), that allows the model to have many points of contact with the real world it models; thus fitting the scientific method of a model-making as has previously been proposed by Saeed.

5. An Approach to Explain Technology-Economy Phenomenon

As described previously, the element of the technology is not explicitly visible in an economic system. The production level of a product (goods or services) that can be produced by an economy is in fact only determined by the presence of two most important production factors, namely capital or capital goods (machinery/equipment and buildings/constructions) and labor; both in terms of quantity and quality (sophisticated machines, highly skilled labors). The technological element is embedded in both production factors: capital and labor

5.1 Proposition of Technology-Indicator in an Economic System

In the context of two factors of production as described above, what is observable (tangible) in the phenomenon of the development of an economic system are, among others, as follows:

1) The economic system of modern society 'has' relatively large artifacts (objects or goods of human creation) (do compare modern society in Java with the traditional society, Dani tribe in Baliem Valley, Papua). [Note: artifacts are produced by 'mixing' (mixing) capital goods (capital, machinery) and labor using 'technology' in a production system. Goods are produced by mixing certain machine (equipment) by certain employees with certain qualifications as well, or produced by mixing the two factors of production using certain technology].
2) Capital goods get more sophisticated or complex, and their volume and modes are also manifold.
3) Labor gets more productive (goods/day/ person or the produced IDR per day per person increases) and the number of labor is multiplied.

Based on the above observations, it can be proposed that the technology indicator in an economic system is the Capital-Labor Ratio (KLR). Technology is embedded in capital and labor input factor, unlike the conventional approach, through residual factor. If "KLR" increases it can be stated that the development of technology increases as well.

This is supported by the US economic growth in 1900-1965 (Source: Bach, George Leland (1968), Economics: An Introduction to Analysis and Policy, Prentice-Hall, Inc., pp.: 209-211). Based on the fact, Bach stated that since 1900 the capital stock has grown much faster than labor (meaning KLR increases); the GNP has grown faster than the combination of labor and capital, and real wage; and the interest rate has moved according to the theory of growth. Based on the observation on the American economy in the period of growth, it is visible and tangible that 'technology' has increased as well.

By using the Capital-Labor Ratio (KLR) as the technology indicator in an economic system, there is an implication that technological developments will be largely determined by the decisions relating to the movement of capital and labor, both in terms of quantity and quality. For capital, the quantity aspect is the investment decision and depreciation; while the quality aspect is the level of productivity. For labor, the quantity aspect is the hire and fire decision of labor; while the quality aspect is the (educational) quality of labor. Therefore, the model of technology in an economic system must accommodate the decision-making process. In addition, the behavior of economic phenomenon, as revealed by Bach in the previous section, shows that in long-term the interest rate is roughly flat in trend and the capital-output ratio (KOR) was also roughly flat in trend. In a technology-economy model developed by these two ratios, the real interest rate and the capital-output ratio (KOR) are considered constant.

5.2 The Technology Model in an Economic System (Technology-Economy Model)

The amount of production (Gross Domestic Product) is selected as a quantity representing the economic (system) phenomenon. Production level, symbolized by the letter q [unit/year], is determined by two production factors, namely: capital (capital, machinery/equipment, and building/construction) and labor. Capital is symbolized by the letter K [unit] and labor is symbolized by the letter L [people]. The determination of the level of production "q", which is determined by the capital "K" and labor "L", is modeled by a production function that meets the requirements of the production function and is made as such that its dimensions (units) are consistent as:

$$q = qo * (K/Ko)^\alpha * (L/Lo)^\beta \qquad (1),$$

α (alpha) as the exponent of capital (capital intensity) and β (beta) as the exponent of labor (labor intensity) are considered constant. Alpha (α) and beta (β) is dimensionless (do not have a unit); qo is the initial production level (level of production in the initial years); Ko is the number of initial capital, and Lo is the number of initial labor. Production function expressed by equation (1) above is referred to as normalized production function, abbreviated as normal production function.

Industrial decision (entrepreneurs) to increase (or reduce) the production factors of capital and labor (the acquisition of production factors), to meet the constantly changing demand for products (goods and services) is considered rational by applying profit-maximizing behavior. It should be noted that changes in demand may occur due to changes in the number of customers or changes in the variety of products caused by innovations (innovations require the touch of technology). The first-order condition for the above profit-maximization behavior is: (1) first-order partial derivative of profit on capital must be equal to zero and the first-order partial derivatives of the profit on labor must also be equal to zero. Such condition can be written as follows:

$$\delta Profit/\delta K = 0 \text{ and } \delta Profit/\delta L = 0 \qquad (2),$$

Profit = profit [IDR/year];
K = the number of capital [unit]; and
L = the number of labor [people].

Completing the above condition for capital K and labor L, whose normal production function meest the Cobb-Douglas production function ($\alpha + \beta = 1$), similarly important equations are obtained as follow:

$$K = \alpha*q/(1/alk+R) \quad (3)$$

$$L = \beta*q/rw \quad (4)$$

$$Alk = KOR/[\alpha-(R*KOR)] \quad (5)$$

$$A = 1-(KOR*rw/KLR) \quad (6)$$

$$B = 1-\alpha \quad (7)$$

$$Gq=\alpha*Gk+\beta*Gl+KOR*(rw/KLR)*\ln(KLR/KLRo)*(Gklr-Grw) \quad (8),$$

q = output or production level [unit/year];
alk = average life of capital [year];
R = real interest rate [1/year]; and
rw = real wage [unit/person/year].

In the above equations α is the exponent of capital (capital elasticity of the output or capital intensity), β is the exponent of labor (labor elasticity of the output or labor intensity), KOR is the capital-output ratio, KLR is the capital-labor ratio, KLRo is initial KLR, Gklr is the growth rate of capital-labor ratio in %/year, Grw is the real wage growth rate in %/year, and ln is the normal algorithm (lon). Equation (8) reveals that economic growth (output) Gq endogenously determined by capital growth Gk, labor growth Gl, and the difference between the growth of capital-labor ratio Gklr and real wage growth Grw.

The analogy with Solow's formula, as has been previously explained in equation (8) above can be written in the following equations:

$$Gq=Ga+\alpha*Gk+\beta*Gl \quad (9)$$

$$Ga =KOR*(rw /KLR)*\ln(KLR/KLRo)*(Gklr- Grw) \quad (10)$$

Unlike Solow's formula, affirming that technology growth is as a residual amount, exogenously contributing to economic growth, equation (10) above, instead, very clearly states that the contribution of technology (capital-labor ratio/ KLR) in economic growth "Gq" is determined by two production factors, capital and labor, through the level of capital-labor ratio (KLR) and the growth rate of Gklr (KLR is the proposition of technology indicator in an economic system). It should be noted that this effect of technology is influenced or corrected by the real wage rate, "rw" and its growth rate, "Grw". In equation (10) above, the value of Ga may be positive (Ga> 0), negative (Ga <0), or equal to zero (Ga = 0). If Ga is positive, it means Ga can contribute to further increase the economic growth rate "Gq", occuring when Gklr> Grw (technological growth is greater than real wages growth). In this condition it can be interpreted that, the growth of technology can further enhance economic growth. When Gklr<Grw (technology growth is smaller than real wage growth), the Ga is negative, Ga contribute negatively to economic growth Gq; whereas when Gklr = Grw (technology growth is similar to real wage growth), Ga is equal to zero; it means Ga does not contribute to economic growth Gq. The description states that the proposition of capital-labor ratio KLR as an indicator of technology in an economic system can already be described and demonstrated, and also in accordance with the statement of Bach (1968), based on empirical evidence of US economic growth as has been described previously. Thus this proposition can be used to construct a model of technology-economy.

6. Using Methodology of System Dynamics

The main assumption in the paradigm of system dynamics is that the structure of the phenomenon is an assembly of causal loop structures. The existence of this structure is a logical consequence of the physical constraints and social goals, reward and the pressure that cause people to behave and cumulatively generate dominant, dynamic tendencies of the overall system. Therefore the system dynamics model is classified into causal mathematical model (theory-like). The causal relationship disclosure of system dynamics model in the form of a mathematical expression is based on the postulated causal relations contained in the phenomenon under study.

In addition, the built simulation model accommodates some of the principles that should exist in a dynamic model, as described previously. The most important principles are: (1) the desired state and the actual state must be explicitly stated and distinguished in the model; (2) the structure of the stock and flow in real life must be represented in the model; (3) only the information that is actually available for actors in the system that should be used in decision modeling; and (4) the structure of decision-making rules in the model must fit with managerial practices.

6.1 System Dynamics Model for Technology-Economy Model

System dynamics model for technology-economy model is constructed by accommodating the above principles, based on equation (3) through (7), described previously (Section 5.2). Since the equations are derived from profit-maximizing behavior, equation (3) for capital and equation (4) for labor have meaning that in an optimal state (maximum profit) the amount of available capital must be similar to equation (3), and the number of available labor must be similar to equation (4). Or, in the decision-making process, equation (3) and equation (4) state the amount of desired capital and the amount of desired labor to generate products in order to meet the demand with the maximum profit.

Therefore equation (3) is used to determine the desired capital Dk into equation (11) as follows:

$$Dk=D\alpha*Eql/(1/alk+R) \quad (11)$$

The amount of Dk is the capital demand [unit], Dα is desired capital intensity [dimensionless], and variable Eql is estimated long-term demand [units/year]. The desired capital intensity (Dα) in equation (11) above represents the influence of the innovations in an economic system resulting from the R&D activities, whose process requires capital. Equation (11) states that the desired capital is not determined by product demand Eql only, but also by the presence of innovations. In the model developed, Dα can be determined exogenously (exogenous technological development) or endogenously based on the R&D capacity (endogenous technological development). Exogenous technological development has the potential to increase imports, while endogenous technological development can also increase imports if the results of R&D activities are not directed to decrease the dependence on technology (capital) from outside.

Eqation (4) is used to determine labor demand Dl into equation (12) as follows:

$$Dl=D\beta*Eqs/rw \quad (12)$$

The amount of Dl is labor demand [person], Dβ (= 1 - Dα, based on equation (7)) is the desired labor intensity [dimensionless], and variable Eqs is expected (estimated) short-term demand. The demand on the production factors will in turn determine the occuring level of capital and labor, and thus will also determine the level of KLR or technological development.

Taking into account the existing capital as an actual state, and its depreciation rate, the variable of capital demand (equation (11)) will determine the need for investment [units/year]. This investment needs shall be the actual state, that will add to the capital, determined by the level of investment fund availability and the level of capital goods availability in the market. In the model, capital [unit] is a variable of stock or level that will grow through investment [units/year] and is reduced due to the depreciation [units/year]. Because investment decisions have a relatively high risk, the capital demand is determined by the long-term estimation of demand Eql; as expressed in equation (11) above. The labor demand (equation (12), taking into account labor and existing unemployment rates as well as the conformity between technological level and the existing labor qualifications, will determine the hire rate and the fire rate. The hire rate [person/year] will add to labor [person], stock variable, as well as reduce the unemployment rate [people]. While the fire rate [person/year] will add to the unemployment level, stock variable, as well as reduce the number of labor available. Decision of hire/fire rate is not determined by the long-term demand expectations as in the determination of capital demand, but rather determined by the short-term estimation of demand. In addition to the inreasing unemployment rate due to the termination of employment, the unemployment rate will increase due to increasing new labor force coming from the population

The stocks of capital and labor, formed (occuring) through the above decision-mechanism (investment, depreciation, and hire/fire rate), will determine the KLR level. By knowing this KLR figure, accompanied by real wage rate rw and the parameter of capital-output ratio KOR; the actual capital intensity α (actual α) and actual labor intensity β (actual β) can be calculated using equation (6) and equation (7). Thus, through the equation (5), the average life of capital 'alk' can be determined. This average life of capital will be used to calculate the amount of capital depreciation; and the depreciation rate will affect the amount of investment decisions as described previously.

After the figure of production factor intensity of α and β are known, these two parameters together with the level of capital and labor will determine the potential production or the production capacity of the economic system, calculated using equation (1). The potential production that has considered the short-term demand will determine the level of production or output (GDP) of the economic system. After deducted by taxes, the GDP or income will determine the permanent income; and it is this permanent income that will ultimately determine the level of consumption in the economic system.

6.2 The Structure of Technology-Economy Model

The description presented in Section 6.1 above forms a technology-economy model such as that depicted in Figure 1.

Figure 1 above shows that the technology-economy model is founded on six submodels: (1) submodel of income, (2) submodel of Technology, (3) submodel of R&D, (4) submodel of population, (5) submodel of Labor, and (6) submodel of wages. The six submodels are interrelated to one another.

In submodel of revenue the macroeconomic aggregates such as GDP, consumption, shopping pemeritah, investment, exports, and imports are determined. This submodel is complemented by inventory as an aggregate stock in the economy. Some of the most important variables are specified in this

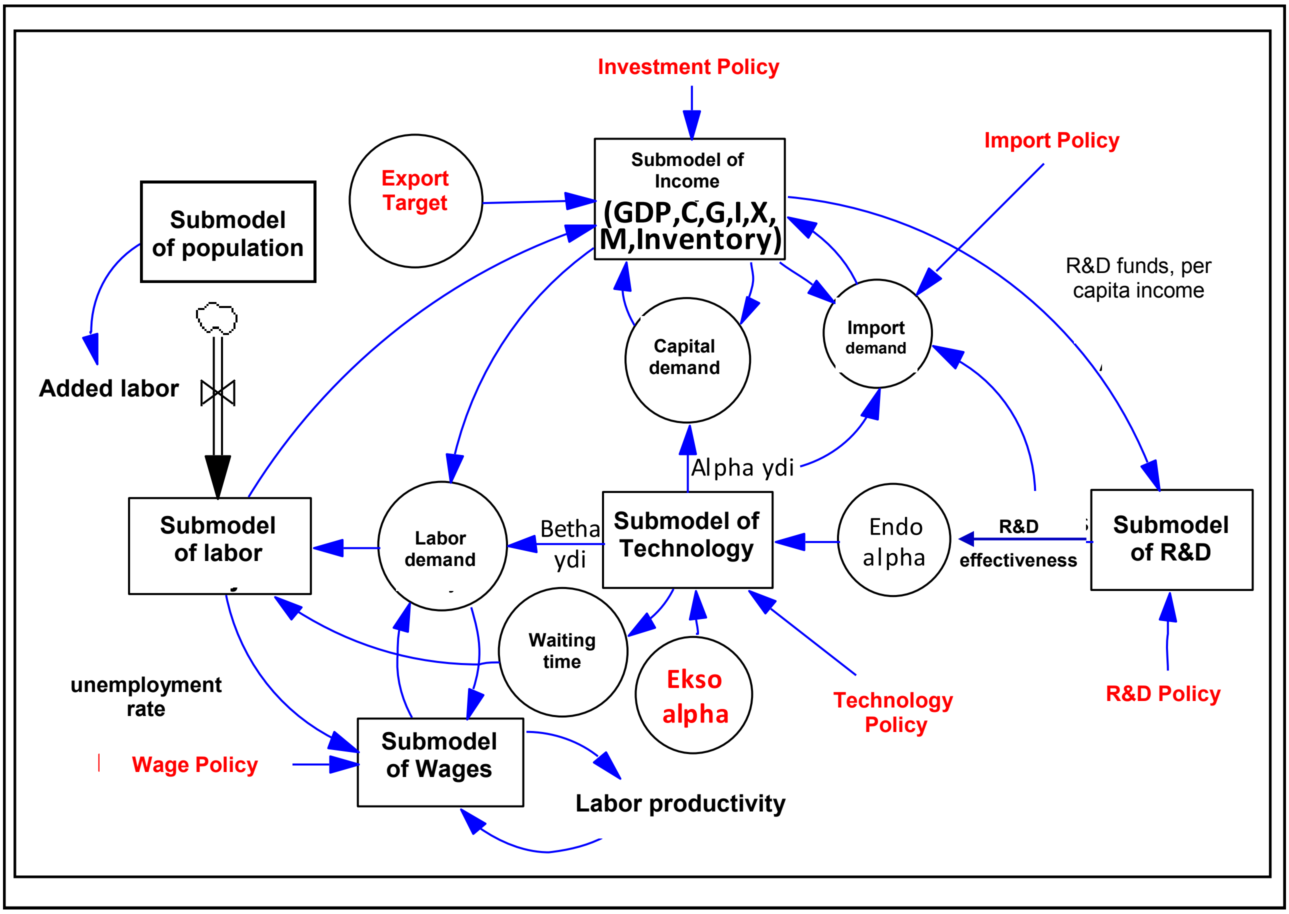


Figure 1. The Global Structure of Technology-Economy Model

submodel of income and related to (affecting or affected) other submodels, among others capital demand, labor demand, and the need for imports. In addition, the level of GDP calculated in this submodel is assumed to affect the amount of R&D funds allocated to R&D submodel. The R&D funds, along with the level of per capita income also generated by submodel of revenue, will determine the dynamics of R&D capacity, calculated in the submodel of R&D. "Export target" is the exogenous amount for Income submodel, and the submodel can be influenced by the "Investment Policy" (policies relating to the availability of investment funds). In addition to this investment policy, the dynamics of imports in Revenue submodel dynamics can be influenced by the "import policy" through the amount of import demand ("import demand" in Figure 1).

In Labor submodel, the number of labor and unemployment rate are determined based on labor demand ("labor demand" in Figure 1) of the Income submodel, "Added labor" (from population submodel), and the "waiting time". The labor demand is influenced by the desired labor intensity ("β ydi" in Figure 1) of the submodel of Technology, and the wage level from the wage submodel, as previously described in Section 6.1. In Wages sub-model, the wage rates and "labor productivity" are determined based on the labor demand, unemployment rate, and labor productivity. In this study, the population variable is treated as exogenous quantity.

In Technology submodel the amount of "α ydi" and "β ydi" are determined. Both amount of intensity (capital and labor) will determine the level of technology in economy which in turn will affect economic growth (GDP) and imports, specified in Revenue submodel. The development of technology can be selected based on the exogenous target ("exo alpha" in Figure 1) or based on the self-skills ("Endo alpha" in Figure 1), determined by the existing R&D capacity (the amount of "R&D effectiveness" in Figure 1). The selection can be determined through the variable of "technology policy" in Figure 1. The "R&D effectiveness" is specified in the R&D sub-model based on the R&D funds allocation and the level of per capita income, described previously, and also affected by the variable of "R&D policy" in Figure 1 above.

6.2.1 Submodel of Income

The following Figure 2 depicts the causal-loop diagram of Income Submodel developed by integrating two macroeconomic models (Forrester, 1982):

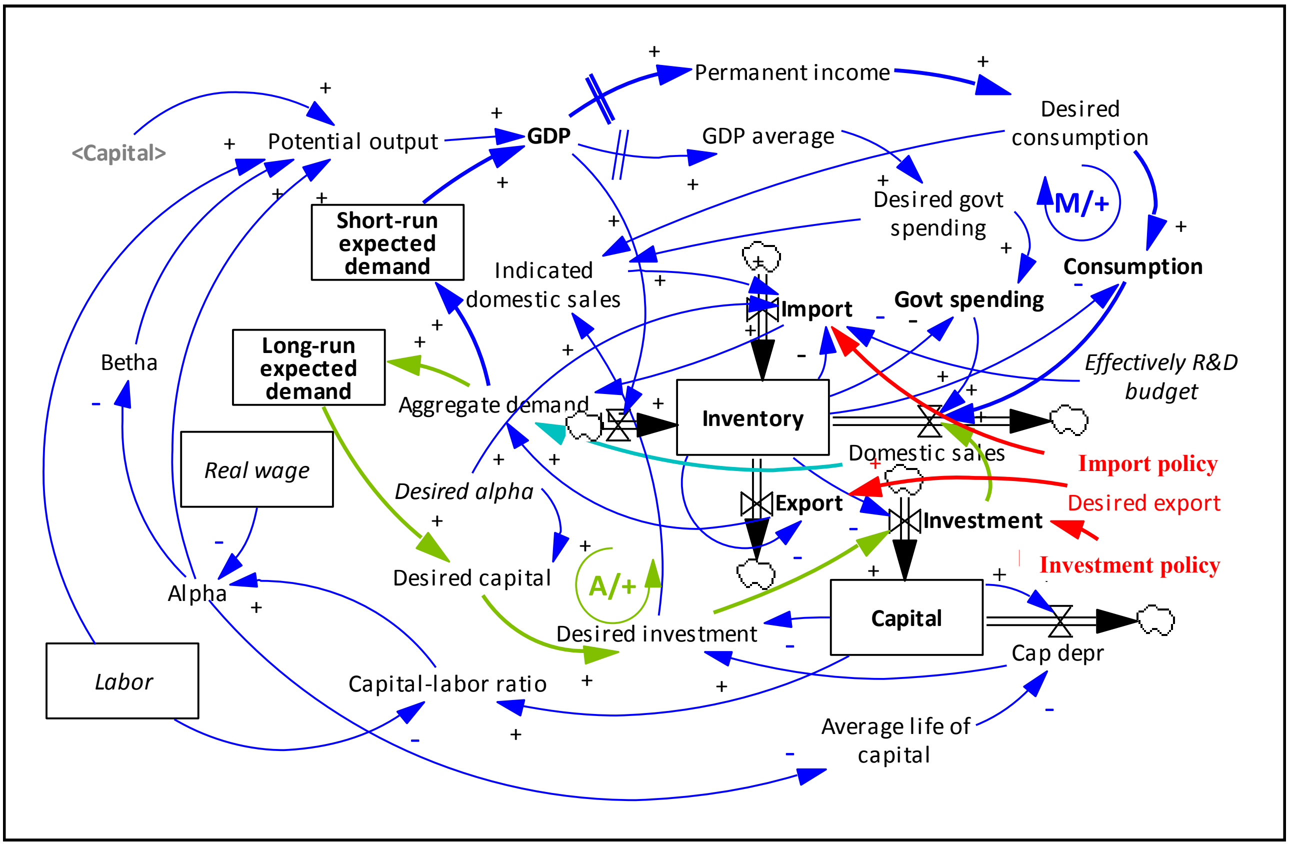


Figure 2. The Causal-loop Diagram of Income Submodel

(1) Samuelson model of multiplier-accelerator (1939); and

(2) Metzler model of inventory adjustment (1941).

Both macroeconomic models are modified to meet the modeling requirements using system dynamics methodology.

The first important concept in multiplier-accelerator model is the mutual dependence between the output (GDP) and consumption (multiplier loop). The demand for consumption (consumption) depends on the level of income (GDP or output); and the output responds to the level of demand (consumption); in system dynamics methodology, this concept forms a positive feedback loop (growth). In Figure 2, the feedback loop is illustrated through a long chain (ring M/+): "GDP" - "Permanent income" - "Desired consumption" - "Consumption" - "Domestic sales" - "Aggregate demand" - "Short-run expected demand" - "GDP". "Consumption" is determined based on the "Desired consumption" which is then corrected by the availability of stock ("Inventory"). Furthermore, the "Desired consumption" is not directly determined by the "GDP", instead through the "Permanent income"; accommodating the permanent-income hypothesis of Friedman (1957): "Consumption is a fraction of permanent income. Permanent income is an exponential lag of current disposable income". In the system dynamics methodology, an exponential lag is modeled as a process containing delay (average), as shown in Figure 2 above.

Gross Domestic Product or GDP (the amount of "GDP" in Figure 2) is determined based on the "Potential output" by considering the request through the amount of "Short-run expected demand". While the "Potential output is" determined by the amounts of "Capital", "Labor", "Alpha", and "Betha" through a Cobb-Douglas production function (Alpha + Betha = 1), calculated using equation (1) in earlier Section 5.2. Alpha (α) [as well as beta (β)] in the model developed are considered not constant, influenced by the amount of "Capital-labor ratio" (an indicator of the technological level in economy) and the amount of "Real wage"; calculated using equation (8) as has been presented in Section 5.2 earlier. The "capital-labor ratio" is the ratio between the amount of "Capital" and "Labor".

The second most important concept in the multiplier-accelerator model is the mutual dependence between the demand (the amount of "Aggregate demand" in Figure 2) and investment (the amount of "Investment" in Figure 2), referred to as the accelerator loop. Investment depends on the level of demand, and on the next turn the investment level will determine the demand; in the system dynamics methodology, this concept forms a positive feedback loop (growth). In Figure 2, the feedback loop is illustrated through a long chain (ring A/+): "Aggregate demand" - "Long-run expexted demand" - "Desired capital" - "Desired investment" - "Investment" – ”Domestic sales" - "Aggregate demand". "Investment" is determined based on the "Desired investment" which is then corrected by the availability of stock ("Inventory"). This accelerator loop modification is: in addition to the "Desired capital" is determined by the demand ("Aggregate demand"), the "Desired capital" is also influenced by the amount of "Desired alpha", an amount reflecting the desired level of technological development (as described previously).

The couple of multiplier and accelerator loops is positive feedback (growth), forming a mechanism for growth in the economic system. The mechanism of growth will be stronger if the level of technology can be sustained to increase (increasing "desired alpha").

"Inventory" in Figure 2 represents the aggregate stock of the economic system. The level of stock availability will affect consumption, government spending, investment, and exports. Production ("GDP") and import will add to the stock ("Inventory"); while consumption, government spending, investment, and exports will reduce inventory. Most of the domestic demand ("Domestic sales") still have to be met by imports, as shown in Figure 2; and this import is also influenced by the stock availability level ("Inventory"). Apart from determined based on the demand and stock, the size of imports is notably determined by the level of technological development ("Desired alpha") and can be influenced by the "import policy" as shown in Figure 2 above.

Capital demand ("Desired capital") is influenced by the desired capital intensity ("Alpha ydi" in Figure 2), as previously described in Section 6.1; while "Alpha ydi" is specified in the submodel of Technology. Import demand is influenced by the pattern of the selected technology development, through the desired capital intensity ("Alpha ydi" in Figure 1) as determined in the submodel of Technology; in addition, it is also influenced by the level of R&D activities effectiveness specified in the submodel of R&D. Furthermore, labor demand will be the input for the submodel of Labor. In submodel of Labor, the labor demand will determine the level of labor (which becomes the input for the submodel of Revenue) by considering the unemployment rate and the increase of new labor force from the population submodel, and the waiting time to get a job ("waiting time" in Figure 1 above).

The waiting time is influenced by the level of technology specified in the submodel of Technology. The import demand specified in the submodel of Revenue is influenced by the pattern of the selected

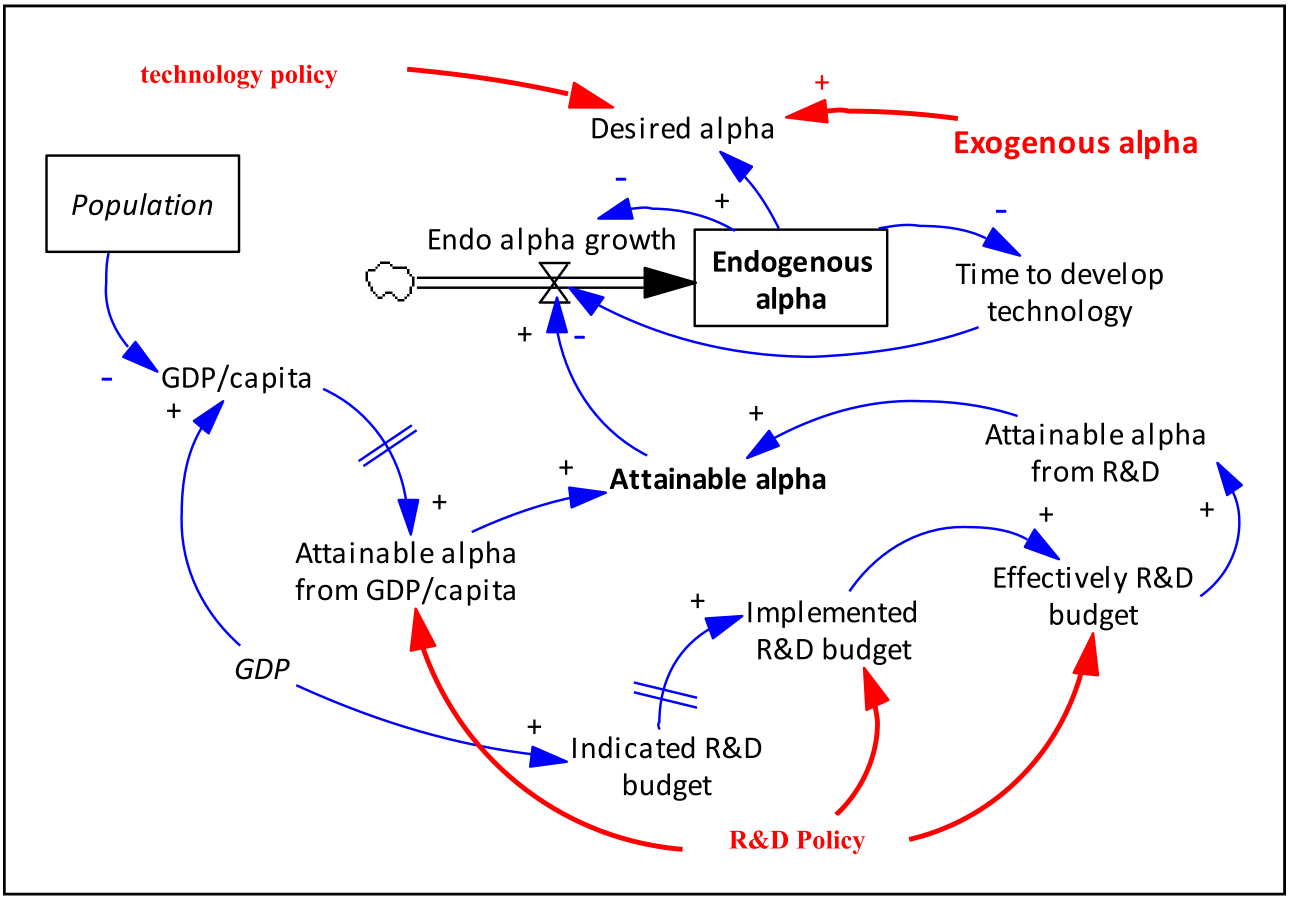


Figure 3. The Causal-loop Diagram of Technology Submodel and R&D Submodel

technology development, through the desired capital intensity ("Alpha ydi" in Figure 1) specified in the submodel of Technology; in addition, it is also influenced by the level of R&D activities effectiveness, specified in the submodel of R&D. Technological developments are exogenously (not based on the existing R&D capacity) potential to increase imports. While the technological development based on the existing R&D capacity (ineffective R&D condition) may only be able to maintain imports in its historical level (still relatively large). The R&D funds will determine the R&D capacity, and the national ability to create (generation capacity); while the per capita income will determine the level of national education, which in turn will determine the nation's ability to perform repetition (repetition capacity).

6.2.2 Submodel of Technology and Submodel of R&D

As described previously, the desired capital intensity ("Alpha ydi" in Figure 1) is specified in this submodel; referred to as the variable of "Desired alpha". In this submodel, the determination of "Desired alpha", which in turn will determine the level of technology, can be selected based on "Endogenous alpha" or "Exogenous alpha" through a "technology policy". "Endogenous alpha" represents the level of technology that can be achieved based on the self-skills (self-contained) in accordance with the "Attainable alpha" depicted in Figure 3 above; through a development process that takes time ("Time to develop technology"). While "Attainable alpha" is determined by the level of national education (in this submodel represented by "GDP/capita") through the variable of "Attainable alpha from GDP/capita" along with the variable of "Attainable alpha from R&D" which determine the ability of the nation in terms of the creation; the latter is largely determined by the effectiveness of expenditure (investment) in R&D activities, referred to as "Effective R&D budget" in the model. The effectiveness of R&D funds is obtained from the implementation of the R&D budget; in this model the amount is assumed proportional to GDP. The development of educational level, implementation of R&D funding, and effectiveness of R&D budget in the model are determined by government policy ("R&D Policy"). In this study the development of technology is exogenously (not based on the existing R&D capacity) potential to increase imports; while the development of technology based on the existing R&D capacity (ineffective R&D condition) may only be able to maintain imports in its historical level (still relatively large).

6.2.3 The Submodel of labor and the Submodel of Wages

The following Figure 4 portrays the causal-loop diagram of Labor Submodel and Wages Submodel.

As seen in the above figure, the "Hire rate" is obtained by dividing the number of unemployed ("Unemployment") by the waiting time of

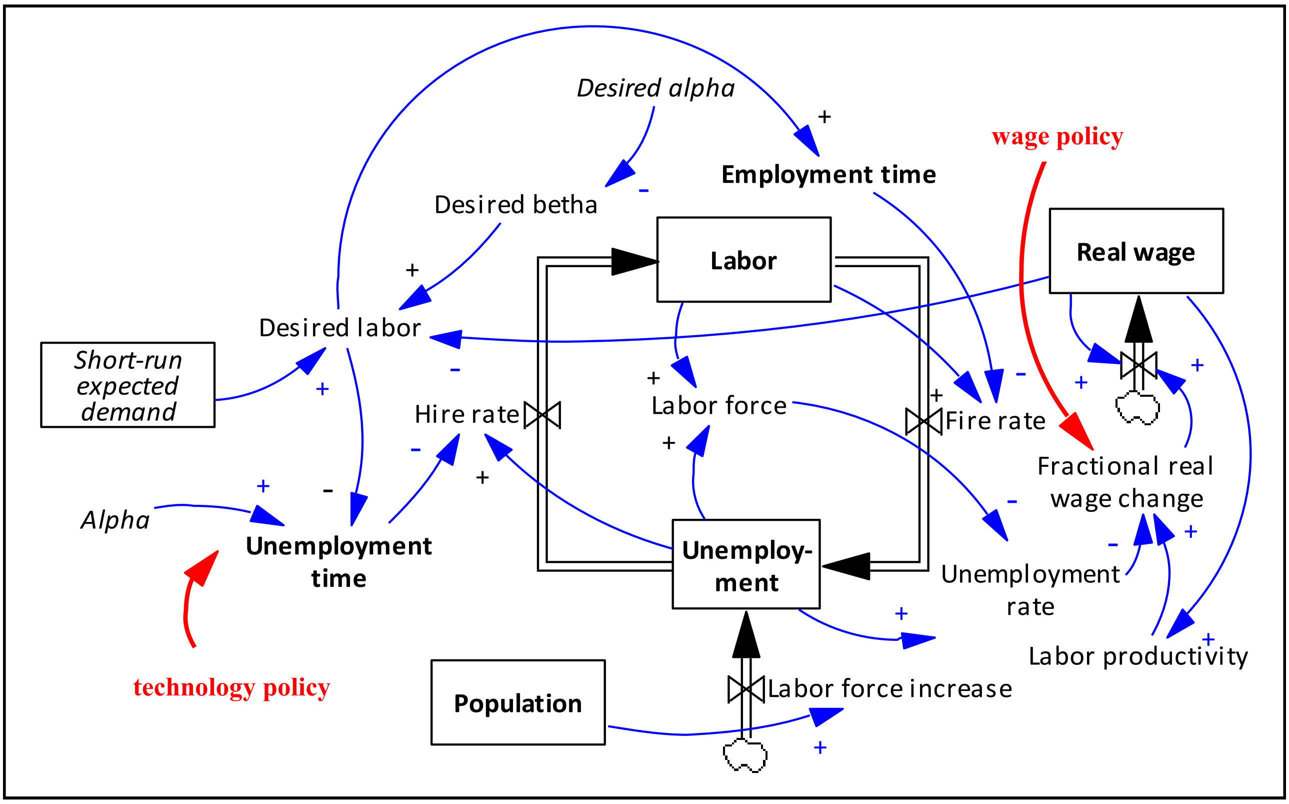


Figure 4. The Causal-loop Diagram of Labor Submodel and Wages Submodel.

appointment ("Unemployment time"). The number of unemployed will increase due to "Fire rate" and the addition of new labor force ("Labor force increase") derived from population growth ("Population"); and will be reduced due to the hire rate. "Unemployment time" is determined by the labor demand ("Desired labor") in the negative direction (opposite); increasing labor demand will shorten the waiting time. While the level of technological development ("Alpha") will potentially increase the waiting time if the development of education is not in line (link and match) with the development of the selected technology. As illustrated in Figure 4 above, the condition of link and match is influenced by technology policy (its relation to education and training policies) issued by the government.

"Hire rate" will increase the level of labor ("Labor"); and number of layoffs ("Fire rate") will reduce the labor. "Fire rate" is calculated by dividing the level of labor by the length of working time, ("Unemployment time") influenced by the labor demand ("Desired labor") in the opposite direction (negative); increasing labor demand will shorten the length of working time. In addition to reducing the level of labor, any layoffs will add to unemployment as shown in Figure 4. The labor demand is influenced by the desired labor intensity ("Desired beta" in Figure 4); the short-term demand expectations ("Short run expected demand"), and real wages ("Real wage") represent equation (14) as described previously in Section 6.1. The "Desired beta" is determined by the "Desired alpha" in the opposite direction (increasing "Desired alpha" will reduce the "Desired beta"); meaning that the increasing capital intensity in the economy due to higher levels of technology will have implications on reducing the labor intensity in the economy. If the decline in labor intensity is also followed by weaken demand and rising wages, this may result in the decrease of labor demand, which in turn can increase the unemployment rate. While real wages is influenced by the unemployment rate and labor productivity as shown in Figure 4. The increased unemployment will lower wages, on the contrary increased productivity will also increase wages. The wage changes can be controlled by the government through the "wage policy".

7. The Scenario of Technological Development and Economic Growth in Indonesia

To obtain technological development and economic growth, the previously described Technology-Economy Model (developed using the methodology of system dynamics) is simulated using a computer from 2000 to 2050. Year 2000 is used as the beginning of the simulation, intended to test the ability of the model to mime the historical behavior of Indonesian economy in the period of 2000-2010. The initial conditions of model (in 2000) for the variables of stock (level) and the parameters in the model are set based on BPS data, calculated based on the structure (equation) of model, or using the results of previous studies. After the year 2010, the model is simulated using several scenarios related to technology, then the impact on economic growth in Indonesia is shown.

7.1. The Historical Behavior Testing of Model

The model is simulated from 2000 to 2010 to get the historical behavior, and subsequently, this historical behavior of model is compared to historical data to build the confidence that the model can simulate the historical data. If the difference is comparatively small, it means the model-structure is approaching the actual structure of Indonesian economy; so that the model can be used to see the development of its behavior in the future. Historical data used are data from the Central Bureau of Statistics (BPS) in 2008 and 2009.

To test whether the model's behavior is similar to the real world (historical data), Theil Test Statistics is used. Deviation (error) is decomposed into three components/parameters: Um = bias; Us = variant; Uc = covariance. The relatively small (near zero) Um value indicates the absence of systematic error and the model is considered sufficiently valid. The comparison between the model simulation results and the historical data for some of the major variables produce a relatively small Um refractive error, close to zero; thus it can be affirmed that the Technology-Economy Model developed does not have a systematic error. Hence, it can be said that the model is valid to be used to simulate the scenarios of technological developments and their impact on the dynamics of the Indonesian economy in the future.

The behavior of the model simulation results, approaching its historical data above, in the period 2000 to 2010, is resulted in the conditions:

a. The availability of investment funds increases at the rate of 6.67% per year;
b. Population growth is 1,285% per year;
c. The development of technology (α) does not take into account the R&D capacity, α max = 0.6 achieved in 2050 (exogenous);
d. The development of technology is not in accordance with the qualification of labor;
e. Export growth target is 7.3% per year (historical figures);
f. Import fraction is not affected by the R&D capacity;
g. The fraction target of government expenditure to

GDP is 10.6%;

h. There is no constraint on the availability of "foreign exchange";

i. The delay of the realization of the R&D funds allocation and the educational delay is 5 years;

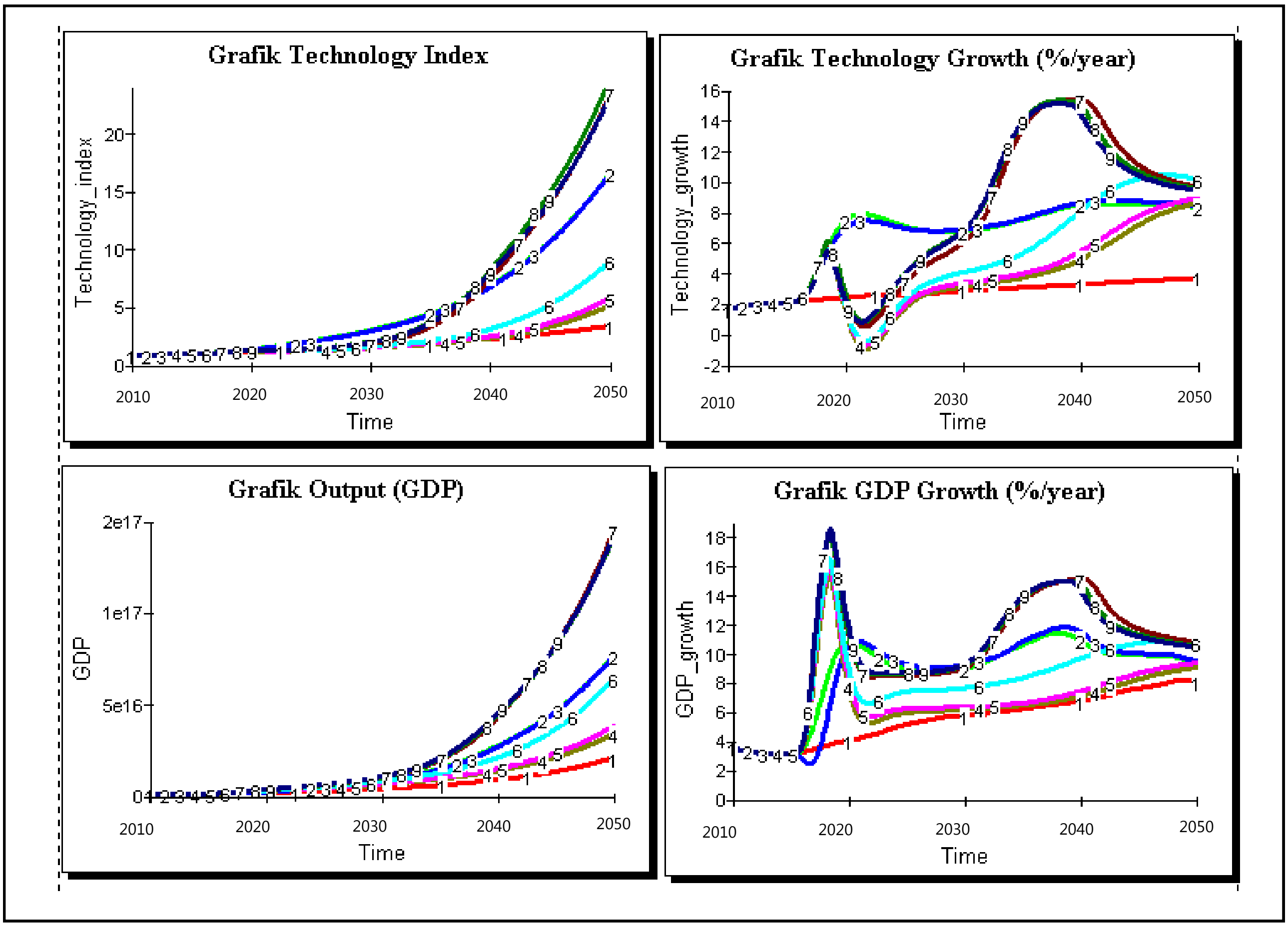
j. The effectiveness of R&D funding is relatively small, 40%; and

k. Wages are controlled by 40%.

7.2. The Scenario of Technological Development and Economic Growth in Indonesia in 2010-2050

First, the model is simulated in the above historical conditions which continued up to 2050 (Figure 5, 6, 7) ; the development scenario is called Basic Scenario (Scenario 1), used as a reference for comparison with other development scenarios. In this basic scenario, the development of technology is determined exogenously (not based on the R&D capacity); imports are set according to the demand (can be increased); the development of technology in relation to education is relatively not suitable, and the R&D activities are not effective. The other scenarios are related to investment funds, technology, imports, exports, budget and quality of R&D, wages, and unemployment.

In the basic scenario, technology develops in a moderate rate and can generate a relatively high economic growth (GDP) compared with the historical growth (period of 2000-2010). In a relatively high economic growth, the growth of exports is greater than the growth of imports (net exports is positive) with a condition of relatively large import persentage as well. In addition, the unemployment rate continues to rise in the condition of improving labor productivity. The rising unemployment rate indicates the absence of a link and match between the development of technology and education. On the other hand, the percentage ratio of R&D budget to GDP continues to increase, yet has not or is even ineffective. The capital growth below the demand is due to the lack



Notes:
number 1 = basic scenario
number 2 = investment scenario
number 3 = optimistic scenario
number 4 = endogenous scenario
number 5 = import scenario
number 6 = export scenario
number 7 = R&D scenario
number 8 = wages scenario upah
number 9 = link and match scenario

Figure 5. Growth Scenarios: Technology and GDP.

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of investment funds availability; based on historical trends, the investment fund in fact remains smaller than its potential.

The condition of the investment funds lacking, in turn, cannot support the exogenous technological development. Therefore, in the following scenario (scenario 2), the structure of the investment decision after 2015 is altered by the determining the availability of investment funds, gradually towards its potential (Investment Scenario). The technological development rate in the investment scenario is greater than the rate in the Basic Scenario, as is GDP. However, this high growth is achieved by negative net exports (imports are greater than exports) although the fraction of imports to GDP declines. In addition, the dynamics of the unemployment rate and labor productivity is relatively unchanged.

By determining the availability of investment funds gradually towards its potential (which is relatively large compared to its historical growth), the actual capital (Capital_K) can approach the demand (Desired capital) and the R&D behavior becomes better although the percentage of effectiveness is still relatively low. Relatively high capital growth has led to an increase in the technological development rate, as described earlier, which in turn further increase the growth rate of GDP; and further escalate the R&D budget. Since in this investment scenario, the R&D effectiveness is still relatively small, its impact to import reduction is also relatively small, resulting in negative net exports.

If α maximum of 0.6, whose achievement is set in 2050 in the Investment Scenario, is set forward into 2040, as the third scenario (Optimistic Scenario); it turns out to give an insignificant influence.

As previously described, in the Basic Scenario, Investment Scenario, and Optimistic scenario, the development of technology is determined exogenously not based on the R&D capacity. The relatively high technological and economic growth rate can be achieved in Investment Scenario and Optimistic Scenario, yet followed by negative net exports. In the following scenario, scenario 4 (Endogenous Scenario), the development of technology is determined by the level of R&D effectiveness, gradually beginning in 2015 with a delay of 10 years despite the relatively low level of effectiveness. The following figures show the technology-economy dynamics in Indonesia in 2010-2050 for endogenous scenario.

The Endogenous Scenario shows that the dynamics of technological development and GDP is lower when compared to the Investment Scenario (2) and Optimistic Scenario (3) (in the two last scenarios of technological development, determined exogenously). However, its growth rate is still above the Basic Scenario. The dynamics of net exports is back to positive, and the percentage of imports falls; while the unemployment rate and labor productivity do not change much. In addition, the dynamics of the R&D budget continues to increase despite the relatively low level of effectiveness; and investment is only used as needed, and the magnitude is below its potential, resulting in relatively low development of technology and economy.

In the following scenario, scenario 5 (Import Scenario), Endogenous scenario is resimulated by adding a condition of the influence of R&D capacity to the decline in imports; although in this scenario the R&D is still not effective. The dynamics of technology development and GDP in this scenario is relatively better than Endogenous Scenario (scenario 4). The dynamics of net export growth, the percentage of imports, unemployment rate and labor productivity is relatively similar to the endogenous scenario. Similarly, the dynamics of R&D and investment is relatively the same as Endogenous Scenario.

It turns out that with the additional import policy above (Import Scenario), the relatively better dynamics of technology and economic growth compared with Endogenous scenario can be generated. This indicates that the R&D effectiveness is very important to be pursued in conjunction with the dynamics of the economy. Prior to the scenario of R&D effectiveness simulation, the following scenario, scenario 6 (Export Scenario), the Import Scenario is added to the policy of raising the export target of 7.3% per year to 9% per year starting in 2015 gradually (delay of 5 years). In this Export Scenario, the growth of technology and GDP is higher than Import Scenario equipped with similarly higher net exports. While the dynamics of the imports percentage, unemployment rate, and labor productivity is relatively similar to its behavior in Import Scenario. In this scenario, the development of R&D is better than Import Scenario, and greater investment, approaching its funding potential.

In the Export scenario above, R&D activities are still not effective. Hence in the following growth scenario, scenario 7 (R&D Scenario), the previous Export Scenario is strengthened by the policy of increasing the R&D effectiveness (policy related to the implementation of R&D funding and quality). In R&D Scenario, the delay of the realization of R&D funding allocation is shortened from the previous five years (in the basic scenario to export scenario) to two years beginning in 2015 gradually (delay of two years). In addition, the quality of the R&D funds utilization increases from 40% to 100% in 2015, gradually as well (delay of five years).

The R&D policy (R&D Scenario) manages to increase technological and economic development, followed by a slight decline in net exports. However, this policy has not been able to reduce unemployment rate and increase labor productivity significantly. Therefore, in the following growth scenario, Scenario 8 (Wages Scenario), the R&D

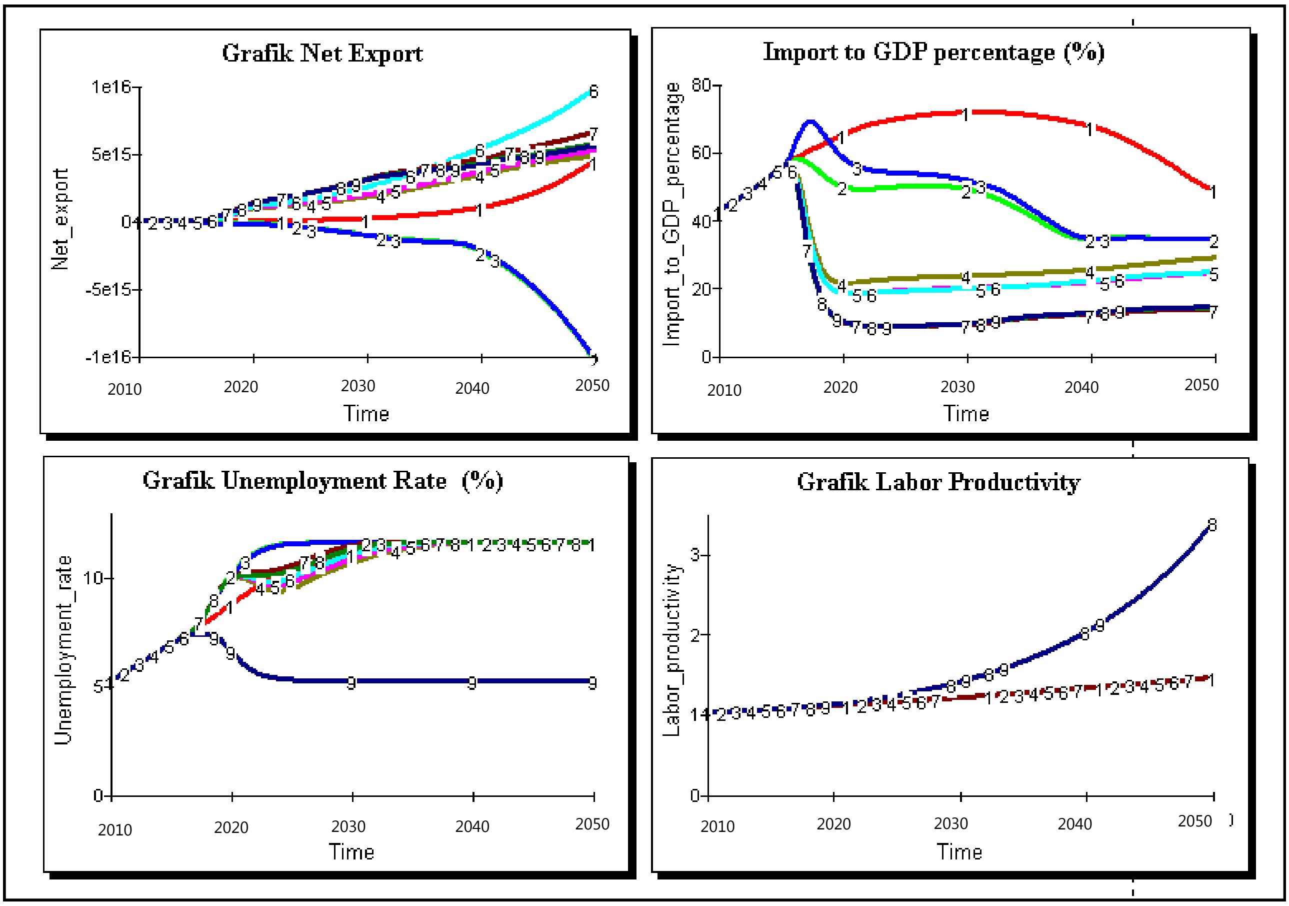

Figure 6. Growth Scenarios: net export, import percentage, unemployment rate, and labor productivity.

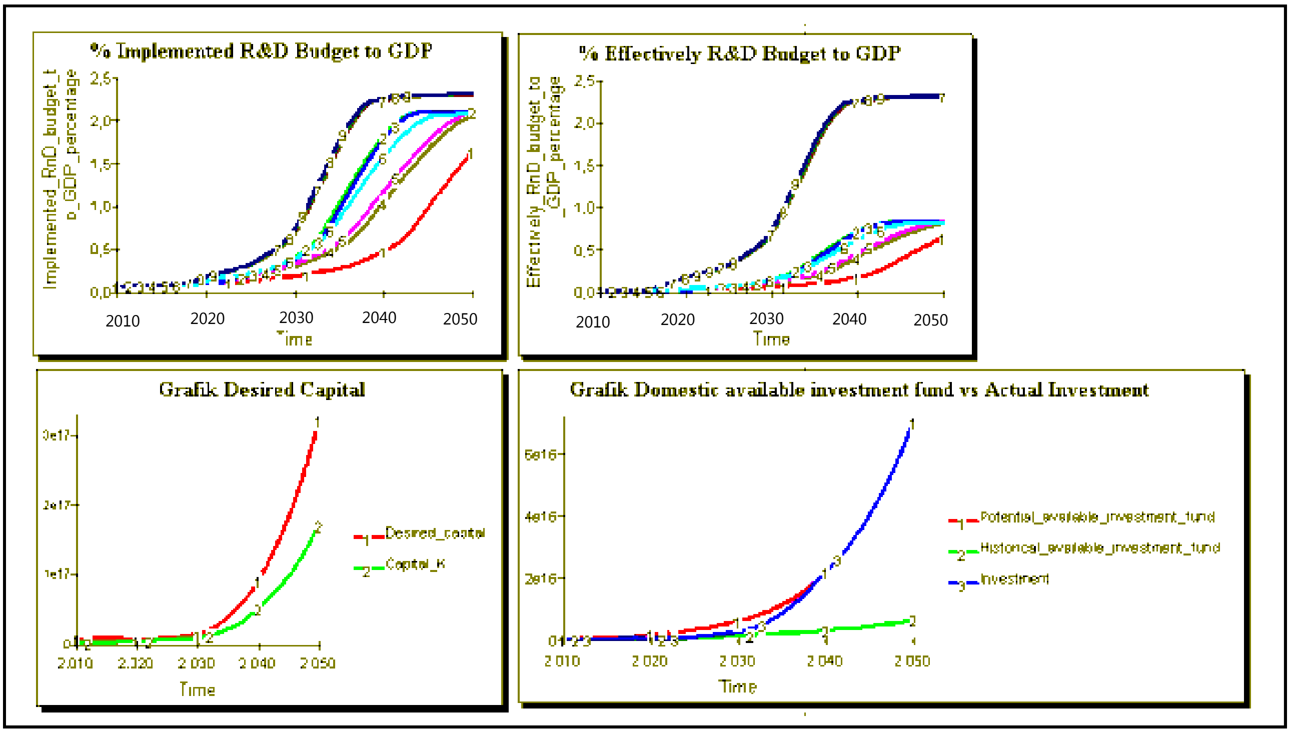

Figure 7. Growth Scenarios: R&D funds, effective R&D fund percentage, capital and demand, and available investment funds.

scenario is added with wage setting policy based on market mechanism, gradually beginning in 2015 (10 years delay). Wages are set by an increase in labor productivity and influenced entirely by inflation. In previous growth scenarios, wage setting is controlled partly by the government.

With the above wage policy (wage is fully set to follow the market mechanism), labor productivity increased significantly with the growth of technology and economy relatively similar to the previous R&D scenario. Nevertheless, the unemployment rate in this Wages scenario has not shown a decline, since the link and match policy has not yet been implemented.

In previous growth scenarios, following the basic scenario, the development of technology is not in accordance with the existing labor qualifications. This means that the occuring development of technology can increase the waiting time of the unemployed to be appointed as labor; which in turn will increase the unemployment rate, as shown in the previous growth scenarios despite the relatively large labor demands. In the following growth scenario, scenario 9 (link and match Scenario) the mismatch of labor qualification can be avoided. This means that the development of education and training programs should be appropriate (link and match) with the development of the selected technology. The figures below show the dynamics of technology-economy in Indonesia in 2010-2050 for all scenarios that have been described previously.

In this latter scenario, the development of technology and economy (GDP) is relatively high (Figure 5), the unemployment rate drops sharply, and the labor productivity increases significantly (Figure 6). In addition, the R&D activities can develop according to expectations; and investment is similar to its funding potential. If observed carefully, this link and match scenario simulates all the policies needed to achieve the goals of expected development of technology and economy, i.e. relatively high development of technology and economy, increasing and continual labor productivity, relatively low unemployment rate, the potential for investment funds that can be used optimally, and positive net exports (exports are greater than imports).

8. Conclusions

After the year 2010, the model is simulated using several scenarios related to changes in technology and economy; then it shows the effect on behavior (performance) of the Indonesian economy. The results of the behavioral analysis of these model simulations conclude the following important propositions:

1. The behavior of the model simulation results that is closer to historical data (2000-2010) is produced under the following conditions:
   a. The availability of investment funds increases at a rate of 6.67% per year;
   b. Population growth is 1,285% per year;
   c. The development of technology does not take into account the R&D capacity with a maximum capital intensity of 0.6, reached in 2050 (exogenous);
   d. The development of technology is not in accordance with the qualification of labor;
   e. Export growth target is 7.3% per year;
   f. Import fraction is not affected by the R&D capacity;
   g. The fraction target ratio of government expenditure to GDP is 10.6%;
   h. There is no constraint on the availability of "foriegn exchange";
   i. The delay of the realization of the R&D funds allocation and educational delay are five years;
   j. The R&D funding effectiveness is relatively small (40%); and
   k. Wages are controlled by 40%.

2. If the above historical conditions continue without any change, the performance of Indonesian economy shows a relatively moderate growth of technology and relatively high GDP growth. Net exports continues to increase and is positive (exports are greater than imports), although the percentage of imports to GDP is relatively high and may rise. In the basic scenario of growth, the unemployment rate continues to increase and labor productivity increases moderately.

3. To achieve the target of future technological and economic growth in Indonesia that is expectedly higher, and to produce a better economic performance than the above scenario (relatively high development of technology and economy, increasing and continual labor productivity, relatively low unemployment rate, the potential for investment funds that can be used optimally, and positive net exports) the following policies are required:
   (a) The R&D activities effectiveness should be sought as much as possible (no budget delay, quality R&D product, and impact on the import reduction).
   (b) R&D development should be linked (link and match) to the development of education and training, also related to economic development (investment, imports, and exports) and industrial development (wages).

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References

Bach, G.L. 1968. *Economics: An Introduction to Analysis and Policy*. 6th edition, Prentice Hall Inc., Englewood Cliff, New Jersey.

Forrester, J.W. 1990. *Principles of Systems*. Productivity Press, Portland, Oregon.

Forrester, N. 1982. A Dynamics Synthesis of Basic Macroeconomic Theory: Implications for Stabilization Policy Analysis. *PhD Dissertation, A.P.* Sloan School of Management, Cambridge, MA.

Graham, A.K., Senge, P.S. 1980. A Long-Wave Hypothesis of Innovation. In *Technological Forecasting and Social Change 17.*

Kendrick, J.G. 1961. *Productivity Trends in the United States*. National Bureau of Economic Research, Princeton, N.J.: Princeton University Press.

Mensch, G. 1979. *Stalemate in Technology*. Ballinger, Cambridge, Massachusetts.

Metzler, L.A. 1941. The Nature and Stability of Inventory Cycles. In *Review of Economics and Statistics.*

Nicholson, W. 1995. *Microeconomic Theory: Basic Principles and Extensions*. (6th ed). The Dryden Press, Harcourt Brace College Publishers.

Parayno, P., Saeed, K. 1991. The Dynamics of Indebtedness in Developing Countries: the Case of the Philippines. In *Proceedings of the 1991 International System Dynamics Conference*. Bangkok, Thailand, August 27-30 System Dynamics Society.

Power, D. 2001. *Advanced Macroeconomics*. (2nded). McGraw-Hill International Editions.

Richardson, G.P., Pugh III, A.L. 1981). *Introduction to System Dynamics Modeling With Dynamo*. MIT Press/Wright-Allen series in system dynamics.

Saeed, K. 1994. *Development Planning and Policy Design: A System Dynamics Approach*. Avebury.

Samuelson, P.A. 1939. Interactions between the Multiplier Analysis and the Principle of Acceleration. In *Review of Economic Statistics*. 21 (May): 75-79.

Sasmojo, S., Tasrif, M., Soemintapoera, K. 1992. *Technological Innovation for Productivity Improvement: A Developing Country Perspective*. 10th Conference of Asean Federation of Engineering Organizations (CAFEO – 10), Manila, the Philippines, 5-6 November.

Solow, R.M. 1956. A Contribution to the Theory of Economic Growth. In *Quarterly Journal of Economics LXX*: 65-94.

Solow, R.M. 1957. Technical Change and the Aggregate Production Function. In *Review of Economic Statistics* 39 (August): 312-320.

Sterman, J.D. 1981. The Energy Transition and The Economy: A System Dynamics Approach. Ph.D. Dissertation, A.P. Sloan School of Management, Cambridge, MA.

Stiglitz, J.E., Uzawa, H. 1969. *Readings in the Modern Theory of Economic Growth*. MIT Press.

Sumanth, D.J. 1985. *Productivity Engineering and Management*. McGraw-Hill Book Company.

Tasrif, M., Saeed, K. 1989. Sustaining Economic Growth with A Nonrenewable Natural Resource: The Case of Oil-Dependent Indonesia. In *System Dynamics Review* 5 (1): 17-34.

Tjahjono, E.D., Anugrah, D.F. 2006. Faktor-Faktor Determinan Pertumbuhan Ekonomi Indonesia. In *Working Paper WP/08/2006 Bank of Indonesia.*