

# Assessments of ICT Policy Options: The Framework of Input–Output Table Linked with Intangible Knowledge Stock



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**Abstract** The 21st century marks the prosperity of cyber systems that drastically reshaped the social economy structure. Confronting the hyper-aging society with shrinking population in Japan, rapid development of ICT/IoT has contributed to social economic change nowadays while evaluating the effectiveness of policy options thus becomes an urgent task for stakeholders. A new type of social economic development with technology substitute of labor deserves more attention to accommodate technology improvement in the society. In order to capture the structural change, we develop a CGE model applying Japan's input–output table from 1995 to 2011 with the disaggregation of 95 sectors. In this model, the capital stock has been distinguished into tangible and intangible capital to better interpret the R&D capital formation and its spillover effect for technology realizations. Based on the mechanism, a user-friendly application called SPIAS-e was developed for policy option evaluation. Finally, the chapter demonstrated simulation results of STI policy options scenarios on how new service platform with ICT would be affected by R&D investments and technological improvement.

**Keywords** Policy evaluation · CGE · ICT/IoT · R&D · SPIAS-e

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# **1 Introduction: Toward the Evidence-based Policy Making**

The rapid development of cyber-physical systems with the stream of technological change has drastically reshaped the social and economic structures. For this change on the structures, the identification of science, technology, and innovation (STI) policy has become much more challenging than ever before and it is essential to provide more quantitative assessment to reflections on policy engagements to policymakers. For the development of science and technology to cope with societal challenges, it is important that scientists accurately grasp the societal expectation for science, based on observations of the present states of sciences, and show evidence-based alternative policy option to solve the societal problems.

Throughout the transition of economy, the social and economic structural changes have made it necessary to develop policy alternatives to deal with challenges and to conduct prior and ex-post evaluations of policies. At this stage, stakeholders are institutionally required to build policy formation process on a circulated way and advocate the academia to discover societal challenges to identify expectations for science to address challenges on designing policy options and making mutual understanding policy implementation impact assessment and evaluation coping with the challenges. On such evidence-based procession of policy-making, policymakers are suggested to be aquatinted with properties of science in order to deepen the understanding of the properties in the modern sciences and society.

The chapter includes three main sections: In the first section, we introduce the history of science, technology, and innovation development and its implication for the information revolution in the 21st century. In the second section, we specify the concept of R&D capitalized into tangible and intangible asset while using Japan's input-output (IO) table of 1995–2011 for quantitative assessment of the R&D investment. In the third section, we develop a recursive CGE model, SPAIS-e for STI policy impact evaluation. Finally, we set a scenario and demonstrate the simulation results of the changes of GDP, capital price, and employment of new capital service platform. Policy recommendations for the compilation of IO table for R&D for making evidence-based policy assessment are proposed accordingly.

## **2 The Advancement of Science and Technology and the Structural Change of Society: The History of Industrial Revolutions**

The first industrial revolution started from eleventh to thirteenth century while miller power was widely used as primary energy source. At that time, the cast iron and other highly agriculture mechanism technology had substantially improved

productivity. The prosperity has activated the urban commercial life and the curiosity thinking with desire of pursuing knowledge, contributing the establishment of university. The first information revolution was activated by the great discovery period of fourteenth to fifteenth century—the invention of compass, gunpowder, and the spread of letterpress printing has contributed to massive knowledge expansion and resulted in popularity of knowledge for the social material foundation in the fifteenth century.

The second industrial revolution in the sixteenth to eighteenth century was stimulated by steam machine and coal energy. Despite that massive production was made possible through mushroomed factories, creating social status of bourgeois as well as urban slum. The boom of democracy spread from America continent to Europe and that the market mechanism had been emphasized. With the discovery and the use of electricity, the science revolution in the late nineteenth century to early twentieth century that made fundamental change on paradigm was achieved through new quantum physics as the third industrial revolution. Later in the fossil energy era, the massive production and consumption have led to a Trans-Science age with information technology boosted by semiconductor, biotechnology with the second information revolution. The fourth industrial revolution with rapid development of Integrated chip (IC), Internet of things (IoT), Artificial intelligence (AI), life science, and cognitive science has risen substantially in the 21st century.

## ***2.1 Japan's Development: From High Economic Growth to Stagflation***

The experience of Japan's postwar development is a comprehensive example to witness the entire economic cycle. It could be regarded as one of the successful STI policy instruments that contributed to high economic growth performance during the modern human history. Seventy years after the WWII, Japanese society has experienced a drastic demographic transition from rapid expansion of labor sources due to the demobilization of the soldiers and the repatriates from abroad to aging society with shrinking population since the beginning of the 21st century. After 1945, Japan's industries had been severely damaged during the war, the rapid recovery because of the aid and abundant labor resource from the rural area to urban area. In this period, industrial reconstruction was made in the designated industries. Since the government was very cautious, the fiscal balance between 1948 and 1965 had been cleared and the deficit has rarely been considered by policymakers. Japan had successful experience of economic expansion between 1960 and 1985 except for the oil shocks in 1973 and 1979.

**Table 1** Source of average annual economic growth (%)

| Indicators/<br>periods | 1965–<br>75 | 1975–<br>85 | 1985–<br>95 | 1995–2000<br>(%) | 2000–05<br>(%) | 2005–10<br>(%) | 2010–14<br>(%) |
|------------------------|-------------|-------------|-------------|------------------|----------------|----------------|----------------|
| Nominal<br>GDP         | 15.2%       | 7.6%        | 4.1%        | 0.3              | −0.2           | −0.9           | 0.2            |
| Real GDP               | 7.4%        | 4.0%        | 3.1%        | 0.8              | 1.2            | 0.3            | 0.6            |
| Population             | 1.3%        | 0.8%        | 0.4%        | 0.2              | 0.1            | 0.0            | −0.5           |
| Labor force            | 1.0%        | 1.1%        | 1.1%        | 0.3              | −0.3           | −0.1           | −0.1           |
| Tangible<br>capital    | n.a.        | n.a.        | n.a.        | 1.7              | 0.4            | 1.0            | 0.4            |
| Intangible<br>capital  | n.a.        | n.a.        | n.a.        | 4.6              | 6.9            | 2.3            | −0.1           |

Source National accounts statistics for 2014, population census, etc.

During this period, Japan's government has been continuing the market intervention through Keynesian fiscal policy by prompting public expenditure on infrastructure and industrial rationalization policies for heavy manufacturing industries. Meanwhile, large science with consumer durable consumption electronic appliances such as refrigerator, washing machine, and television appeared to become common in the household. Flying geese paradigm (Akamatsu 1962) has been proven again in the economic linkage among Japan and other newly industrial economies like South Korea, Singapore, and Taiwan. Vogel's *Japan As Number One* (1979) had been one of the best sellers and lessons for successful economy.

In 1985, Japan was forced to adapt the agreement of the Plaza Accord. Afterward, the exchange rate of the Japanese Yen versus US dollar appreciated by 51% from 1985 to 1987. Consequently, Japan suffered from the bubble economy while its economic growth had reached its limitation with the coming of stagflation in the burst of bubble. Since the 1990s, the feature of Japan's economy had changed from massive consumption market to hobby and high-quality demand along with the expansion of fiscal burden, social insurance, medical care, education expenditure. The damage of Kobe earthquake in 1995 and Asian financial crisis in 1997 had again deterred the confidence, resulting into a more cautious and hesitation for investment and that had frustrated several economic stimulus plans.

Table 1 shows that Japan had positive economic performance till 2000, and on contrary, the stagflation, decrease in population and labor force became severer subsequently. Japan had stepped into hyper-aging society since 2006, with the purpose of leading to sustainable development, and Japan realized that the key solution for aging society, shrinking population, and reduction of fiscal deficit might depend on the knowledge and experiments between science and technology responding to societal problems.

## ***2.2 The Fluctuation of Modernism and STI***

From the twentieth to twenty-first century, with the advancement of science and technology, huge issues have been embraced by the entire society. The modernistic social regulations have been undergoing a fluctuation in democracy, market mechanism, and scientific philosophy. Meanwhile, the diminution of energy and resource has been advocating the society to switch from fossil energy to sustainable energy. The globalization led by information technology has somehow inferior the income gap and disparity, while populism has experienced great expansion along with the development of Social Networking System (SNS).

The productivity gain stimulated by aggressive STI spending policy throughout the structural change of society on science and technology. However, the stimulus plans are obligated to follow government's budgetary concerns with efficiency and feasibility. This may contain the expectation and confidence in the public for STI policy that may satisfy the transparency and the understanding of the public by putting policymaker's reflections on policy engagements. Traditionally, the policymaking mechanism could be derived into PDCA cycle, referring as "plan-do-check-act" four-step management method used in business for the control and continual improvement of processes and products. Such process has been widely used as a scientific method of implementing STI policy for solving normative approach. The revolutionary development in the information science and technology since the beginning of twentieth century had enormous impacts on all of the science fields including life, material physics, and environmental science methodologically and conceptually. Deepening the properties and the structure of trans-scientific relationships among various sciences is essential to manage the promotion of the STI and apply their results on the policies in order to solve complex problems in modern society.

## ***2.3 The Objective of Science for Science Policy and Policy for Science to Achieve the Co-improvement***

STI has been highly expected to cope with societal challenges to appropriately respond to growing economic and social structural changes. Deepening the understanding for the properties in the modern science and society relies on the interpretation of the relation between the technology and modern socio-economy. Moreover, trans-scientific issues which arise in the course of the interaction between science, technology, and society remained unsolved. In order to solve such complicated issues, reliable collaborations among scientists, citizens, and politicians are indispensable in order to fulfill their responsibility.

The development of new trans-sciences has not only brought a variety of benefit, but also unpredictable impacts, disasters, and damages on environment of earth and public controversy. These mean that such impacts could be fairly difficult to understand for their fragile and complex characteristics. A solid and effective collaboration among various science including natural sciences and humanities is strongly recommended with the aim of analyzing their phenomenon scientifically and finds efficient policy instruments as a STI policy.

### 2.4 Pyramid Hierarchy and the Categories of Industrial Structure

The development of ICT has changed the way of life prevailing from ownership to the right to use. Such transition has made the physical input such as land, building, or merchandise no longer necessary conditions for economic activities. The shared value economy (Fig. 1) may gradually replace the traditional economic mechanism while the material input for production is only secondary and what really matters is the service provided through the newly created platform based on the Internet and SNS that link the demand and supply on their most efficient and least costly pathway. Cases like Uber, Airbnb, YouTube, and other e-commerce have re-designed the nowadays consumption style with sharp advice for the existing IO analysis and its compilation.

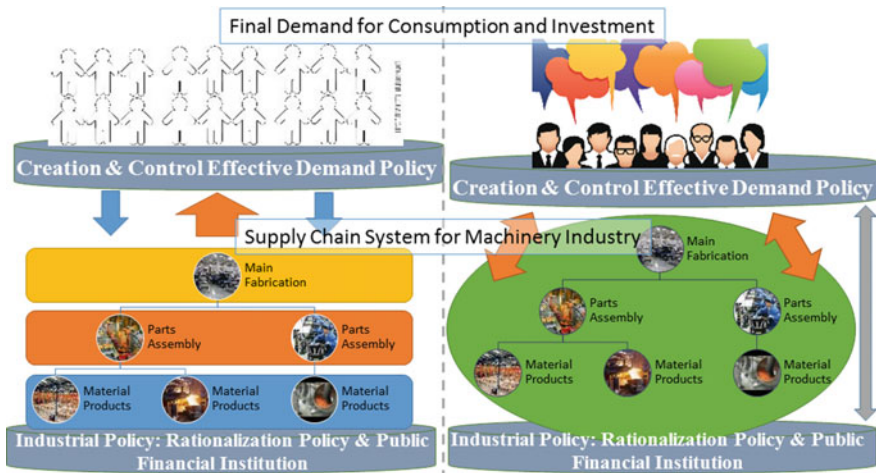


Fig. 1 Transition for consumption and investment. Source GRIPS SciREX Center

### 3 Quantitative Modeling for Science and Technology

The impact assessment of STI policy requires the development of adequate modeling frameworks in order to capture the specific characteristics of research and innovation. Their structural equations are estimated econometrically very rich in economic details. Tsujimura et al. (1981) decomposed Japanese economy structure with analyzing economic policy with the interpretation of their general interdependence. Based on the analysis of different periods of Japanese economic development, they presented quantitative theory of price and built a CGE empirical model for quantitative approach. The base of recursive CGE models relies on markets equilibrium balancing supply and demand through the system of prices. Policies that alter the equilibrium are considered shocks that induce new equilibria in the interaction between consumers and producers in the different markets.

There is a general consensus among economists and policymakers that R&D activities play a decisive role in fostering productivity growth. Aulin-Ahmavaara (1999) uses dynamic IO model to examine the effective rates and prices of the inputs treated as produced. The conclusion indicated that such rates are determined by production technology. For recent R&D expenditure studies, Kristkova (2013) indicates that the public R&D sector is not involved in the production of capital varieties, whereas the production of general knowledge is contained in the production processes of both public and private R&D as a specific factor. Comite and Kancs (2015) compares several macroeconomic models, in which they pointed out that modeling public intervention in R&D as a free productive input as determination of optimal policy, or a type of subsidy may be underprovided by the market because of positive spillover across firms. They also suggest that determination of the parameters capturing this effect in the economy should be carefully examined with evidence. The redesign of the STI policy assessment is suggested in order to enable the reconstruction on planning and the implementation of the STI policy, and further, to have such methodology developed as one branch of science. Deepening the understanding of the processes could be operated by involving STI and visualizing their social and economic impacts of STI policy. While the results of these alternative policy options could be examined with scientific evidences, such process is emphasized and regarded effectively with the intention of ensuring transparency in decision-making and provision of accountability to the general public.

#### 3.1 *The Capture of Capital Stock Flow*

For the assessment of R&D expenditure impact on productivity, we propose a framework of measurement to show the effectiveness of the impacts on the production activities by the accumulation of the knowledge stock through the R&D investment based on Kuroda and Nomura (2004). We try to capitalize the R&D

expenditure as an intangible asset from sources of investments for R&D activities provided both from the public and the private by government and private industry. The investments assume to create the knowledge for science and technology, in which the science fields are divided into several fields of sciences. R&D activities are introduced by public and private research institutes like university and affiliated research institutes, independent research institutes as private enterprises, and intra-enterprise R&D activity affiliated by private enterprises. The R&D products and services created by these agencies are accumulated into the knowledge as intangible assets in each agency.

R&D investments are introduced separately investments by government and nonprofit organizations, research institute by private institutions and intra-research activities within the private firm. While introducing the R&D activities into the IO framework explicitly, we could show the theoretical frame to measure how the accumulated intangible assets (knowledge stock) could create the efficiency of the production activities. It is assumed that each R&D investment is accumulated as intangible assets and the capital service flows as technological knowledge are created by the accumulated intangible assets. Capital stock is estimated by perpetual inventory method in tangible and intangible assets by activity in each industry. The real quantity of investment by activity is induced by the nominal investment deflated by price index of investment by activity. The real quantity of investment in time series is utilized to estimate the capital stock by activity in the perpetual inventory method.

Langlois (2002) indicates that if intra-firm R&D activities are assumed to increase the gross output, final demand, and value added shall be explicitly estimated as new concepts. In the current Japanese IO table, intra-firm R&D activity has been taken account of the activity as one independent activity although all of intra-firm R&D activity is aggregated in one activity. The output is transferred into the users as intermediate inputs, but not in the capital formation except capital depreciation allowance. In our analysis, the intra-firm R&D activity could be treated as one of activities in each sector, by which each firm assumed to be able to create new knowledge as one of intangible assets. Furthermore, the capital service flow accumulated in the intangible knowledge stock is assumed to be transferred to the firm main production activity as a type of capital input, but not intermediate input.

### **3.2 From 1993SNA to 2008SNA**

Transaction of knowledge service which is created by knowledge stock is a vital issue. In the 1993 System of National Accounts (SNA), R&D expenditure has been treated as intermediate inputs (United Nations 1993; OECD 2002). Research activities by market producers have been accounted in the gross output in the old SNA in Japan. However, they have not been treated as the transactions in the final demand, but in intermediate transactions. In the revision of JSNA in 2016, the capitalization of the R&D expenditure was regarded in the macroaggregated level



as a type of intangible assets. It is treated as one of intangible investment goods, but not as intermediate goods (Cabinet Office of Japan 2017). Since the R&D Expenditure includes total labor cost for R&D, intermediate inputs as well as tangible and intangible capital inputs in public and private research and development activities include university, public, and private research institutes.

The treating the entity of patents and licensing service of patents is also important. Transactions of knowledge service which are creating from knowledge stock by capitalization of R&D activity, most of all, treatments of entity of patents, and transactions of licensing service, should be treated explicitly in SNA and input–output statistics (OECD 2010). The 2008SNA regards entity of patents as fixed productive capital formation; licensing fees of patents as output of the licensing service; and their transactions are treated as intermediate demand or fixed capital formation. However, in Japanese IO table, patent service is not specialized as an industrial sector. Therefore, net transaction of licensing fee of patents are including in the property income in each industrial sector. In the aggregate of the nation-wide, transaction of licensing fee among domestic sectors is canceled out and taken account of the net outside transaction.

The JSNA has revised accordingly with the amendment on R&D from the intermediate inputs to final demand as investment of intangible assets in 2016. The 2015 IO table in Japan will be revised into 2008SNA with inclusion of final demand as capital formation adding to new items of the value added as business surplus and capital depreciation allowance (Kobayashi 2016). On the other hand, intra-firm R&D activities by market producers have not been taken accounts of output measures, but in the business surplus implicitly. Treatment of the capitalization of R&D expenditure based on SNA2008 has been employed in many countries such as Australia (2009), Canada (2012), USA (2013), Korea (2014), and UK (2014), respectively.

### ***3.3 Data Structure***

For the sake of making coevolutionary relationship among scientists, citizens, and politicians, and activating STI capabilities for value capture in the society, we aim to construct a policy simulator to give evidence-based policy options. We compose the following data framework for our objectives. In the measurement of private or public R&D expenditure, such investment activity in capital stock should be regarded from dimensions of tangible and intangible knowledge capital stock. As suggested by 2008SNA, the R&D investment should be taken as intangible knowledge stock formation. Such compilation has been done in Japan's 2016 national accounts as an aggregated measure but not yet the IO table of 2011 (released in 2015). The data used in our model (Fig. 2) were sourced from Japan's IO tables and with extended estimation (red blocks) to distinguish tangible and intangible capital investments by 95 sectors (Table 3), considering long-/short-run

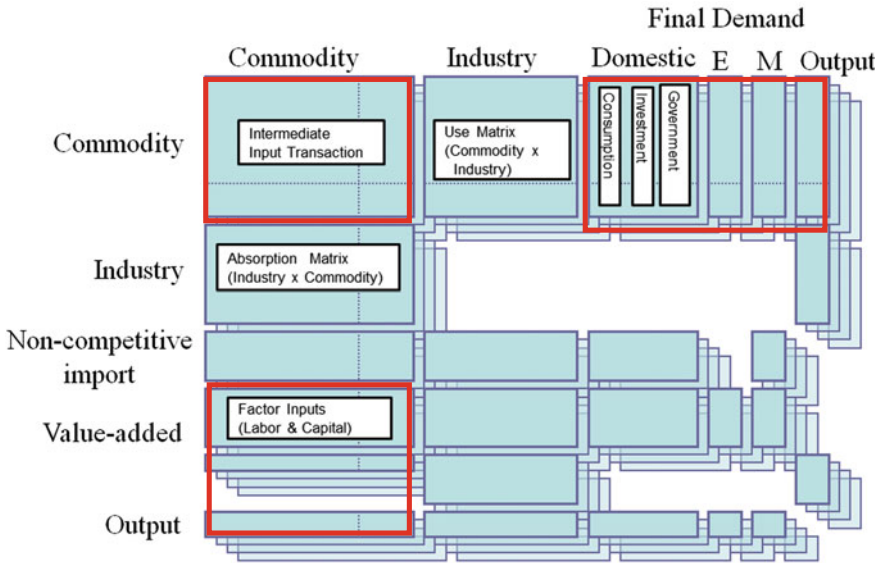


Fig. 2 Structure of input–output data layers. Source Kuroda et al. (2016)

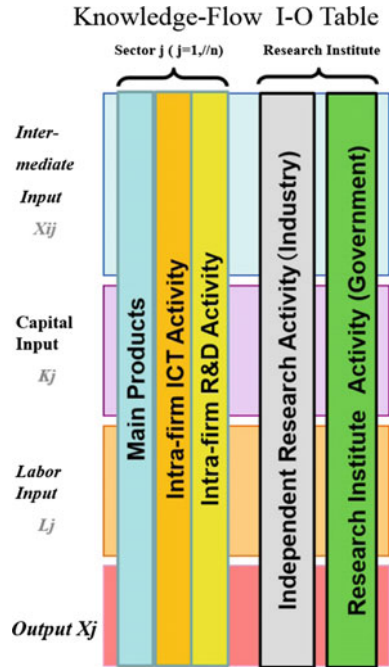
block, labor market modeling, value added and wage determinant, government balance sheet, and the final demand block.

In advance, here we try to revise the Japanese IO Tables to be capitalized the R&D investment during the year 1995–2011. The production activity at the year  $t$  depends upon the tangible and intangible capital assets accumulated at the prior years and embodied the technological properties at the time when they were invested. Through investment, accumulated productive capital is composed of the capital goods from prior periods. The idea could evaluate the contribution of knowledge stock which is accumulated by the R&D investment as intangible assets. We assume that the knowledge of science and technology is accumulated and deepened by the R&D activities with R&D investment. Then we assume that the R&D investment is accumulated as intangible assets and intangible asset creates knowledge proportionally to the amount of intangible capital stock.

In our IO table, R&D activities are assumed to be separately identified as intra-firm R&D activity, independent public and nonprofit private R&D activities including government institutes and nonprofit institutions and independent private R&D industrial activity. In each industrial sector excluding the above R&D activities with the assumption to be divided into the production activity of main products and infra-industry R&D activity. We also assume that independent public and nonprofit private R&D activity and private R&D industrial activity are divided into several fields by science and technology.

Figure 3 shows that sectors except research institutes by government and industry are divided into the following three categories: (a) main product;

**Fig. 3** Data framework—  
production activity by sector.  
Source GRIPS SciREX  
Center



(b) intra-firm ICT activity; and (c) intra-firm R&D activity. Under such disaggregation, we may obtain a systematic view of capital service flow facilitated by the ICT/IoT implementation for information allocation and processioning to accelerate its productivity for manufacturing. The R&D activities by industry and government as independent research institute are divided into ten research fields of ICT, environment, materials, energy, space, oceanography, other natural sciences and social sciences and humanity.

In order to analyze the impacts of the development of the knowledge in science and technology on the economy and society, it is necessary to establish the analytical tool to observe the impacts theoretically and empirically. Capital stock matrix both in tangible and intangible assets assumes to be estimated by the perpetual inventory method with given economic rate of replacement. We can define capital coefficients by tangible and intangible assets as the ratio by capital stock and output in main products and R&D activities, respectively.

The intra-R&D activity and intra-information activity including software development in-house from the main productive activity in the enterprise are classified separately. The knowledge services created inside of the enterprise are counted as capital formation of intangible assets and accumulated to the intangible assets. On the other hand, the fixed capitals which are used in the intra-activity of R&D and software development are counted at the fixed capital formation as investment and they are accumulated to the tangible assets in these two activities. In our model, these factor inputs represent the capitalization of intangible assets so that

such capital inputs are measured by quantity and price of the capital services which were imputed from capital stock and capital cost. The capital stocks and capital cost are measured consistently with IO tables as for tangible and intangible assets while the intangible assets are separately estimated by software and knowledge stock in research fields. Finally, the capital formation matrices by flow and stock for tangible and intangible assets were estimated annually while labor inputs by sector and activity are separately estimated.

### 4 The Mechanism of Policy Formation and Its Evaluation

For activating science and technology capabilities for value capture in the society, we constructed a recursive CGE model (Kuroda et al. 2016) that illustrates the new business platforms reflecting the investment on R&D for facilitating capital service flow (Fig. 4). The model is expected to shed lights on implication of total factor productivity (TFP) for its process change on the demand side while the productivity improvement in information provision service sector that enlarges the platform business, assisting manufacturing sectors to create new market and variate the international production networking structure.

On such platform, scientists need to move from Science for Science’s sake to Science for Society while policymakers want to design an evidence-based STI policy scientifically to realize the capability of science and technology toward the value captured, while the predetermined endogenous variable such as capital stock

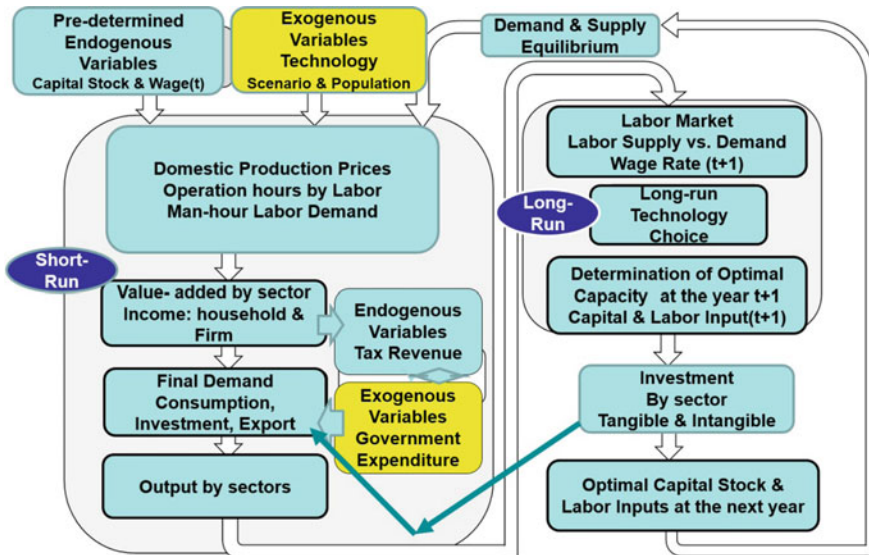


Fig. 4 Recursive CGE model structure. Source GRIPS SciREX Center

and wage interacted with exogenous variable of technology and population generates the output of short-run equilibrium and determines new equilibrium as the predetermined variables for the next time period.

Moreover, the information management could benefit from outsourcing and externalization while the cross-sectional platform of information management may thus be established. The simulation results showed the change on employment and production division along with the ICT/IoT advancement of its short-/long-run effect.

#### ***4.1 The SciREX Policy Intelligence Assistance System— Economic Simulator (SPIAS-e)***

In this process, the change of capital service and labor service could be observed, indicating the gap of income and capital formation. There are different level of procession/production efficiency and are set technology parameters in the activity divisions of marketing, planning, R&D, procurement, operation and sales, maintenance will be calibrated through a database system—SciREX Policy Assistance Intelligence System (SPIAS) containing research grants, academic performance based on scientific papers, patents, and news releases.

Based on the structure of the recursive CGE model, we develop a user-friendly simulator “SPIAS-e” affiliated in our SPIAS platform. The key parameters and the volume of government R&D investment could be easily controlled with the visualized results of the year 2005–2050 comparing the business as usual (BAU) path on GDP growth, impact, changes on indicators and stock in visualized graphs of policy options (Appendixes).

#### ***4.2 Scenarios***

Two scenarios are made to examine the impact of R&D investment on medical service sector (Table 2). The BAU scenario gives us the overview of the baseline economic and social trend until 2050 from the year 2005. The R&D investment (tangible and intangible) made by government remained the same and no improvement of technology production while the structural changes of the population by age and gender are assumed exogenously. The ICT+R&D scenario referred to more R&D investment in ICT and other science R&D fields, with higher efficiency to be actualized from the year 2020 in production efficiency led by more R&D investment in the designated sectors such as semiconductor, software, Internet, information management, and communication service-related sectors. The knowledge stock accumulated by the government R&D expenditure is assumed to

**Table 2** Scenarios and parameter setting

|  | Business as usual (BAU) | ICT+R&D   |
|--|-------------------------|-----------|
| Life science R&D investment <sup>a</sup>                 | 1                       | 1         |
| ICT & communication R&D investment <sup>a</sup>          | 1                       | 1.5 times |
| Material science R&D investment <sup>a</sup>             | 1                       | 1         |
| Energy science R&D investment <sup>a</sup>               | 1                       | 1         |
| Other sciences R&D investment <sup>a</sup>               | 1                       | 1.5 times |
| Production efficiency improvement from 2020 <sup>b</sup> | 1                       | 1.2 times |

<sup>a</sup>Comparing with 2005 level

<sup>b</sup>In semiconductor, ICT, software, Internet and information-related sectors

have an impact on the productivity increases in the private sectors as public goods thanks to the patent released.

### ***4.3 Assumptions on Exogenous Policy Variables for the Baseline Scenario***

We have set assumptions for Baseline scenario of the Japanese economy during the future years 2020–2050 as following: (i) Government R&D expenditure scale remains the same during 2005–2050; (ii) Constant tax rates including personal income tax, corporate income tax, consumption tax, indirect tax and property for the 2005 level; (iii) Government consumption expenditure will be assumed to be constant to nominal GDP endogenously; (iv) Government capital formation for tangible and intangible assets will be fixed at the 2005 level nominally; and (v) Structure of the population will be assumed to be given by the projections with fertility medium-variant case by National Institute of Population and Social Security Research.

### ***4.4 Simulation Results***

When R&D investment policy options of government R&D expenditure and assumed productivity efficiency improvement are inserted in the SPIAS-e, the system on Webpage generates the projection of economic performance and indicators 2005–2050 (while the results from 2005 to 2011 are the actual data) as alternative policy option assessment. The GDP growth (upper panel) and percentage change (middle panel) and the breakdown of GDP growth contributed by value add (lower panel) are displayed in Fig. 5. (Abbreviations could be referred to Table 4.)

Simulation results showed that ICT+R&D scenario will lead to higher real GDP since 2020 and gradually increase its growth path. The GDP change seemed to fluctuate from the BAU but remained on positive scale. While the production



**Fig. 5** GDP change and contribution by value add (unit: million JPY, %). Source GRIPS SciREX Center SPIAS-e

efficiency improvement was actualized in 2020, the GDP growth reached its peak by 0.8% and decrease due to its marginal effect diminishing. In the breakdown of the contribution, it could be found that the share of OS (operation surplus) and DEPK (tangible capital depreciation provision) kept increasing and served as the growth engine with its spillover pull for the economy.

### 4.5 Employment Change

The employment by gender and age has also been an important concern as the economic indicator and assessment. The employment projection on three representing sectors of selected capital service platforms is (Fig. 6): Information and Communication, Software and Information Management Service.

Overall speaking, the aging society and shrinking population seem to be inevitable while the employment in the three sectors showed a continuous drop.

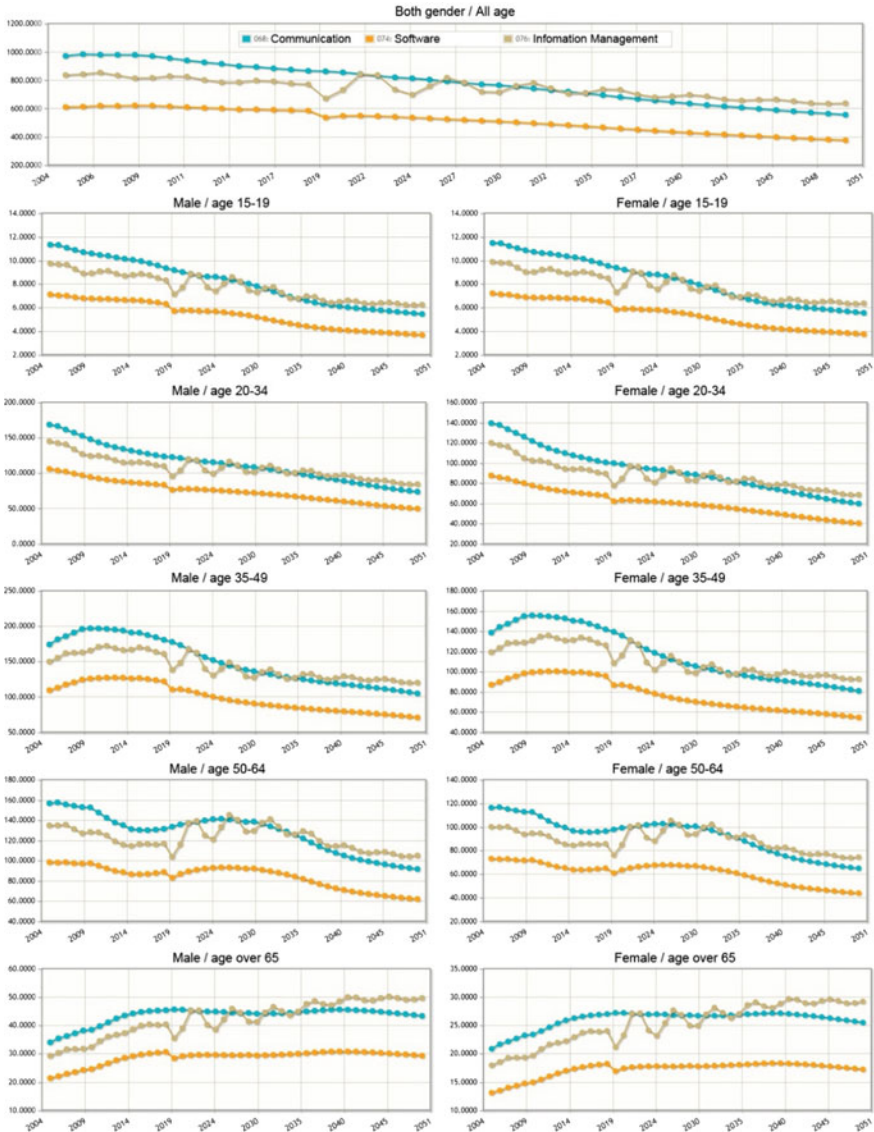


Fig. 6 Sectoral employment change (unit: person). Source GRIPS SciREX Center SPIAS-e

In the group of younger age 15–34, the trend has been decreasing mainly due to the shrinking population; whereas in categories of age over 65-year old, the share of employment continue to growth, implying that the ICT and R&D investment could stimulate the employment for the whole generation and sustain the employment till their silver age. The information management service overtook the information and communication sectors in a longer term.



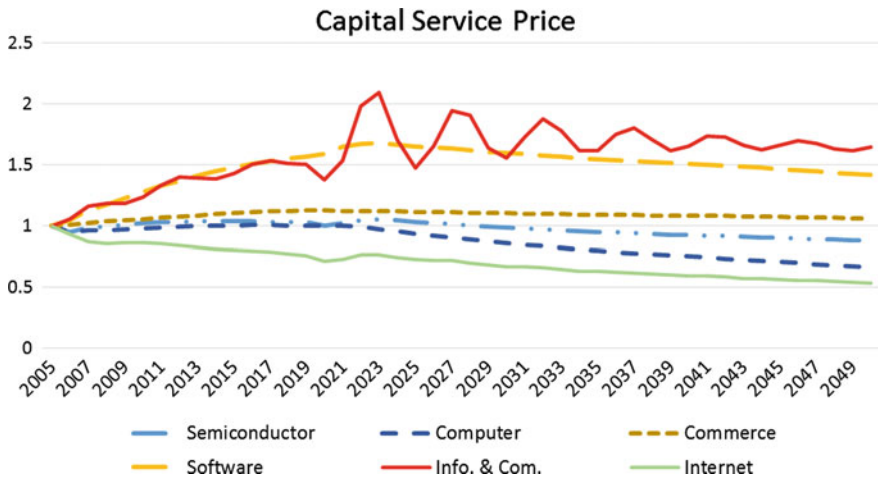


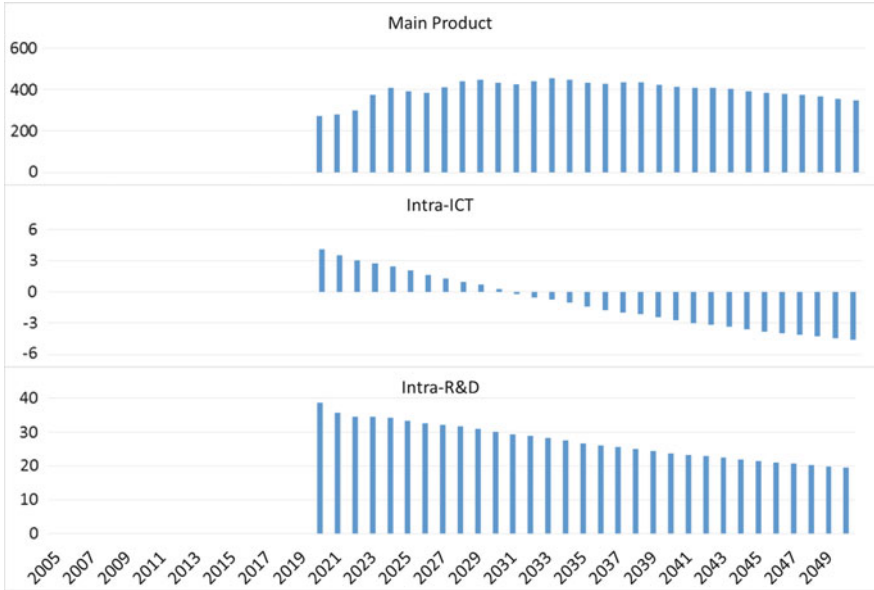
Fig. 7 Capital service price index. Source GRIPS SciREX Center SPIAS-e

Comparing the capital service price among six sectors that highly related to the ICT/IoT (Fig. 7), sectors such as Software and Information and Communication showed a vibrant growth while computer and semiconductor revealed decrease, most of all in Internet sector. On other hand, commerce remained steady with only very slight improvement. This comparison showed that the new platform created in the new society will be mainly led by information revolution while software and information management service will have most significant role. These newly boomed sectors may overtake the traditional commercial mode; nevertheless, they may well face drastic business cycle, which actually reflecting the current situation of SNS platform. In spite of its essential role supporting the new platform base, the Internet sector will just become a basic provision and thus no more additional surplus granted.

#### 4.6 Disguised Unemployment and Work Sharing

Under the current model structural and predetermined inter-temporal formula, with the assumption of fully employment. The declining labor supply, especially in working hour may imply that much labor-intensive chores, could be done by senior citizen with the support of ICT and robot. The fact of less working hour and the substitute of man labor by ICT and event robot for “working sharing,” creating another phenomenon of “disguised unemployment.”

By comparing the divisions of employment multiplying real hourly wage between BAU and policy option, Fig. 8 shows the trend of disguised unemployment in the three categories. The declining number of intra-ICT indicated the



**Fig. 8** Disguised unemployment in three categories (unit: thousand people). *Source* GRIPS SciREX Center SPIAS-e

massive demand of employment in such sector, while main product and intra-R&D only decrease in a mild pace.

Up to date in 2018, a decent job regarded a reasonable work is 8 h a day (40 h weekly or 1775 h annually). With higher production efficiency led by the technology advancement, declining working hour is foreseeable in the very near future, just as the implementation of two-day weekend and holiday system in the twentieth century. The simulation results provided the motivation by social needs and through innovation that provides feedback to current social economy and leads new social economy. With less working and more leisure time, leaving human being more freedom to consider complicated issues for achieving a sustainable socio-economy under more newly established service platforms. The improvement of work and life balance could contribute to quality of life (QoL) improvement.

### 5 Concluding Remarks

The impact assessment and evaluation of STI policy options have been regarded top priority for Japanese government to allocate its budget efficiently and effectively. The simulation results calculated by SPIAS-e illustrate a possible picture of Japan’s development under a society of aging and shrinking population. It is implied that various system and reforms should be established to cope with the change of social

structure as well as the new service platforms. The SPIAS-e is not only an evidence-based, user-friendly tool but mostly it demonstrates a platform to understand the process and socioeconomic change among “good translational relationship” between natural and social and humanity sciences.

Based on the 2008SNA, the new IO table compilation of R&D will help to make more accurate STI policy recommendations. With the development of the system and more precise calibrations on the technologies, the quantified and visualized results could assist policymaking. An important and necessary condition is to create “policy options” with consistency and accountability to redesign the new social and economic structures. SPIAS-e is expected to help policymakers better understand the substitution between machine and unskilled labor, and the expansion of income differences domestically and internationally.

While the recent rapid improvement of *AI* and *Big-Data* is contributing to the effective collection of data that will help us redefining neoclassical economics for obtaining sustainable development. Confronting the challenges of aging society with shrieking population, the lack of effective demand should be solved by continuously created platform of knowledge-based open innovation so that such unstable conflicts among countries with perception gaps could be observed and overcome.

## Appendixes

### *Appendix 1: SPIAS-e Architecture*

SPIAS-e is a Web-based system consisting of (1) economic model module by Java languages and (2) front-end/visualization module by Python 3.x Language. The data are stored in MySQL (compatible MariaDB) Database and running in Linux/Windows OS environment.

Initially, user could set policy parameter (a) R&D expenditure in six categories for both public and private sectors and (b) short-term and long-term sectoral productivity (classified in Table 3) through Web browser and other exogenous variables are stored in *csv* format. After initialization, front-end modules call economic model module in parallel with policy parameter.

In the simulation process, economic model module stores macro-data into MySQL database, and front-end module fetches yearly GDP data. After completion of economic simulation, economic model module returns simulated endogenous and exogenous variables (listed in Appendix 2) and those are stored into MySQL DB (Fig. 9).

**Table 3** Sector classification

| No. | Sector                                       | No. | Sector  |
|-----|--|-----|---|
| 1   | Agriculture (main products, ICT activity)    | 49  | Robot (intra-firm R&D activity)                       |
| 2   | Agriculture (intra-firm R&D activity)        | 50  | Precise machinery (main products)                     |
| 3   | Mining (main products, ICT activity)         | 51  | Precise machinery (intra-firm ICT activity)           |
| 4   | Mining (intra-firm R&D activity)             | 52  | Precise machinery (intra-firm R&D activity)           |
| 5   | Food (main products)                         | 53  | Petroleum, coal (main products)                       |
| 6   | Food (intra-firm ICT activity)               | 54  | Petroleum, coal (intra-firm ICT activity)             |
| 7   | Food (intra-firm R&D activity)               | 55  | Petroleum, coal (intra-firm R&D activity)             |
| 8   | Synthetic (main products)                    | 56  | Miscellaneous manufacturing (main products)           |
| 9   | Synthetic (intra-firm ICT activity)          | 57  | Miscellaneous manufacturing (intra-firm ICT activity) |
| 10  | Synthetic (intra-firm R&D activity)          | 58  | Miscellaneous manufacturing (intra-firm R&D activity) |
| 11  | Pulp, paper (main products)                  | 59  | Energy manufacturing (main products)                  |
| 12  | Pulp, paper (intra-firm ICT activity)        | 60  | Energy manufacturing (intra-firm ICT activity)        |
| 13  | Pulp, paper (intra-firm R&D activity)        | 61  | Energy manufacturing (intra-firm R&D activity)        |
| 14  | Chemical (main products)                     | 62  | Construction (main products)                          |
| 15  | Chemical (intra-firm ICT activity)           | 63  | Construction (intra-firm ICT activity)                |
| 16  | Chemical (intra-firm R&D activity)           | 64  | Construction (intra-firm R&D activity)                |
| 17  | Material (main products)                     | 65  | Transportation (main products)                        |
| 18  | Material (intra-firm ICT activity)           | 66  | Transportation (intra-firm ICT activity)              |
| 19  | Material (intra-firm R&D activity)           | 67  | Transportation (intra-firm R&D activity)              |
| 20  | Machinery (main products)                    | 68  | Communication (main products)                         |
| 21  | Machinery (intra-firm ICT activity)          | 69  | Communication (intra-firm ICT activity)               |
| 22  | Machinery (intra-firm R&D activity)          | 70  | Communication (intra-firm R&D activity)               |
| 23  | Electronic devices (main products)           | 71  | Commerce (main products)                              |
| 24  | Electronic devices (intra-firm ICT activity) | 72  | Commerce (intra-firm ICT activity)                    |
| 25  | Electronic devices (intra-firm R&D activity) | 73  | Commerce (intra-firm R&D activity)                    |

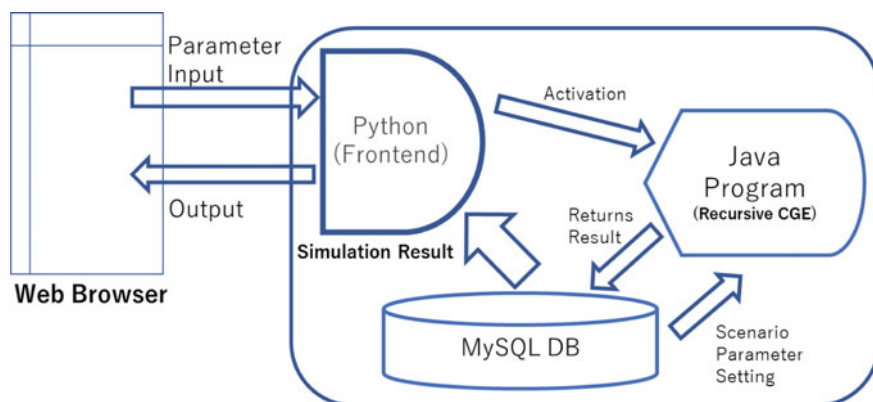
(continued)

**Table 3** (continued)

| No. | Sector  | No. | Sector  |
|-----|---|-----|---|
| 26  | Fiber-optical cable (main products)                                 | 74  | Software (main products)                            |
| 27  | Fiber-optical cable (intra-firm ICT activity)                       | 75  | Software (intra-firm R&D activity)                  |
| 28  | Fiber-optical cable (intra-firm R&D activity)                       | 76  | Info. mgmt. (main products)                         |
| 29  | Semiconductor manufacturing (main products)                         | 77  | Info. mgmt. (intra-firm R&D activity)               |
| 30  | Semiconductor manufacturing (intra-firm ICT activity)               | 78  | Internet (main products)                            |
| 31  | Semiconductor manufacturing (intra-firm R&D activity)               | 79  | Internet (intra-firm R&D activity)                  |
| 32  | Communication devices (main products)                               | 80  | Medical, welfare services (main products)           |
| 33  | Communication devices (intra-firm ICT activity)                     | 81  | Medical, welfare services (intra-firm R&D activity) |
| 34  | Communication devices (intra-firm R&D activity)                     | 82  | Education (main products)                           |
| 35  | Computing equipment (main products)                                 | 83  | Education (intra-firm R&D activity)                 |
| 36  | Computing equipment (intra-firm ICT activity)                       | 84  | R&D life science (Public, nonprofit)                |
| 37  | Computing equipment (intra-firm R&D activity)                       | 85  | R&D information communication (public, nonprofit)   |
| 38  | Semiconductor devices (main products)                               | 86  | R&D materials (public, nonprofit)                   |
| 39  | Semiconductor devices (intra-firm ICT activity)                     | 87  | R&D ecology, energy (public, nonprofit)             |
| 40  | Semiconductor devices (intra-firm R&D activity)                     | 88  | R&D miscellaneous (industry)                        |
| 41  | Electronic component (main products)                                | 89  | R&D life science (industry)                         |
| 42  | Electronic component (intra-firm ICT activity)                      | 90  | R&D information communication (industry)            |
| 43  | Electronic component (intra-firm R&D activity)                      | 91  | R&D materials (industry)                            |
| 44  | Heavy machinery, transportation equipment (main products)           | 92  | R&D ecology, energy (industry)                      |
| 45  | Heavy machinery, transportation equipment (intra-firm ICT activity) | 93  | R&D miscellaneous (industry)                        |
| 46  | Heavy machinery, transportation equipment (intra-firm R&D activity) | 94  | Miscellaneous service (main products)               |
| 47  | Robot (main products)   | 95  | Miscellaneous service (intra-firm R&D activity)     |
| 48  | Robot (intra-firm ICT activity)                                     |     |   |

**Table 4** Breakdown of value add

| Abbreviation | Content  |
|--------------|--|
| BCT          | Household expenditure in $t$ -period                               |
| YE           | Total employer income  |
| YSEFW        | Income of employer and family workers                              |
| OS           | Potential output   |
| DEPK         | Tangible capital depreciation provision                            |
| DEPKN        | Intangible capital depreciation provision                          |
| DEPKITE      | Tangible capital depreciation provision on ICT activity            |
| DEPKRDE      | Intangible capital depreciation provision on R&D activity          |
| DEPKPI       | Tangible capital depreciation provision on main product activity   |
| DEPKNITE     | Intangible capital depreciation provision on ICT activity          |
| DEPKNRDE     | Tangible capital depreciation provision on R&D activity            |
| DEPKNPI      | Intangible capital depreciation provision on main product activity |
| TKAN         | Indirect tax   |
| HOJO         | Operation surplus  |

**Fig. 9** Structure and illustration of MySQL DB

## Appendix 2: List of Variables

### Variable Subscripts

$a(1, \dots, 5)$ : age range

1: 15–19, 2: 20–34, 3: 35–5, 4: 51–64, 5: over 65.

$i, j (1, \dots, 93)$ : Product

$o(1, \dots, 3)$ : Category of intra-firm activity

1: Main products, 2: Intra-firm ICT activity, 3: Intra-firm R&D activity.

Agriculture and fishery, mining, software, information management and service, Internet, other service, intra-firm ICT activity including two kinds of product, the public R&D activity without occupation classification

$s(M, F)$ :  $M$ : male,  $F$ : female

$t$  (1, ...,  $T$ ): period

$\theta(1, \dots, 5)$ : R&D classification of purpose.

Public R&D activity is classified into five sectors as well as private R&D sector.

### **Exogenous Variables**

$a_{ij}^{DINVK}$ :  $j$ -sector,  $o = 1$  (main products) nominal input share of  $i$ -capital goods

$a_{ij}^{MINVK}$ :  $j$ -sector,  $o = 1$  (main products) nominal input share of  $i$ -capital goods

$a_{ij}^{DINVKITE}$ :  $j$ -sector,  $o = 2$  (intra-firm ICT activity) nominal input share of  $i$ -capital goods

$a_{ij}^{MINVKITE}$ :  $j$ -sector,  $o = 2$  (intra-firm ICT activity) nominal input share of  $i$ -capital goods

$a_{ij}^{DINVKRDE}$ :  $j$ -sector,  $o = 2$  (intra-firm ICT activity) nominal input share of  $i$ -capital goods

$a_{ij}^{MINVKRDE}$ :  $j$ -sector,  $o = 2$  (intra-firm ICT activity) nominal input share of  $i$ -capital goods

$e$ : Exchange rate (¥/\$)

$h^*$ : Regular working hour

$IM_i^{CIF}$ : Import

$K_j^{GN\theta t}$ : Intangible capital stock of public R&D activity in  $t$ -period (classified in  $\theta$  purpose)

$LC_j$ : Current compensation

$LC_{SEYj}$ : Self-employed income

$LC_{FWYj}$ : Income of family worker

$LC^R$ : Income of oversea employee

$N^t$ : Population

$PC^R$ : Net asset income from oversea

$P^{BCTt}BC_t^t$ : Nominal household expenditure in  $t$ -period

$P_i^{Ex} Ex_i$ : Export (final demand block)

$P^{GC}CG$ : Government expenditure

$P^{GDEP}GDEP_t$ : Social cost depreciation

$P^{GI}IG$ : Public tangible capital formation (excluding R&D investment)

$P_j^{INVKG}KG_j$ : Public R&D activity investment (Classified in  $\theta$  purpose)

$P_j^{INVKG\theta} K_j$ : Public tangible capital formation R&D activity (Classified in  $\theta$  purpose)

$P_j^{INVKN\theta}$   $KN G_j$ : Public intangible capital formation R&D activity (Classified in  $\theta$  purpose)

$P_\theta^{INVKN G t}$   $KN G_\theta^t$ : Public nominal R&D investment in  $t$ -period (Classified in  $\theta$  purpose)

$P_\theta^{INVKN E t}$   $KN E_\theta^t$ : Private nominal R&D investment in  $t$ -period (Classified in  $\theta$  purpose)

$P_i^M$   $M_i$ : Import (final demand block)

$P_i^m$ : Price of intermediate import goods of  $i$ -sector

$P_j^{m^{t+1}}$ : Price of import goods from  $j$ -sector

$P_j^{MIT}$ : Price function of aggregate intermediate import goods of intra-firm ICT activity in  $j$ -sector

$P_j^{MRD}$ : Price function of aggregate intermediate import goods of intra-firm R&D activity in  $j$ -sector

$P_T^Z$   $Z_T$ : Net capital stock

$r^*$ : Average interest rate in capital market

$SS^{GP}$ : Personal social insurance premium by age

$SS^{PG}$ : Personal social insurance payment by age

$T^M$ : Custom tax, tariff

$TRC^{PG}$ : Capital transfer from private to public

$TRC^{RP}$ : Capital transfer from overseas to individual

$TRE^{GP}$ : Net current transfer from public to individual

$TRE^{GR}$ : Net current transfer from public to overseas

$TRE^{PR}$ : Net current transfer from individual to overseas

$TRE^{RG}$ : Net capital transfer from overseas to public

$TRE^{RP}$ : Net capital transfer from overseas to individual

$W$ : World trade volume

$\text{weight}_j^{Et^*}$ : Cost share of employee wage on  $j$ -sector at the start of  $t$ -period

$\text{weight}_j^{SEFWt^*}$ : Cost share of self-employed and family worker wage on  $j$ -sector at the start of  $t$ -period

$X_j^{*t+1}$ : Assumed demand of  $j$ -sector

$Y$ : Assumed gross output

$Z$ : Net capital stock (nominal)

$\delta_j$ : Capital depreciation on main products of  $j$ -sector

$\delta_j^{KIT}$ : Capital depreciation on intra-firm ICT activity of  $j$ -sector

$\delta_j^{KPE}$ : Capital depreciation on intra-firm R&D activity of  $j$ -sector

$\delta_j^{KN}$ : Intangible Capital depreciation of  $j$ -sector

$\tau^C$ : Consumption tax rate

$\tau^I$ : Net indirect tax rate



$\tau^K$ : Capital income tax rate (investment revenue tax rate) on tangible capital (main product)

$\tau^{KIT}$ : Capital income tax rate (investment revenue tax rate) on tangible capital (intra-firm ICT activity)

$\tau^{KPE}$ : Capital income tax rate (investment revenue tax rate) on tangible capital (intra-firm R&D activity)

$\tau^{KN}$ : Capital income tax rate (investment revenue tax rate) on intangible capital (main product)

$\tau^{SKPIN}$ : Capital income tax rate (investment revenue tax rate) on intangible capital (intra-firm ICT activity)

$\tau^{KNE}$ : Capital income tax rate (investment revenue tax rate) on intangible capital (intra-firm R&D activity)

$\tau^L$ : Personal income tax rate

$\tau_i^M$ : Custom tax, tariff rate

$\tau^P$ : Fixed asset tax rate

$\tau^{PKN}$ : Fixed asset tax rate on tangible capital (main products)

$\tau^{PIT}$ : Fixed asset tax rate on tangible capital (intra-firm ICT activity)

$\tau^{PPE}$ : Fixed asset tax rate on tangible capital (intra-firm R&D activity)

### ***Endogenous Variables***

$a_{ij}^d$ : Input share of nominal domestic intermediate  $i$ -goods on  $j$ -sector at the beginning

$a_{ij}^m$ : Input share of nominal import intermediate  $i$ -goods on  $j$ -sector at the beginning

$a_j^{DD}$ : Input share of nominal domestic intermediate goods on  $j$ -sector at the beginning

$a_j^{MM}$ : Input share of nominal import intermediate goods on  $j$ -sector at the beginning

$a_{ij}^{d*}$ : Input coefficient of intermediate input on domestic goods

$a_{ij}^{m*}$ : Input coefficient of intermediate input on import goods

$AN^t$ : Labor force

$AN_{as}^t$ : Labor force by age ( $a = 1, \dots, 5$ ), gender (Survey on employment structure<sup>1</sup>)

Labor force = Employed person + Job seeker (among unemployed person)

Employed person = Full-time employee + Part-time employee

Unemployed person = Work applicant (job seeker) + Non-work applicant

$BC_j$ : Household expenditure

$BS_j$ : Capital cost of  $j$ -sector

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<sup>1</sup>Based on the population distribution of Japan's Employment Status Survey. <http://www.stat.go.jp/english/data/shugyou/>

$C_j^*$ : Long-term cost function of  $j$ -sector

$C_j^{L*}$ : Total employment cost of  $j$ -sector

$DEP_j$ : Capital depreciation provision of  $j$ -sector

$DEP_j^{KNITE}$ : Tangible capital depreciation provision on intra-firm ICT activity of  $j$ -sector

$DEP_j^{KNITE}$ : Intangible capital depreciation provision on intra-firm ICT activity of  $j$ -sector

$DEP_j^{KNRDE}$ : Tangible capital depreciation provision on intra-firm R&D activity of  $j$ -sector

$DEP_j^{KNRDE}$ : Intangible capital depreciation provision on intra-firm R&D activity of  $j$ -sector

$DEP_j^{PK}$ : Tangible capital depreciation provision of  $j$ -sector

$DIV_j$ : Dividends of  $j$ -sector

$ED_{jas}^t$ : Demand for employment of  $j$ -sector by age, gender in  $t$ -year

$ES_{as}^t$ : Supply of employment by age, gender in  $t$ -year<sup>2</sup>

$FW_{as}^t$ : Family workers by age and gender in  $t$ -year

$g(\cdot)$ : Formula of technology improvement

$h_j$ : Working hours on  $j$ -sector

$h_j$ : Actual working hour

$INVK_j$ : Tangible capital formation on  $j$ -sector (real)

$INVKN_j$ : Intangible capital formation on  $j$ -sector (real)

$IY_{jSEFW}^t$ : Self-employed, family worker income per person

$K_j$ : Tangible capital stock of main product of  $j$ -sector is endogenous at the start of time period as long-term selection. In the main product sectors, the tangible capital stock is endogenous. From tangible capital to capital service, the capital stock ratio is following the assumption of  $SK_j^t = K_j^t$

$KC_j$ : Capital revenue

$KG_j$ : Sectoral public tangible capital stock, public R&D sectors ( $j = 82-86$ )

$KPI_j$ : Private R&D on tangible capital stock of  $j$ -sector

$KNG^{0t}$ ,  $KNPI^{0t}$ : Intangible public and private capital stock on R&D sector (by  $\theta$  purpose) at the start of  $t$ -period

$KNITE_j$ : Intangible capital stock of intra-firm ICT activity of  $j$ -sector

$KNRDE_j$ : Intangible capital stock of intra-firm R&D activity of  $j$ -sector

$KNPI_j$ : Private intangible capital stock of intra-firm R&D activity of  $j$ -sector

$L_j$ : Number of employment in  $j$ -sector

$LITE_j$ : Number of ICT-related employment in  $j$ -sector

<sup>2</sup>It is given exogenously. While in the Employment Status Survey, the distribution of employer is sourced from the employment matrix of input-output table by product sector. In addition, the number of employer is accessible from the distribution table in the Employment Status Survey.

$LRDE_j$ : Number of R&D-related employment in  $j$ -sector

$L_j^*$ : Labor input of  $j$ -sector predetermined by long-term production block

$MITE$ : Aggregate of domestic and import intermediate goods of intra-firm ICT activity

$MNE$ : Aggregate of domestic and import intermediate goods of intra-firm R&D activity

$MR_j$ : Marginal short-term income of  $j$ -sector

$N_{as}$ : Population by age ( $a = 0, 1, \dots, 5$ ) and gender ( $s = M, F$ )

$P$ : Current price level

$P^{BCT}$ : Price of household expenditure

$P_T^C$ : Price function of aggregate consumption goods

$P_j^d$ : Price of domestic goods of  $j$ -sector in current period

$P_i^{dc}$ : Price after consumption tax

$P_{ij}^{DMt}$ : Price of good and service determined by the equilibrium of short-term good and service market. In the assumption of competitive input–output table, the import price  $P_i^{mt}$  of  $i$ -sector is set as exogenous variable.

$P^{Et}$ : Aggregate price of employed labor service by gender and age of current period. The price of labor service is determined by the technology choice of the next time period as well as the equilibrium of labor market; with the technology choice, the price of labor service is predetermined at the start of current period.

$P_j^{Et}$ : Labor service price employed in  $j$ -sector at current period, predetermined endogenously. The price gaps exist in sectors such as agriculture, mining, manufacturing (main product, organizational, ICT activity, intra-firm R&D activity), energy, service (main product, organization, ICT activity, intra-firm R&D activity), public, private R&D.

$P_{jas}^{Et}$ : Wage by age ( $a = 1, \dots, 5$ ) and gender ( $s = M, F$ ) of  $j$ -sector

$P_j^{INVK}$ : Price of capital investment good of tangible capital formation of  $j$ -sector. Aggregated from the share weight of investment price (aggregate price of domestic and import good) in the matrix of tangible capital. The price of investment good of tangible capital formation of public R&D  $j$ -sector ( $\theta$ ) and private R&D sector is also calculated according to share weight of tangible capital matrix, as well as determined by the short-term equilibrium of good and service market.

$P_j^{INVKIT}$ : Price of capital investment good in tangible capital formation of intra-firm ICT activity of  $j$ -sector

$P_j^{INVKPE}$ : Price of capital investment good in tangible capital formation of intra-firm R&D activity of  $j$ -sector

$P_j^{INVKNE}$ ,  $P_j^{INVKNG\theta t}$ ,  $P_j^{INVKNP\theta t}$ : Price of intangible capital investment good of price intra-firm R&D activity, public R&D sector ( $\theta$ ), private R&D sector ( $\theta$ ), determined by short-term equilibrium of goods and service market.

$P_j^{DIT}$ : Aggregate price function of domestic intermediate goods of intra-firm ICT activity of  $j$ -sector

$P_j^{DRD}$ : Aggregate price function of domestic intermediate goods of intra-firm R&D activity of  $j$ -sector

$P_j^{MIT}$ : Aggregate price function of import intermediate goods of intra-firm ICT activity of  $j$ -sector

$P_j^{MRD}$ : Aggregate price function of import intermediate goods of intra-firm R&D activity of  $j$ -sector

$P_j^{DMIT}$ : Aggregate price function of intermediate input of intra-firm ICT activity of  $j$ -sector

$P_j^{DMRD}$ : Aggregate price function of intermediate input of intra-firm R&D activity of  $j$ -sector

$P_j^L$ : Price of labor service of  $j$ -sector

$P_j^{LIT}$ : Price of labor service of intra-firm ICT activity of  $j$ -sector

$P_j^{LNG*}$ : Price of labor service predetermined by long-term production block of  $j$ -sector

$P_j^{LRD}$ : Price of labor service of intra-firm R&D activity of  $j$ -sector

$P_j^{mc}$ : Import price after consumption tax

$P_j^{Mt}$ : Price of intermediate good determined by the process of short-term equilibrium in goods and service market of  $j$ -sector in current period

$P_j^{Set}$ : Average income per employer of  $j$ -sector in current period

$P_j^{Set}$ : Average income per family worker of  $j$ -sector in current period

$P_j^{SEFWt*}$ : Price of labor service per employer or family worker of  $j$ -sector in  $t$ -year ( $IY_{jSEFW}^t / h^*$ )

$P_j^{SK}$ : Price of tangible capital service of  $j$ -sector

$P_j^{SKt}$ ,  $P_j^{SKG\theta t}$ ,  $P_j^{SKPI\theta t}$ : Price of tangible capital service of  $j$ -sector. The price is derived from the tangible capital investment price, function of rate of return/depreciation of capital. Among them, the price of tangible capital service of public R&D sector ( $\theta$ ) and private R&D sector ( $\theta$ ) is corresponded with special purpose R&D activity ( $\theta$ ).

$P_j^{SKPI}$ : Price of tangible capital service in private R&D of  $j$ -sector

$P_j^{SKIT}$ : Price of tangible capital service of intra-firm ICT activity of  $j$ -sector

$P_j^{SKK}$ : Price of tangible capital service input ( $SK_j + SKPE_j$ ) of  $j$ -sector

$P_j^{SKNE}$ : Price of intangible capital service in intra-firm R&D of  $j$ -sector

$P_\theta^{SKNEt}$ ,  $P_\theta^{SNGt}$ ,  $P_\theta^{SKNPt}$ : Price of intangible capital service of intra-firm R&D activity, public R&D sector ( $\theta$ ), and private R&D sector ( $\theta$ ). With the respect to the intangible capital stock in the different R&D activity, the capital service price is derived from the intangible capital investment price, function of rate of return/depreciation of capital.

$P_j^{SKNG}$ : Price of intangible capital service in public R&D of  $j$ -sector

$P_j^{SKNPI}$ : Price of intangible capital service in private R&D of  $j$ -sector

$P_j^{SKPE}$ : Price of tangible capital service of intra-firm R&D activity of  $j$ -sector

$Q_j$ : Potential output of  $j$ -sector in the period

$r_j^K$ : Rate of capital return on tangible capital (main products and organizational activity)

$r_j^{KIT}$ : Rate of capital return on tangible capital (intra-firm ICT activity)

$r_j^{KNE}$ : Rate of capital return on tangible capital (intra-firm R&D activity)

$r_j^{KPI}$ : Rate of capital return on private R&D tangible capital

$r_j^{KNPI}$ : Rate of capital return on private R&D intangible capital

$r_j^{KG}$ : Rate of capital return on public R&D tangible capital

$r_j^{KNG}$ : Rate of capital return on public R&D intangible capital

$r_j^{KN}$ : Rate of capital return on intangible capital (main product and organizational activity)

$r_j^{SKPINN}$ : Rate of capital return on intangible capital (intra-firm ICT activity)

$S^G$ : Public saving

$S^P$ : Private gross saving

$S^PN$ : Private net saving

$SE_{as}^t$ : Number of employer by age and gender in  $t$ -year

$SK_j$ : Tangible capital service of  $j$ -sector

$SKG_j$ : Tangible capital service of public R&D of  $j$ -sector

$SKI_j$ : Tangible capital service of private R&D of  $j$ -sector

$SKK_j$ : Tangible capital service input of  $j$ -sector ( $SK_{j+}$   $SKPE_j$ )

$SKITE_j$ : Tangible capital service of intra-firm ICT activity of  $j$ -sector

$SKNE_j$ : Intangible capital service of intra-firm R&D activity of  $j$ -sector

$SKNITE_j$ : Intangible capital service of intra-firm ICT activity of  $j$ -sector

$SKNRDE_j$ : Intangible capital service of intra-firm R&D of  $j$ -sector

$SKPE_j$ : Tangible capital service of intra-firm R&D of  $j$ -sector

$SKNG_j$ : Intangible capital service of public R&D of  $j$ -sector

$T^C$ : Consumption tax revenue

$T^G$ : Gross tax revenue on public sector

$T^I$ : Net indirect tax revenue

$T^K$ : Capital income tax revenue

$T^L$ : Personal tax revenue

$T^P$ : Tax revenue on fixed asset

$v_j^K$ : Cost share function on capital

$v_j^L$ : Cost share function on labor

$v_j^M$ : Cost share function on intermediate input

$v_j^X$ : Cost share function on output

$X_j$ : Output of  $j$ -sector

$x_{ij}^{DINVK}$ : Domestic capital investment in original product tangible capital formation of  $j$ -sector

$x_{ij}^{MINVK}$ : Import capital investment in original product tangible capital formation of  $j$ -sector

$x_{ij}^{DINVKIT}$ : Domestic capital investment in intra-firm ICT activity tangible capital formation of  $j$ -sector

$x_{ij}^{MINVKIT}$ : Import capital investment in intra-firm ICT activity tangible capital formation of  $j$ -sector

$x_{ij}^{DINVKPE}$ : Domestic capital investment in intra-firm R&D activity tangible capital formation of  $j$ -sector

$x_{ij}^{MINVKPE}$ : Import capital investment in intra-firm R&D activity tangible capital formation of  $j$ -sector

$Y$ : Personal disposable income

$Y_{jFW}^t$ : Income per person of family worker of  $j$ -sector at the start of  $t$ -year

$Y_{jSE}^t$ : Income per person of employer of  $j$ -sector at the start of  $t$ -year

$YE_j^t$ : Total employer income of  $j$ -sector in  $t$ -year

$YSEFW_j^t$ : Income of employer and family workers of  $j$ -sector in  $t$ -year

$\Delta BP^R$ : Current gap from oversea (nominal)

$\Delta IS^G$ : Fiscal gap of government (nominal)

$\Delta IS^P$ : Gap on national saving

$\lambda_{ANas}^t$ : Ratio labor force of age and gender over total labor force in  $t$ -year

$\lambda_{ANas}^t$  = Labor force of age and gender ( $AN_{as}^t$ )/Total labor force ( $AN^t$ )

$\lambda_{ESas}^t$ : Ratio of employment by age and gender in  $t$ -year

$\lambda_{SEas}^t$ : Ratio of employer by age and gender in  $t$ -year<sup>3</sup>

$\lambda_{SEas}^t$  = Number of employer ( $SE_{as}^t$ )/ labor force ( $AN_{as}^t$ )

$\lambda_{FWas}^t$ : Ratio of family workers by age and gender in  $t$ -year

$\lambda_{FWas}^t$  = Family workers ( $FW_{as}^t$ )/Total labor force ( $AN_{as}^t$ )

Supply of employment = Employed person + Job seeker

$\mu_{ESas}^t$ : Rate of employed person by age and gender ( $ES_{as}^t$ )/Labor force by age and gender ( $AN_{as}^t$ )

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<sup>3</sup>It is given exogenously. While in the Employment Status Survey, the distribution of family workers is sourced from the employment matrix of input-output table by product sector. In addition, the number of family workers is accessible from the distribution table in the Employment Status Survey.

### Appendix 3: Model Formula Structure

The formula structure of the model is derived as follows:

*Goods and service demand market (t-period)*

*j*-sector domestic goods and production

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \left[ \left( \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right) + \left[ L_j P_j^L P_j^{L0} / \left\{ \alpha_j \left( a_j K_j^{bj} KNITE_j^{cj} KNRDE_j^{dj} KNG_{\theta}^{ej} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (1)$$

- Intra-firm ICT activity

$$P_j^d \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \left[ \left( \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right) + \left[ LITE_j P_j^{LITE} P_j^{LITE0} / \left\{ \alpha_j \left( a_j KITE_j^{bj} KNITE_j^{cj} KNG_{(0=1)}^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (2)$$

- Intra-firm R&D activity

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \cdot \left[ \sum_{(i \neq j)} \left( P_i^d a_{ij}^d + P_i^m a_{ij}^m \right) + \left[ LRDE_j P_j^{LN} P_j^{LN0} / \left\{ \alpha_j \left( a_j KRDE_j^{bj} KNRDE_j^{cj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (3)$$

- Private sector R&D activity

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \left[ \sum_{(i \neq j)} \left( P_i^d a_{ij}^d + P_i^m a_{ij}^m \right) + \left[ LRDE_j P_j^L P_j^{L0} / \left\{ \alpha_j \left( a_j KPI_j^{bj} KNPI_j^{cj} KNRDE_j^{dj} KNG_{\theta}^{ej} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (4)$$

- Public R&D activity

$$P_j^d = C_j/X_j = \left[ \left\{ \left(1 + \tau_j^l\right) / \left(1 - \left(1 + \tau_j^l\right) a_{jj}^d\right) \right\} \right] \cdot \left[ \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right. \\ \left. + \left( L N G_j h_j P_j^{L N G^l} P_j^{L N G^0} + K G_j^l P_j^{S K G^l} P_j^{S K G^0} + K N G_j^l P_j^{S K N G^l} P_j^{S K N G^0} \right) / X_j \right] \quad (5)$$

- ICT activity

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \left[ \left( \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right) \right. \\ \left. + \left[ L_j P_j^L P_j^{L0} / \left\{ \alpha_j \left( a_j K_j^{bj} K N R D E_j^{cj} K N R D E_j^{dj} K N G_0^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (6)$$

- ICT R&D activity

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \cdot \left[ \sum_{(i \neq j)} \left( P_i^d a_{ij}^d + P_i^m a_{ij}^m \right) \right. \\ \left. + \left[ L R D E_j P_j^{L N} P_j^{L N 0} / \left\{ \alpha_j \left( a_j K R D E_j^{bj} K N R D E_j^{cj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (7)$$

- Other product activity

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \cdot \left[ \left( \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right) \right. \\ \left. + \left[ L_j P_j^L P_j^{L0} / \left\{ \alpha_j \left( a_j K_j^{bj} K N R D E_j^{cj} K N G_0^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (8)$$



- Other R&D activity

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \left\{ \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right\} \right] \cdot \left[ \sum_{(i \neq j)} \left( P_i^d a_{ij}^d + P_i^m a_{ij}^m \right) \right. \\ \left. + \left[ LN_j P_j^{LN} P_j^{LN0} / \left\{ \alpha_j \left( a_j K R D E_j^{bj} K N R D E_j^{cj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (9)$$

*Value-added block*

Labor income

$$Y E_j^t = E_j^t h_j P_j^{Et} P_j^{E0} \quad (10)$$

$$Y S E F W_j^t = I Y_{j S E F W}^t \left( S E_j^t + F W_j^t \right) \quad (11)$$

Capital income

$$B S_j^t + D E P_j = P_j^d X_j / \left( 1 + \tau_j^l \right) - \Sigma_i P_i^d a_{ij}^d X_j - \Sigma_i P_i^m a_{ij}^d X_j - B C_j - L C_j \quad (12)$$

$$P_j^{SK} = \left( 1 - \tau^K \right) r_j^K P_j^{INVKt-1} + \delta_j P_j^{INVKt} - \left( P_j^{INVKt} - P_j^{INVKt-1} \right) + \tau^P P_j^{INVKt-1} \quad (13)$$

$$P_j^{SKITt} = \left( 1 - \tau^{KIT} \right) r_j^K P_j^{INVKITt-1} + \delta_j P_j^{INVKITt} \\ - \left( P_j^{INVKITt} - P_j^{INVKITt-1} \right) + \tau^{PIT} P_j^{INVKITt-1} \quad (14)$$

$$P_j^{SKPEt} = \left( 1 - \tau^{KPE} \right) r_j^K P_j^{INVKPEt-1} + \delta_j P_j^{INVKPEt} \\ - \left( P_j^{INVKPEt} - P_j^{INVKPEt-1} \right) + \tau^{PPE} P_j^{INVKPEt-1} \quad (15)$$

$$P_j^{SKN} = \left( 1 - \tau^K \right) r_j^{KN} P_j^{INVKNt-1} + \delta_j^{KN} P_j^{INVKNt} - \left( P_j^{INVKNt} - P_j^{INVKNt-1} \right) + \tau^P P_j^{INVKNt-1} \quad (16)$$

$$P_j^{SKPINt} = \left( 1 - \tau^{SKPIN} \right) r_j^{SKPIN} P_j^{INVSKPINt-1} + \delta_j^{KN} P_j^{INVSKPINt} - \left( P_j^{INVSKPINt} - P_j^{INVSKPINt} \right) \\ + \tau^{SKPIN} P_j^{INVSKPINt-1} \quad (17)$$

$$P_j^{SKNE} = \left( 1 - \tau^K \right) r_j^{KNE} P_j^{INVKNEt-1} + \delta_j^{KNE} P_j^{INVKNEt} - \left( P_j^{INVKNEt} - P_j^{INVKNEt-1} \right) + \tau^P P_j^{INVKNEt-1} \quad (18)$$

$$\begin{aligned}
BS_j &= SK_j P_j^{SK} + SKN_j P_j^{SKN} + SKNE_j P_j^{SKE} \\
&= K_j \left\{ (1-\tau^K) r_j^K P_j^{INVKt-1} + \delta_j P_j^{INVKt} - \left( P_j^{INVKt} - P_j^{INVKt-1} \right) + \tau^P P_j^{INVKt-1} \right\} \\
&\quad + KN_j \left\{ (1-\tau^K) r_j^{KN} P_j^{INVKNt-1} + \delta_j^{KN} P_j^{INVKNt} - \left( P_j^{INVKNt} - P_j^{INVKNt-1} \right) + \tau^P P_j^{INVKNt-1} \right\} \\
&\quad + KNE_j \left\{ (1-\tau^K) r_j^{KNE} P_j^{INVKNEt-1} + \delta_j^{KNE} P_j^{INVKNEt} - \left( P_j^{INVKNEt} - P_j^{INVKNEt-1} \right) + \tau^P P_j^{INVKNEt} \right\}
\end{aligned} \tag{19}$$

Sectoral capital depreciation

$$DEP_j^{INVK} = \delta_j P_j^{INVK} K_j \tag{20}$$

$$DEP_j^{INVKN} = \delta_j P_j^{INVKN} KN_j \tag{21}$$

$$DEP_j^{INVKNE} = \delta_j P_j^{INVKNE} KNE_j \tag{22}$$

$$DEP_j^{INVKG} = \delta_j P_j^{INVKG} KG_j \tag{23}$$

$$DEP_j^{INVKGN} = \delta_j P_j^{INVKGN} KGN_j \tag{24}$$

Sectoral dividends

$$DIV_j = (1 - \tau^K) BS_j - \tau^P P_j^{INVK} K_j - \tau^P P_j^{INVKN} KN_j - \tau^P P_j^{INVKNE} KNE_j \tag{25}$$

Individual disposable income

$$\begin{aligned}
Y &= (1 - \tau^L) \sum_j (LC_j + LC_{SEY_j} + LC_{FWY_j}) + (1 - \tau^L) LC^R \\
&\quad + \sum_{j \in \mathcal{I}} DIV_j + (1 - \tau^P) PC^R + TRE^{GP} - TRE^{PR} + SS^{GP} - SS^{PG} + TRC^{RP} - TRC^{PG}
\end{aligned} \tag{26}$$

Gross saving and net saving

$$S^P = (Y - TRC^{RP} + TRC^{PG}) - P^C C \tag{27}$$

$$S^{PN} = S^P - \sum_{(j \in IND)} DEP_j^P \tag{28}$$

$$\begin{aligned}
\Delta IS^P &= S^P - \left( \sum_j P_j^{INVK} INVK_j + \sum_j P_j^{INVKN} + INVKN_j + \sum_j P_j^{INVKNE} INVKNE_j \right) \\
&\quad - Z + TRC^{RP} + TRC^{PG} = \Delta BP^R \Delta IS^G
\end{aligned} \tag{29}$$

*Government block*

$$T^L = \tau^L \left\{ \sum_j (LC_j + LC_{SEYj} + LC_{FWYj}) + LC^R \right\} \quad (30)$$

$$T^K = \tau^K \sum_j KC_j \quad (31)$$

$$T^P = \tau^P \left( \sum_j P_j^{INVK} K_j + PC^R \right) \quad (32)$$

$$T^I = \sum_j \left\{ \left( \tau_j^I / (1 + \tau_j^I) \right) P_j^d X_j \right\} \quad (33)$$

$$T^C = (1 + \tau^C) \sum_i P_i^C C_i \quad (34)$$

$$T^M = \sum_i \tau_i^M IM_i^{CIF} \quad (35)$$

$$T^G = T^L + T^K + T^P + T^I + T^C + T^M \quad (36)$$

$$S^G = T^G - TRE^{GP} - TRE^{GR} - P^{GC} C^G - SS^{GP} + SS^{PG} \quad (37)$$

$$\begin{aligned} \Delta IS^G = S^G + TRC^{PG} + TRC^{RG} \\ - \left( P^{GI} I^G + \sum_{j=82-86} P_j^{INVK} INVK_j + \sum_{j=82-86} P_j^{INVKN} INVKN_j \right) \end{aligned} \quad (38)$$

*Product*

$$X_i = \sum_j a_{ij}^d X_j + BC_T + CK_i + GC_T + GDEP_T \quad (39)$$

$$X = [I - A_d]^{-1} F_d \quad (40)$$

*Product calculation*

$$\begin{aligned} X_i = \sum_j a_{ij}^d X_j + BC_T + CK_i + GC_T + GDEP_T + INVKG_i + INVKGN_i \\ + INVK_i + INVKITE_i + INVKRDE_i + INVKPI_i + INVKN_i + INVKNITE_i \\ + INVKNRDE_i + INVKNPI_i + Z_T + EX_i + M_i \end{aligned} \quad (41)$$

$$X = [I - A_d]^{-1} F_d \quad (42)$$

*Long-term product block*

Price function of intermediate goods

$$\ln P_j^{DIT} = \sum_i a_j^{dIT} \ln P_i^d \quad (43)$$

$$\ln P_j^{DRD} = \sum_i a_j^{dRD} \ln P_i^d \quad (44)$$

$$\ln P_j^{MIT} = \sum_i a_j^{mIT} \ln P_i^m \quad (45)$$

$$\ln P_j^{MRD} = \sum_i a_j^{mRD} \ln P_i^m \quad (46)$$

$$\ln P_j^{DMIT} = a_j^{DDIT} \ln P_j^{DIT} + a_j^{MMIT} \ln P_j^{MIT} \quad (47)$$

$$\ln P_j^{DMRD} = a_j^{DDRd} \ln P_j^{DRD} + a_j^{MMRD} \ln P_j^{MRD} \quad (48)$$

Price function of aggregate tangible capital and intangible investment goods

$$\ln P_j^{INVK} = \sum_i a_i^{DINVK} \ln P_i^d + \sum_i a_{ij}^{MINVK} \ln P_i^m \quad (49)$$

$$\ln P_j^{INVKIT} = \sum_i a_i^{DINVKIT} \ln P_i^d + \sum_i a_{ij}^{MINVKIT} \ln P_i^m \quad (50)$$

$$\ln P_j^{INVKPE} = \sum_i a_i^{DINVKPE} \ln P_i^d + \sum_i a_{ij}^{MINVKPE} \ln P_i^m \quad (51)$$

$$a_{ij}^{DINVK} = P_i^d x_{ij}^{DINVK} / \left( \sum_i P_i^d x_{ij}^{DINVK} + \sum_i P_i^m x_{ij}^{MINVK} \right) \quad (52)$$

$$a_{ij}^{MINVK} = P_i^m x_{ij}^{MINVK} / \left( \sum_i P_i^d x_{ij}^{DINVK} + \sum_i P_i^m x_{ij}^{MINVK} \right) \quad (53)$$

$$a_{ij}^{DINVKIT} = P_i^d x_{ij}^{DINVKIT} / \left( \sum_i P_i^d x_{ij}^{DINVKIT} + \sum_i P_i^m x_{ij}^{MINVKIT} \right) \quad (54)$$

$$a_{ij}^{MINVKIT} = P_i^m x_{ij}^{MINVKIT} / \left( \sum_i P_i^d x_{ij}^{DINVKIT} + \sum_i P_i^m x_{ij}^{MINVKIT} \right) \quad (55)$$

$$a_{ij}^{DINVKPE} = P_i^d x_{ij}^{DINVKPE} / \left( \sum_i P_i^d x_{ij}^{DINVKPE} + \sum_i P_i^m x_{ij}^{MINVKPE} \right) \quad (56)$$

$$a_{ij}^{MINVKPE} = P_i^m x_{ij}^{MINVKPE} / \left( \sum_i P_i^d x_{ij}^{DINVKPE} + \sum_i P_i^m x_{ij}^{MINVKPE} \right) \quad (57)$$

Price function of aggregate labor service

$$P_j^{L+1} = F(P_j^L, P_j^{LNPE}, P_j^{LNG}, P_j^{LNPI}) \quad (58)$$

Long-term cost function

$$\begin{aligned} \ln C_j^{ITE} &= \alpha_j^{ITE0} + \sum_k \alpha_j^{ITEk} \ln P_j^{k*} + \alpha_j^{ITEx} \ln X_j^* + \alpha_j^{ITEt} g(KNG_{j(j=83)}^t) + (1/2) \sum_k \sum_l \ln \beta_j^{ITEkl} \ln P_j^{k*} \ln P_j^{l*} \\ &+ \sum_k \beta_j^{ITEkx} \ln P_j^{k*} \ln X_j^* + \sum_k \beta_j^{ITEkt} \ln P_j^{k*} g(KNG_{j(j=83)}^t, P\text{-Index}(k)) \end{aligned} \quad (59)$$

$$\begin{aligned} \ln C_j^{RDE*} &= \alpha_j^{RDE0} + \sum_k \alpha_j^{RDEk} \ln P_j^{k*} + \alpha_j^{RDEx} \ln X_j^* + \beta_j^{RDEt} g(KNG_j^t) + (1/2) \sum_k \sum_l \ln \beta_j^{RDEkl} \ln P_j^{k*} \ln P_j^{l*} \\ &+ \sum_k \beta_j^{RDEkx} \ln P_j^{k*} \ln X_j^* + \sum_k \beta_j^{RDEkt} \ln P_j^{k*} g(KNG_j^t, P\text{-Index}(k)) \end{aligned} \quad (60)$$

$$\begin{aligned} \ln C_j^* &= \alpha_j^0 + \sum_k \alpha_j^k \ln P_j^{k*} + \alpha_j^x \ln X_j^* + \alpha_j^t g(SKNG_\theta^t, SKNE_j^t) + (1/2) \sum_k \sum_l \ln \beta_j^{kl} \ln P_j^{k*} \ln P_j^{l*} \\ &+ \sum_k \beta_j^{kx} \ln P_j^{k*} \ln X_j^* + \sum_k \beta_j^{kt} \ln P_j^{k*} g(SKNG_\theta^t, SKNE_j^t) \end{aligned} \quad (61)$$

Function of technology improvement

$$g(SKNG_\theta^t, SKNE_j^t) = \mu_j(SKNG_\theta^t + SKNE_j^t) / \{1 + \mu_j(SKNG_\theta^t + SKNE_j^t)\} \quad (62)$$

Share function

$$v_j^K = \partial \ln C_j^* / \partial \ln P_j^{k*} = a_j^k + \sum_i \beta_j^{ki} \ln P_j^{i*} + \beta_j^{kx} \ln X_j^* + \beta_j^{kt} g(SKNG_\theta^t, SKNE_j^t) \quad (63)$$

$$v_j^L = \partial \ln C_j^* / \partial \ln P_j^{l*} = a_j^l + \sum_i \beta_j^{li} \ln P_j^{i*} + \beta_j^{lx} \ln X_j^* + \beta_j^{lt} g(SKNG_\theta^t, SKNE_j^t) \quad (64)$$

$$v_j^M = \partial \ln C_j^* / \partial \ln P_j^{m*} = a_j^m + \sum_i \beta_j^{mi} \ln P_j^{i*} + \beta_j^{mx} \ln X_j^* + \beta_j^{mt} g(SKNG_\theta^t, SKNE_j^t) \quad (i = K, L, M) \quad (65)$$

$$v_j^X = \partial \ln C_j^* / \partial \ln X_j^{k*} = \alpha_j^X + \sum_i \beta_j^{kX} \ln P_j^i + \beta_j^{XX} \ln X_j^* + \beta_j^{XT} g(K^{GNt+1}) \quad (66)$$

Output

$$K_j^* = v_j^K \left( C_j^* / \left( P_j^{K*} P_j^{K0} \right) \right) (j = 1, \dots, n) \quad (67)$$

$$L_j^* = v_j^L \left( C_j^* / \left( P_j^{L*} P_j^{L0} \right) \right) / h_j^* (j = 1, \dots, n) \quad (68)$$

$$a_{ij}^d = V_{ij}^d P_j^d / P_i^d \quad (i, j = 1, \dots, n) \quad (69)$$

$$a_{ij}^m = V_{ij}^m P_j^d / P_i^m \quad (i, j = 1, \dots, n) \quad (70)$$

Current rate of return

$$r_j^K = \frac{BS_j - \left\{ \begin{array}{l} K_j \left\{ \delta_j P_j^{INVKt} - \left( P_j^{INVKt} - P_j^{INVKt-1} \right) + \tau^P P_j^{INVKt-1} \right\} \\ + KRDE_j \left\{ \delta_j^{KRDE} P_j^{INVKRDEt} - \left( P_j^{INVKRDEt} - P_j^{INVKRDEt-1} \right) + \tau^{PKRDE} P_j^{INVKRDEt-1} \right\} \\ + KITE_j \left\{ \delta_j^{KITE} P_j^{INVKITEt} - \left( P_j^{INVKITEt} - P_j^{INVKITEt-1} \right) + \tau^{PKITE} P_j^{INVKITEt-1} \right\} \\ + KN_j \left\{ \delta_j^{KN} P_j^{INVKNt} - \left( P_j^{INVKNt} - P_j^{INVKNt-1} \right) + \tau^{PKN} P_j^{INVKNt-1} \right\} \\ + KNRDE_j \left\{ \delta_j^{KNRDE} P_j^{INVKNRDEt} - \left( P_j^{INVKNRDEt} - P_j^{INVKNRDEt-1} \right) + \tau^{PKNRDE} P_j^{INVKNRDEt-1} \right\} \\ + KNITE_j \left\{ \delta_j^{KNITE} P_j^{INVKNITEt} - \left( P_j^{INVKNITEt} - P_j^{INVKNITEt-1} \right) + \tau^{PKNITE} P_j^{INVKNITEt-1} \right\} \end{array} \right\}}{K_j (1 - \tau^K) P_j^{INVKt-1} \\ + KRDE_j (1 - \tau^{KRDE}) P_j^{INVKRDEt-1} \\ + KITE_j (1 - \tau^{KITE}) P_j^{INVKITEt-1} \\ + KN_j (1 - \tau^{KN}) P_j^{INVKNt-1} \\ + KNRDE_j (1 - \tau^{KNRDE}) P_j^{INVKNRDEt-1} \\ + KNITE_j (1 - \tau^{KNITE}) P_j^{INVKNITEt-1}} \quad (71)$$

Expected rate of return of next period

$$r_j^{*K} = f(r, r_j^K) \quad (72)$$

Price function of aggregate capital service

$$PSK_j^t = F \left( P_j^{SKt} \cdot P_j^{SKNPlt} \right) \quad (73)$$

$$P_j^{SKt} = (1 - \tau^K) r_j^K P_j^{INVKt-1} + \delta_j P_j^{INVKt} - \left( P_j^{INVKt} - P_j^{INVKt-1} \right) + \tau^P P_j^{INVKt-1} \quad (74)$$

$$P_j^{SKITEt} = (1 - \tau^{KITE})r_j^K P_j^{INVKITEt-1} + \delta_j P_j^{INVKITEt} - \left( P_j^{INVKITEt} - P_j^{INVKITEt-1} \right) + \tau^{PITE} P_j^{INVKITEt-1} \quad (75)$$

$$P_j^{SKRDEt} = (1 - \tau^{KRDE})r_j^{KRDE} P_j^{INVKRDEt-1} + \delta_j P_j^{INVKRDEt} - \left( P_j^{INVKRDEt} - P_j^{INVKRDEt-1} \right) + \tau^{PRDE} P_j^{INVKRDEt-1} \quad (76)$$

$$P_j^{SKNt} = (1 - \tau^{KN})r_j^K P_j^{INVKNt-1} + \delta_j P_j^{INVKNt} - \left( P_j^{INVKNt} - P_j^{INVKNt-1} \right) + \tau^{PKN} P_j^{INVKNt-1} \quad (77)$$

$$P_j^{SKNITEt} = (1 - \tau^{KNITE})r_j^{KNITE} P_j^{INVKNITEt-1} + \delta_j^{KNITE} P_j^{INVKNITEt} - \left( P_j^{INVKNITEt} - P_j^{INVKNITEt-1} \right) + \tau^{PKNITE} P_j^{INVKNITEt-1} \quad (78)$$

$$P_j^{SKNRDEt} = (1 - \tau^{KNRDE})r_j^{KNRDE} P_j^{INVKNRDEt-1} + \delta_j^{KNRDE} P_j^{INVKNRDEt} - \left( P_j^{INVKNRDEt} - P_j^{INVKNRDEt-1} \right) + \tau^{PSKNRDE} P_j^{INVKNRDEt-1} \quad (79)$$

### Capital cost

$$\begin{aligned} BS_j &= SK_j P S K_j + SKPE_j P S KPE_j + SKIT_j P S KIT_j + SKNE_j P S KNE_j \\ &= K_j \left\{ (1 - \tau^K) r_j^K P_j^{INVKt-1} + \delta_j P_j^{INVKt} - \left( P_j^{INVKt} - P_j^{INVKt-1} \right) + \tau^P P_j^{INVKt-1} \right\} \\ &\quad + KPE_j \left\{ (1 - \tau^{KPE}) r_j^K P_j^{INVKPEt-1} + \delta_j^{KPE} P_j^{INVKPEt} - \left( P_j^{INVKPEt} - P_j^{INVKPEt-1} \right) + \tau^{PKPE} P_j^{INVKPEt-1} \right\} \\ &\quad + KIT_j \left\{ (1 - \tau^{KIT}) r_j^K P_j^{INVKITt-1} + \delta_j^{KIT} P_j^{INVKITt} - \left( P_j^{INVKITt} - P_j^{INVKITt-1} \right) + \tau^{PKIT} P_j^{INVKITt-1} \right\} \\ &\quad + KNE_j \left\{ (1 - \tau^{KNE}) r_j^K P_j^{INVKNEt-1} + \delta_j^{KNE} P_j^{INVKNEt} - \left( P_j^{INVKNEt} - P_j^{INVKNEt-1} \right) + \tau^{PKNE} P_j^{INVKNEt-1} \right\} \end{aligned} \quad (80)$$

*Short-term supply of goods and service*  
*j*-sector product

$$C_j = P_j^d X_j = \left( 1 + \tau_j^t \right) \left\{ \sum_i P_i^d a_{ij}^d X_j + \sum_i P_i^m a_{ij}^m X_j + L_j h_j P_j^{Et} P_j^{E0} + IY_{jSEFW}^t (SE_j^t + FW_j^t) + \left( K_j^t + KPE_j^t \right) P_j^{SKKt} P_j^{SKK0} \right\} \quad (81)$$

$$P_j^d X_j / P = \alpha_j^s Y + \beta_j^s W + \gamma_j^s \left( P_j^d / P \right) + \eta_j^s \quad (82)$$

$$MR_j = - P_j^d \left( \gamma_j^s / \left( X_j - \gamma_j^s \right) \right) \quad (83)$$

$$X_j = Q_j h_j^* \left( h_j / h_j^* \right)^{\alpha_j} \quad (84)$$

$$Q_j = a_j(K_j + KPE_j)^{bj} KNE_j^{cj} KNG_{\theta}^{dj} \quad (85)$$

$$h_j = \left( X_j/a_j(K_j + KPE_j)^{bj} KNE_j^{cj} KN_{\theta}^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \quad (86)$$

$$\begin{aligned} P_j^d = & \left[ \left\{ (X_j - \gamma_j^s) (1 + \tau_j^l) \right\} / \gamma_j^s \left( (1 + \tau_j^l) a_{jj}^d - 1 \right) \right] \cdot \left[ \left( \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right) \right. \\ & \left. + \{ L_j P_j^L P_j^{L0} / \left\{ \alpha_j \left( a_j (K_j + KPE_j)^{bj} KNE_j^{cj} KN_{\theta}^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \end{aligned} \quad (87)$$

### Intra-firm ICT activity

$$\begin{aligned} C_j = & P_j^d X_j \\ = & \left( 1 + \tau_j^l \right) \left\{ \sum_i P_i^d a_{ij}^d X_j + \sum_i P_i^m a_{ij}^m X_j + (LIT_j h_j P_j^{LIT} P_j^{LIT0} + KIT_j P_j^{SKIT} P_j^{SKIT0}) \right\} \end{aligned} \quad (88)$$

$$P_j^d X_j / P = \alpha_j^s Y + \beta_j^s W + \gamma_j^s \left( P_j^d / P \right) + \eta_j^s \quad (89)$$

$$MR_j = -P_j^d \left( \gamma_j^s / \left( X_j - \gamma_j^s \right) \right) \quad (90)$$

$$X_j = Q_j h_j^* \left( h_j / h_j^* \right)^{\alpha_j} \quad (91)$$

$$Q_j = a_j KIT^{bj} KNG_{(\theta=1)}^{dj} \quad (92)$$

$$h_j = \left( X_j / a_j KIT^{bj} KNG_{(\theta=1)}^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \quad (93)$$

$$\begin{aligned} P_j^d = & \left[ \left\{ (X_j - \gamma_j^s) (1 + \tau_j^l) \right\} / \gamma_j^s \left( (1 + \tau_j^l) a_{jj}^d - 1 \right) \right] \cdot \left[ \left( \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m \right) \right. \\ & \left. + \{ LIT_j P_j^{LIT} P_j^{LIT0} / \left\{ \alpha_j \left( a_j KIT_j^{bj} KNG_{j(\theta=1)}^{cj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \cdot X_j^{(1-\alpha_j)/\alpha_j} \right] \end{aligned} \quad (94)$$

### Intra-firm R&D activity

$$\begin{aligned} C_j = & P_j^d X_j = \left( 1 + \tau_j^l \right) \left\{ \sum_i P_i^d a_{ij}^d X_j + \sum_i P_i^m a_{ij}^m X_j + LN_j h_j P_j^{Et} P_j^{E0} \right. \\ & \left. + IY_{jSEFW}^t \left( SE_j^t + FW_j^t \right) + KPE_j^t P_j^{SKPEt} P_j^{SKPE0} + KNE_j^t P_j^{SKNEt} P_j^{SKNE0} \right\} \end{aligned} \quad (95)$$

$$X_j = Q_j h_j^* \left( h_j / h_j^* \right)^{\alpha_j} \quad (96)$$



$$Q_j = a_j K N E_j^{bj} \quad (97)$$

$$h_j = \left( X_j / a_j K N E_j^{bj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \quad (98)$$

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right. \\ \left. \cdot \left[ \sum_{(i \neq j)} \left( P_i^d a_{ij}^d + P_i^m a_{ij}^m \right) + \left\{ L N_j P_j^{LN} P_j^{LN0} / \alpha_j \left( a_j K N E_j^{bj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] X_j^{(1-\alpha_j)/\alpha_j} a \right] \quad (99)$$

Private R&D activity (STI category)

$$C_j = P_j^d X_j = \left( 1 + \tau_j^l \right) \left\{ \sum_i P_i^d a_{ij}^d X_j + \sum_i P_i^m a_{ij}^m X_j + E_j h_j P_j^{Et} P_j^{E0} \right. \\ \left. + IY_{jSEFW}^t \left( SE_j^t + FW_j^t \right) + KPI_j^t P_j^{SKPIt} P_j^{SKPI0} + KNPI_j^t P_j^{SKNPIt} P_j^{SKNPI0} \right\} \quad (100)$$

$$X_j = Q_j h_j^* \left( h_j / h_j^* \right)^{\alpha_j} \quad (101)$$

$$Q_j = a_j KPI_j^{bj} KNPI_j^{dj} \quad (102)$$

$$h_j = \left( X_j / a_j KPI_j^{bj} KNPI_j^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \quad (103)$$

$$P_j^d = \left[ \left\{ \left( X_j - \gamma_j^s \right) \left( 1 + \tau_j^l \right) \right\} / \gamma_j^s \left( \left( 1 + \tau_j^l \right) a_{jj}^d - 1 \right) \right. \\ \left. \cdot \left[ \sum_{(i \neq j)} \left( P_i^d a_{ij}^d + P_i^m a_{ij}^m \right) + \left\{ E_j P_j^E P_j^{E0} / \alpha_j \left( a_j KPI_j^{bj} KNPI_j^{dj} h^{*(1-\alpha_j)} \right)^{(1/\alpha_j)} \right\} \right] X_j^{(1-\alpha_j)/\alpha_j} \right] \quad (104)$$

Public R&D sector (STI category)

$$C_j = P_j^d X_j = \left( 1 + \tau_j^l \right) \left\{ \sum_i P_i^d a_{ij}^d X_j + \sum_i P_i^m a_{ij}^m X_j \right. \\ \left. + \left( L N_j^G h_j P_j^{LNGt} P_j^{LNG0} + K G_j^t P_j^{SKGt} P_j^{SKG0} + K N G_j^t P_j^{SKNGt} P_j^{SKNG0} \right) \right\} \quad (105)$$

$$P_j^d / X_j = \left\{ \left( 1 + \tau_j^l \right) / \left( 1 - \left( 1 + \tau_j^l \right) a_{jj}^d \right) \right\} \cdot \left[ \sum_{(i \neq j)} P_i^d a_{ij}^d + \sum_i P_i^m a_{ij}^m + \left( L N_j^G h_j P_j^{LNGt} P_j^{LNG0} + \right. \right. \\ \left. \left. + K G_j^t P_j^{SKGt} P_j^{SKG0} + K N G_j^t P_j^{SKNGt} P_j^{SKNG0} \right) / X_j \right] \quad (106)$$

*Labor block*

## Labor force

$$AN_{as}^{t+1} = \lambda_{ANas}^{t+1} \times N_{as}^{t+1} \quad (107)$$

$$SE_{as}^{t+1} = \lambda_{SEas}^{t+1} \times AN_{as}^{t+1} \quad (108)$$

$$FW_{as}^{t+1} = \lambda_{FWas}^{t+1} \times AN_{as}^{t+1} \quad (109)$$

$$ES_{as}^{t+1} = (1 - \lambda_{SEas}^{t+1} - \lambda_{FWas}^{t+1}) \times AN_{as}^{t+1} \quad (110)$$

$$ES_{as}^t = \lambda_{ESas}^t \times ES_{as}^t (a = 1, \dots, 5), (s = M, F) \text{ while } \lambda_{ESas}^t = 1 - \lambda_{SEas}^t - \lambda_{FWas}^t \quad (111)$$

## Price of labor service

$$P^{Et} = \sum_j \sum_a \sum_s \text{weight}_{jas}^t P_{jas}^{Et} \quad (112)$$

$$\text{weight}_{jas}^t = P_{jas}^{Et} ED_{jas}^t / \sum_j \sum_a \sum_s P_{jas}^{Et} ED_{jas}^t \quad (113)$$

$$P_j^{SEFWt*} = IY_{jSEFW}^t / h^* = F(P^{Et*}) \quad (114)$$

## Labor wage

$$\begin{aligned} \ln C_j^* &= \alpha_j^0 + \sum_k \alpha_j^k \ln P_j^{k*} + \alpha_j^x \ln X_j^* + \alpha_j^t g \left( K_j^{GNt+1} \right) + (1/2) \sum_k \sum_l \ln \beta_j^{kl} \ln P_j^{k*} \ln P_j^{l*} \\ &\quad + \sum_k \ln P_j^{k*} \ln X_j^* + \sum_k \beta_j^{kt} \ln P_j^{k*} g(K^{GNt+1}) \end{aligned} \quad (115)$$

$$v_j^L = \partial \ln C_j^* / \partial \ln P_j^{L*} = \alpha_j^L + \sum_l \beta_j^{Ll} \ln P_j^{l*} + \beta_j^{LX} \ln X_j^* + \beta_j^{LX} g(K^{GNt+1}) \quad (116)$$

$$P_j^{L*} = \text{weight}_j^{Et*} P_j^{Et*} + \text{weight}_j^{SEFWt*} P_j^{SEFWt*} \quad (117)$$

$$C_j^{L*} = v_j^L \times C_j^* \quad (118)$$

## Wage gap of labor service by gender, age, and occupation

$$P_{jaso}^{Et+1*} = \theta_{Jaso}^{Et+1*} P^{Et*} \quad (119)$$

## Determinant of wage and employment level in the next period

$$v_j^L = \partial \ln C_j^* / \partial \ln P_j^{L*} = \alpha_j^L + \sum_i \beta_j^{Li} \ln P_j^i + \beta_j^{LX} \ln X_j^* + \beta_j^{LT} g(SK^{GNt+1}) \quad (120)$$

$$P_j^{Lt+1*} = P_j^{Lt} \quad (121)$$

$$P_j^{Et+1*} = P_j^{Et} \quad (122)$$

$$P_j^{SEFWt+1*} = P_j^{SEFWt} \quad (123)$$

$$P_j^{SKt*} = P_j^{SKt\blacktriangle} \quad (124)$$

$$P_j^{DMt*} = P_j^{DMt\blacktriangle} \quad (125)$$

$$ED_{jas}^{t+1*} = v_{jas}^{L*} \times Y_{jE}^{*t+1} / (P_{jas}^{Et+1*} \cdot h^*) \quad (126)$$

Formula of occupation and industry

$$\begin{aligned} \ln C_j^* = & \alpha_j^0 + \sum_k \alpha_j^k \ln P_j^{k*} + \alpha_j^x \ln X_j^* + \alpha_j^t g \left( K_j^{GNt+1} \right) + (1/2) \sum_k \sum_l \ln \beta_j^{kl} \ln P_j^{k*} \ln P_j^{l*} \\ & + \sum_k \ln P_j^{k*} \ln X_j^* + \sum_k \beta_j^{kt} \ln P_j^{k*} g \left( K^{GNt+1} \right) \end{aligned} \quad (127)$$

$$P_j^{SKt*} = \sum_o \text{weight}_j^{ot} P_j^{oSKt} \quad (128)$$

$$\text{weight}_j^{ot} = P_j^{oSKt} SK_j^{ot} / \sum_o P_j^{oSKt} SK_j^{ot} \quad (129)$$

$$P_j^{SKNt*} = \sum_o \text{weight}_j^{ot} P_j^{oSKNt} \quad (130)$$

$$\text{weight}_j^{ot} = P_j^{oSKNt} SKN_j^{oNt} / \sum_o P_j^{oSKNt} SKN_j^{oNt} \quad (131)$$

$$P_j^{Mt} = \sum_o \text{weight}_j^{ot} P_j^{oMt*} \quad (132)$$

$$\text{weight}_j^{ot} = P_j^{oM*} M_j^{oMt} / \sum_o P_j^{oM*} M_j^{oMt} \quad (133)$$

$$P_j^{Lt*} = \sum_o \text{weight}_j^{ot} P_j^{oLt*} \quad (134)$$

$$\text{weight}_j^{ot} = P_j^{oL*} L_j^{oLt} / \sum_o P_j^{oL*} L_j^{oLt} \quad (135)$$

$$v_j^L = \partial \ln C_j^* / \partial \ln P_j^{Lt*} = \alpha_j^L + \sum_l \beta_j^{Ll} \ln P_j^{l*} + \beta_j^{LX} \ln X_j^* + \beta_j^{LX} g \left( K^{GNt+1} \right) \quad (136)$$

$$ED_{as}^{t+1*} = \sum_j ED_{jas}^{t+1*} \quad (137)$$

*Optimal capital stock in  $t + 1$  period*

$$INVK_j = K_j^* - (1 - \delta_j^K)K_j \quad (138)$$

$$INVKITE_j = KITE_j^* - (1 - \delta^{KITE})KITE_j \quad (139)$$

$$INVKRDE_j = KRDE_j^* - (1 - \delta^{KRDE})KRDE_j \quad (140)$$

$$INVKPI_j = KPI_j^* - (1 - \delta_j^{KPI})KPI_j \quad (141)$$

$$INVKN_j = KN_j^* - (1 - \delta_j^{KN})KN_j \quad (142)$$

$$INVKNITE_j = KNITE_j^* - (1 - \delta^{KNITE})KNITE_j \quad (143)$$

$$INVKNRDE_j = KNRDE_j^* - (1 - \delta^{KNRDE})KNRDE_j \quad (144)$$

$$INVKNPI_j = KNPI_j^* - (1 - \delta_j^{KNPI})KNPI_j \quad (145)$$

*Investment demand*

$$INVK_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVK} P_j^{INVK} INVK_j}{P_i^d} \quad (146)$$

$$INVKITE_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKITE} P_j^{INVKITE} INVKITE_j}{P_i^d} \quad (147)$$

$$INVKRDE_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKRDE} P_j^{INVKRDE} INVKRDE_j}{P_i^d} \quad (148)$$

$$INVKPI_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKPI} P_j^{INVKPI} INVKPI_j}{P_i^d} \quad (149)$$

$$INVKN_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKN} P_j^{INVKN} INVKN_j}{P_i^d} \quad (150)$$

$$INVKNITE_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKNITE} P_j^{INVKNITE} INVKNITE_j}{P_i^d} \quad (151)$$

$$INVKNRDE_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKNRDE} P_j^{INVKNRDE} INVKNRDE_j}{P_i^d} \quad (152)$$

$$INVKNPI_i = \frac{\sum_{j \in IND} \omega_{ij}^{INVKNPI} P_j^{INVKNPI} INVKNPI_j}{P_i^d} \quad (153)$$

*Foreign block*

$$\Delta IS^R = \sum_{(\varepsilon IND)} P_i^d Ex_i - \sum_{(I \varepsilon IND)} (1 - \tau_i^M) IM_i^{CIF} + LC^R + PC^R - TRE^{GR} - TRE^{PR} \quad (154)$$

$$\Delta B^R = \Delta IS^R + TRC^{RC} + TRC^{RP} \quad (155)$$

*Final demand block*

$$P_i^{dc} = (1 + \tau^C) P_i^d \quad (156)$$

$$P_i^{mc} = (1 + \tau^C) P_i^m \quad (157)$$

$$\ln P_T^C = \sum_i \alpha_i^{dC} \ln P_i^{dc} + \sum_i \alpha_i^{mC} \ln P_i^{mc} \quad (158)$$

$$C_T = \alpha_c + \beta_c (Y/P_T^C) \quad (159)$$

$$F^D = BC^T + C^T + GC^T + GDEP^T + INVKG^T + INVK^T \\ + INVKGN^T + INVKN^T + INVKNE^T + Z^T \quad (160)$$

$$X^D = (I - A + M^D)^{-1} (F^D + E^T) \quad (161)$$

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