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Informatization and Growth: The regional analysis in East Asia I The case of Korea†

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情報化と成長：東アジアの地域分析 I 韓国の場合

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Abstract

Now we often hear the importance of the information technology sector. In this paper, I have considered about the roles of development in information sector for economic growth in the point of the macroeconomic views, and I shall examine to analyze the empirical facts of Korea (Rep. of.). It would be said that Asian less developed countries (LDCs) has been attained the rapid economic growth, because of the rise of yen after Praza agreement in the mid 80's and the increment of foreign direct investment (FDI) for Asian countries, the exports in these countries has been increased comparison to before 80's. The fact is what we call, " Asian Miracles " . In Asian LDCs, Korea has attained the economic recoveries and growth, first of all. Before I shall consider of all Asian LDCs, first I shall begin to analyze the Korean Miracles. Most of all, I shall discuss the problems how the expansion of the sector will be converged to the balanced growth pass, using the context of exogenous or endogenous growth theory. And I shall refer to the future of the relations of information sector and economic growth.

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1 Introduction

This paper is considered about the roles of development in information sector for economic growth in the point of the macroeconomic views, and positively analyzed the empirical facts of Korea (Rep. of.). When we reffer to information used the several methods of economic theory, it is frequently said that weneed to distinguish the case of *industrialization of information and informatization of industry.* In this paper I consider it on the latter point of view. As well known,in the supply side, the information plays the role that, with its vailability beingeasy, brings new cost improvingprocess of production, and thus this new process, the improvement of Research and Development (R & D) may be gradually used in the production of goods, as result, the supply carve of this industry may be able to sift to downward in the assumption of *ceteris paribus*[1]. Otherwise, in the demand side, consumers may be able to obtain more lower cost goods than before, if there is no qualitative variety since the agents gain the information related to the goods.

If we intend to think of economic growth with technical improvement in information sector, it may be important to define as the idea of informatization itself. In this paper, I would take it in the narrow sense of the definition, the informatization means the increment of the growth rate of added value in information industry. Consideringon this point of view is on the supply side in the economies[2]. This definition concerningto the supply side is useful for achievingmy purpose that I would want to consider the relation between the information and the productivity of growing economies. Therefore, this paper also adopted the narrow sence of definition.

It would be said that Asian less developed countries (LDCs) has been attained the rapid economic growth, because of the rise of yen after Praza agreement in the mid 80's and the increment of foreign direct investment (FDI) for Asian countries, the exports in these countries has been increased comparison to before 80's.Of course, as World Bank [32] pointed out, it is observed the facts that each government in these countries positively intervened to market, but this intervention policy was export oriented and was carried out to make up for the market failure and to arrange their inflastructure. Thus, LDCs have gradually came up with the developed countries[3]. Of course, there are pessimistic views represented Krugman [12], what is called, the myth of Asia's miracle. Anyw y, it could be certain that most of all economists and the others are interested in the sustainability of growth in this area.

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[1] In this paper,as tractable assumption,I assume to regard industry as firms.Under this assumption, the agent i the industry is equal to the representativ firm.

[2] Against the narrow sense, Kuriyama and Oniki [11],using Input Output (I-O) analysis, pointed out the user effects which is economic gains derived from the information goods and service being used in the other sector of the economy, that is, they adopted the wide sence of the definition including the factors of demand side.

[3] There are so much refference to development in East Asia and LDCs.Most of all, the optimistic views as to sustainability of economic growth in Asia depend on the increment of not only inter-industry trade, but also intra-industry trade, and also on improvment of total factor of productibity (TFP).

At the same time, it began to study the endogenous growth theory[4]. Though, these theories themselvs have fandamentally followed *`a la* Solow [27] which treated technology as exogenous, the different features of them are to treat the innovation as endogenous, *i.e.,* regarding techniques and skils of production as the accumulation of know how, R & D and human capital and so on, which brings education in school and training in firms for long time. According to the insistence of these theory, development in human capital and R & D my be able to affirmative for positive growth policy. But, the roles of information so as to reduce the production cost and push on with the productivity have scarcely been treated in the context of macroeconomics[5]. I hope to establish the position of information in the growing economy.

On the other hand, Jonscher [8] and Voge [31] advocated that in the economy where the share of information sector would be reached at 50%, if it were not for improvement of productivity in the information sector, the growth of whole economy might be limited (Jonscher = Voge hypothesis). Though, this hypothesis w s mainly introduced by Jonscher and Voge from the analysis of developed countries, but I attempt to inspect wheter it would be true of this hypothesis in the case of Asian LDCs, above all, in this paper, I shall consider the case of Korea.

In this paper, to begin with, I h ve to start to grasp at the informatization. To realize this informatization as visible forms, I shall deal with the roles of knowledge stock which is accumulated with informatization in Asia countries. Hence, I heve necessity to estimate the knowledge stock. In the next section, I shall estimate the knowledge stock to grasp at the informatization in this area. And in the Section 3 , I shall estimate the production function and convergence speed of growth, and elucidate the sustainability of growth in the case of exogenous or endgenous technology. In the Section 4 , I shall inspect the Jonscher = Voge hypothesis. And finally in the Section 5 , I shall conclude the remarks and discuss about the future of this area and some limitations of the method so as to use the present model.

2 **Informatization in Korea**

I shall start with the outlooks of informatization in Korean economy. Above all, to begin with, it may be useful to recognize the expantion of computer industry's supply and demand in Korea. Because, the developpment of information technology has just come with the mature of computer industry. In 1967, IBM computers were first introduced in Korea. Since then, Korea has made steady progress towards an information society. In paticular, at the end of the 1980's, the demand-base for computers expanded

[4]See Lucas [15]and P. Romer [25], [26] and so on. Aghion and Howitt [1], Barro and Sala-i-Martin [3] and D. Romer [24] are useful for refference of this field. The pioneering works are Solow [27], [28], Ramsey [23], Cass [5], Koopmans [10] and Uzawa [29], [30] and so on.

[5]There is already in the context of microeconomics, as the information economics or the ecoinomics of uncertainty

remarkably as result of the continuous progress in constructing national computer network such as the administrative network, bankingcomputer network and educational computernetwok. The trade liberalization policy and the small to madium-size company computerization policy have also enhanced the demand.

In 1997, the computer market saw incresingdemand for personal computers in advanced countries, the modernization of systems such as multi-media, and the expanded popularization of the *Internet*. Thus, exports of computer compornents incresed 38.9% to 221 million dollars over the previous year, but domestic sales decreased 0.4%. This w s because consumers chose to upgrade existingcomputers rather than purchase new ones.

As for peripheral devices, the capacity of HDD (Hard Disk Drive) was elevated from 2GB to 3GB, which simulated an increse in both exports and domestic sales. CRT terminals prices were lowered by virture of supply surplus, and the domestic production of 14 ” and 15 ” CRT terminals was reduced. For these reasons, exports decreased 14.0% from the previous year ; printers and FDDs (Floppy Disk Drives) also decreased both in exports and domestic sales (see Table 1).

Otherwise,since mid 1980s, Korea has heavily invested in the field of momory devices, and the korean semiconductor industry as result achived outstanding growth. in 1995, it became the flagship industry of Korea, and for the first time, single product had supassed 20 billion dollars. Korea is now the third country in the field of memory after America and Japan.

Total seniconductor production amounted only to 1.5 billion dollars in 1990. But in just five years, that level was extended to 16.1 billion dollars every year markingan increase rate of more than 60%. However,

Table 1 Computer Industry Supply and Demand

(Unit: Production・Domestic Sales-100 million won, Exports・Imports-million dollars, %)

		1996	1997	Increase rate	
				1996	1997
Cmputers	Production	11,616	12,309	7.9	6.0
	Imports	1,012	856	13.3	-15.4
	Domestic sales	10,678	10,638	27.4	-0.4
	Exports	159	221	-28.9	38.9
Peripheral devices	Production	51,631	62,968	24.0	22.0
	Imports	2,517	2,240	18.9	-11.0
	Domestic sales	9,733	11,584	21.6	19.0
	Exports	4,963	5,658	18.5	14.0
Total	Production	63,449	75,488	15.2	19.0
	Imports	3,948	3,515	17.5	-11.0
	Domestic sales	20,484	22,292	10.6	8.8
	Exports	5,138	5,895	15.9	14.7

Source: Electronic Industries Association of Korea, Korea Foreign Trade Association

Table 2 Supply and Demand of Semiconductors

(Unit: million dollars, %)

	1995	1996	1997	Increase rate	
				1996	1997
Production 1)	16,150	11,914	9,713	-26.2	-18.5
Imports	3,081	3,560	4,200	15.1	18.0
Domestic demands	4,399	4,985	5,460	15.7	9.5
Exports 1)	14.602	10,679	8,626	-26.9	-19.2
Overseas dependency ratio	70.0	71.4	76.9	-	-

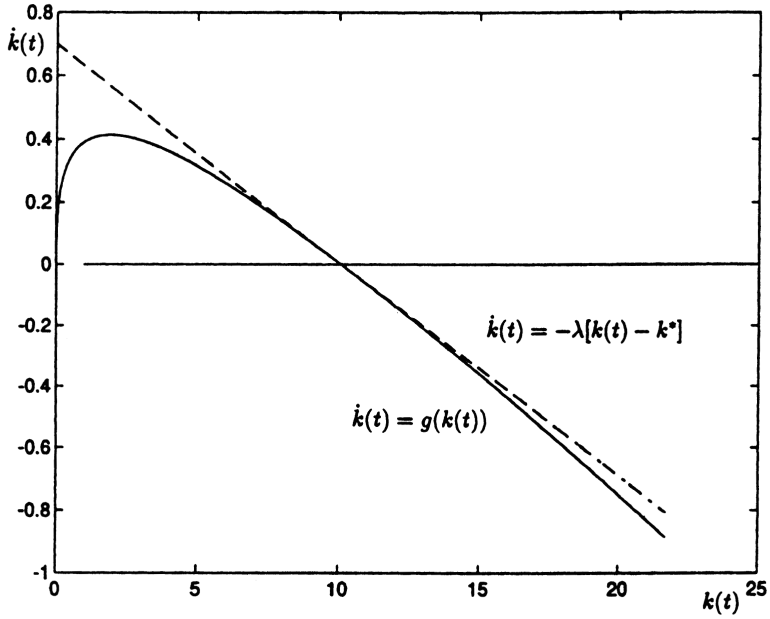
Notes: 1) Based on five companies with integrated process
Source: Korea Semiconductor Industry Association

since the end of 1996, because of the surplus of memory products around the world and the recession of the PC market and the followingfall of DRAM market price, the total production of the semiconductor industry has stabilized, 11.9 billion dollars in 1996 and 9.7 billion dollars in 1997. In 1997, imports of semiconductors increased 18.0% to 4.2 billion dollars, and the overseas dependency ratio increased to 77.0% from 71.4% in 1996 (see Table 2). The exots of semiconductors in 1997 declined in value to 8626 million dollars, decrease of 19.2%, due to the delayed recovery of memory products. Unlike slowdown in exports, domestic demand totaled 5460 million dollars. This increase of 9.5% over the previous year resulted from the advencement in high technology used in electronic goods, the better loadeingratio of semiconductors, and the increase indemand for informative communication products (cited from National Statistical Office, Republic of Korea [20] pp.39-42).

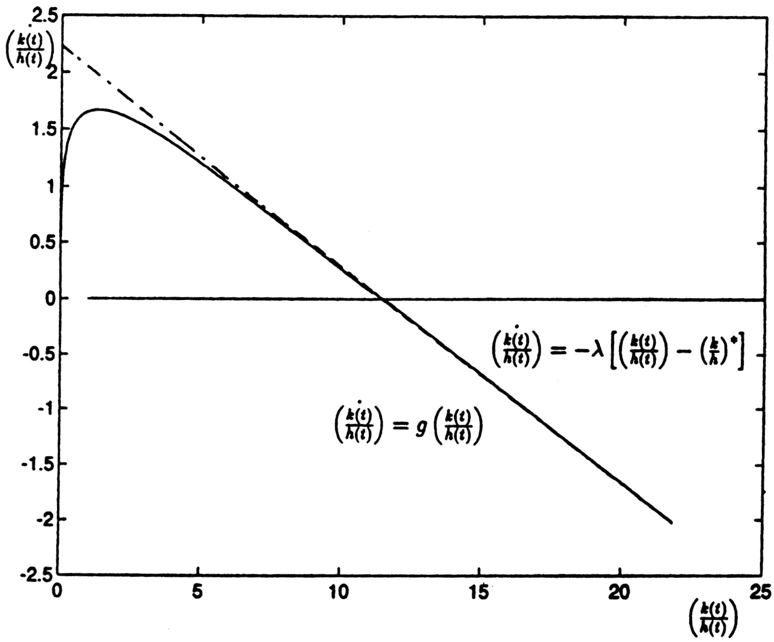
Since the previous economic investigations used economic theory (e.g. Solow [27], [28]), the innovation of tchnology has been treated as Solow residual (or TFP) which is estimated as technological progress in growth accounting. And of course, there are already so many studies whether economic growth would be on the steady state pass and this economy would be converged or not as time goes on. Most of all, as for convergence, there are two arguments, the divergence hypothes represented by Myrdal [18] and the convergence hypothesis insisted by Kuznets [13], [14], Barro and Sala-i-Martin [3], and most of recent investigations in this field. As the latter insistence has been analyzed in details usingstatisitical methods, the convergence hypothesis becomes now the majority of these arguments. Hence I would follow in the latter convergence hypothesis, analyze to use the neoclassical growth model taken the initiative by Solow [27]. And in the information sector, now I would attempt to consider the two types of technology that are exogenous and endgenous for Korean information industry.

3 **Speed of cnovergence**

In this section, at first, I shall ague the speed of convergence to stationaly solution useing simple vergion of the neoclassical growth model in the case of exogenous technology. And second, I shall estimate using the method of Ortigueira and Santos [22] in the case of endogenous technology. To understand the construction of the economy or industry in the country, in the context of macroeconomics, it has often been used to estimate the parameter of its production function.Most of all, it is important the function gives me the information of the several economc valuables that maight be converge to the fixed values in the steady state. Hence, now I shall caluculate the rate of convergence speed by usingthe method of Appendix A.1 and A.2. First I h ve to estimate the knowledgstock. And from the estimation values, next I consider my benchmark economy with parameter values, $\sigma = 0.05$, $\rho = 0.05$, n = 0.01, A = 1, $\delta = 1.5$, $\beta = 0.4$. As result of the caliculation. Consequently, I obtaion the followingsteady-state values, c* = 1.91, k* =10.0 and the rate of convergence speed is $\tilde{\lambda}_{exo.}$ =0 .07. Figure 1 displays the laws of motion of the linear and non-linear systems for the baseline economy. It can be observed that the linearized system mimics well the nonlinear dynamics over significative range of the capital domain. Similar patterns were found for alternative calibrations of the model. Hence, it may be said that the local speed of convergence, $\tilde{\lambda}_{exo.}$, is good estimate of the global converging behavior.



Source : Ortigueira and Santos [22] **Figure 1**



Source : Ortigueira and Santos [22] **Figure 2**

Next, I consider the case of endogenous growth model.As same as the case of exogenous model, I shallassume that the benchmark economy has the following parameters, that is, $\gamma = 0.45$, $\delta = 1.5$, $\rho = 0.05$, $n = 0.01$, $A = 3$, $\alpha = 0.07$, $\beta = 0.4$, $\sigma = 0.05$, $\theta = 0$. Let $z = c/k$ and $x = h/k$, these parameters give rise to the followingsteady-state values: $z^* = 0.26$, $x^* = 0.09$, $\ell^* = 0.43$, $u^* = 0.28$, and convergence speed, $\tilde{\lambda}_{end.}$, is $\tilde{\lambda}_{end.} = 0.20$. The dynamics of the convergence is display in Figure 2. Judgeing from the result of the estimation, it may say the paformance of endogenous model is better than the one of the exogenous model.

4 **Robustness of Jonscher = Voge hypothesis**

In 1983, Jonscher [8] showed the two sectors model which is separated from goods and service sector to information sector. His idea is that, being the economy matured, the task of the information technology would be increasing, so as to the support and manegement of the economic systems.And he applyed his idea to the American economy. From his model, the relation of the number of workers in the information sector and one of workers in the other sectors is inverse proportion to the labor productivities in each sectors. In addition to this results, he insisted that if the productivity in the information sector is exceed the one of the other sectors, the number of labors engaged in information setor would be able to decreasingin near future. At the same time, Voge [31] insisted the hypothesis that the maximized GDP could be attained till the scale of information sector would be reached at the half of GDP, and he called the point of this situation *the wall of*

50%.

Cosidering the Korean economy, as it is now on the way to development about information technology, it is unwise of us to make decision so hastily. And it is difficult to decide the definition of the labors engaged in information sector. In the first place, where is the line that separates information sector from other sectors ? The answer is difficult. But, accordingto National Statistical Office, Republic of Korea [20], the ratio of information sector's labor is 6.3% (1960), 10.1% (1970), 14.6% (1980), 20.3% (1990), it has tendency to increase.

For the moment in my study, I have difficulty to judge exactly whether the hypothesis has robustness or not in Korean economy. However, I think it may be very difficult to observe the fact that Korean economy climbs the wall of 50% in the near future. Because, now the Korea has the comparative advantage of manufacturing goods and play very significant roles in world market, furthermore, the other LDCs has no technology that produce same lebel as Korea.

5 **Concluding remarks**

In this paper I tried to describe the Informatization of Korean Economy.The macroeconoic analysis of informatization has just begun yet since recent years. So it may not be said the tools of analysis has been established. Nevertheless, followingresult may be able to say, the computer industry, bove all, semiconductor industry is rapidly expanded its share in Korean eeconomy (section 2), and the growth of information sector is endogenous (section3), but I have rooms for investigate about robustness of Jonscher = Voge hypothesis, considering the movement of the Korean information sector (section 4).

Finally, bout the other LDCs, there are so many problems that it is not easy to analyze to this subject. The statistical arrangement requires immidiate attention, too. However, I hope that this paper maight be pioneerig analysis of the informatizaion in Asian countries, usingmacroeconomic theory.

A. Mathematical Appendix

A.1 Estimation of knowledge stock (R(*t*))

As for estimation of $R(t)$, I fandamentally obey the same analytical method in Nadiri [19] and Goto et al. [6]. The superiority of this approach exist in the classification of flow side and stock side of information. The method is introduced the *permanent stock approach* beingin the plant and equipment investment and the capital stock, between the knowledge stock and the flow of expenditures of R & D, estimate the knowledge stock. The theoretical equation for thisestimation are given in

$$R(t) = RF(t) + R(t-1). \tag{1}$$

In this paper, the obsolescence rate of patent of the production[6]. And I express η as the terms (development lag) that R & D effects exchange the knowledge stock, $RF(t)$ denote as $RF(t) = E(t-\eta)$[7]. Thus, (1) is given as

$$R(t) = E(t-\eta) + R(t-1). \tag{2}$$

In this equation, $E(t-\eta)$ denotes the value of R & D expenditures in the sector of information industries in $t-\eta$ period (real base expression). This one is translated into

$$R(t-1) = \frac{E(t-\eta)}{h}, \text{ where } h = \frac{R(t)}{R(t-1)} - 1\,. \tag{3}$$

But h in (3) is actually obscure, and is approximated as

$$h \approx \frac{RF(t)}{RF(t-1)} \tag{4}$$

and then I estimate $R(t)$[8].

A.2 Estimation of convergence speed

A.2.1 Estimation of production function in information industry

The estimation of macroeconomic production function is owed to Mansfield [17].

I apply to consider the method for Ortigueira and Santos [22] model which contains the information as endogenous, calculate the convergence speed for steady state growth in Asian countries, and compare with each countries. I denote Y is each countries' GDP, K is capital stock and L is labor. The small letter means valuable per capita. Now I characterize the production function for convinience.

$$y_i(t) = A_i(t)k^{\beta}, \qquad \forall A_i > 0, \beta \in [0,1]. \tag{5}$$

Where A is parameter, and equation (5) is used in the case of exogenous growth model. Otherwise, in the occation of the endogenous innovation, I consider the forms of production function as

$$y_i(t) = A_i(t)k^{\beta}(u_i(t)r_i(t))^{1-\beta}, \qquad \forall A_i > 0\,,\ \beta \in [0,1]. \tag{6}$$

Where $r_i(t) \equiv R_i(t)$ per capita and $u_i(t)$ denotes the relative amount of effort devoted to the production of good.

A.2.2 Exogenous growth model

The exogenous growth model presented by neoclassical optimal growth model is the model that

[6] Strictly speaking, it would not so much to say that there are the rooms for consideration of the obsolescence rate of one (See Goto *et al.* [6])

[7] In the context of accounting, the assumption between the flow and stock are ad hoc and may be able to deny. therefore, more exactly, I need to measure the estimation from the data from each country own, but, as tractable assumption in this paper,it is treated as given. Quoting the result of Goto *et al.* [6], the mean lag (η) of realization in・rms of technologies after R & D expenditures in information industries each countries is assumed to 3 years.

[8] $R(t)$ is used in A.3.1.

representative gents would maximize the utility function $U(c(t))$ (c is consumption (C) per capita, *i.e.*, c =C/L) under constraint. The utility function is constant elasticity of substitution (CES) function, and σ (>0) means an elastisity of substitution, and ρ (>0) is discount rate. On the other hand, the production goods by way of (5) is destributed consumption and investment. And the depreciation rate is δ (>0), and popuration grows at an exoginous rate n (>0), with $\rho \geq n$. Hence the constraint that the representative agent faced on is $\dot{k}_i(t) = A_i(t)\, k^{\beta} - (\delta + n)\, k_i(t) - c_i(t)$, the utility maximize problem is

$$\text{Max.} \quad \int_0^{\infty} e^{-(\rho - n)t} \frac{c_i(t)^{1-\sigma} - 1}{1-\sigma} dt$$

$$\text{s.t.} \quad k_i(t) = A_i(t)\, k^{\beta} - (\delta + n)\, k_i(t) - c_i(t),$$

$$c_i(t) \geq 0,\ c_i(t) \geq 0,\ k_i(0) = \bar{k}\ (const.). \tag{7}$$

From the method of Barro and Sala-i-Martin [3],

$$\dot{c}_i(t) = -\frac{c_i(t)}{\sigma} [\rho + \delta - \beta A_i(t)\, k(t)^{\beta - 1}] \tag{8}$$

$$\dot{k}_i(t) = A_i(t)\, k^{\beta} - (\delta + n)\, k_i(t) - c_i(t). \tag{9}$$

The steady state solutions of $c_i(t)$ and $k_i(t)$ are attained $\dot{c}_i(t) = 0$ and $\dot{k}_i(t) = 0$.

linearizing (8) and (9) at the steady state, I would get the $\tilde{\lambda}$, given by

$$\tilde{\lambda}_{exo.} = \frac{1}{2} \left\{ \rho - n - \left[(\rho - n)^2 + \frac{4(1-\beta)(\rho+\delta)}{\sigma} \left(\frac{\rho + \delta}{\beta} - (\delta + n) \right) \right] \right\}^{1/2} \tag{10}$$

Let $\lambda \equiv -\tilde{\lambda}$, I shall define it as the *convergence of speed.*

A.2.3 Endogenous growth model

Next I reffer to the speed of convergence in the case of endogenous growth. In the context of Ortigueira and Santos [22], the production function is given by (6). Of course, $r_i(t)$ is the levle of R & D, education or human capital. In the R & D sector, the low of mortion of $r_i(t)$ is given by linear technology, that is,

$\dot{r}_i(t) = \alpha(1 - u_i(t) - \ell_i(t))\, r_i(t) - \theta r_i(t)$, where $(1 - u_i(t) - \ell_i(t))$ is the fraction of time devoted to R & D, and $\ell_i(t)$ is the fraction of time spent in leasure activities, denotes the depreciation of $r_i(t)$ and holds non-negative, and α is non-negative parameter. The instantaneous utility function is represented by CES function, $U(c, \ell h) = [(c_i(t)^{\gamma}(\ell_i(t)\, r_i(t))^{1-\gamma})^{1-\sigma}]/(1-\sigma)$. Therefore, social planning problem is written as

$$\text{Max.} \quad \int_0^{\infty} e^{-(\rho - n)t} \frac{(c_i(t)^{\gamma}(\ell_i(t)\, r_i(t))^{1-\gamma})^{1-\sigma} - 1}{1-\sigma} dt$$

$$\text{s.t.} \quad \dot{k}_i(t) = A_i(t)\, k^{\beta}(u_i(t)\, r_i(t))^{1-\beta} - (\delta + n)\, k_i(t) - c_i(t),$$

$$\dot{r}_i(t) = \alpha(1 - u_i(t) - \ell_i(t))\, r_i(t) - \theta\, r_i(t),$$

$$0 \leq u_i(t) \leq 1,\ 0 \leq \ell_i(t) \leq 1,\ 0 \leq u_i(t) + \ell_i(t) \leq 1$$

$$c_i(t) \geq 0,\ k_i(t) \geq 0,\ r_i(t) \geq 0,\ k_i(0),\ r_i(0) = const.,\ \rho - n > (\alpha - \theta)(1 - \sigma). \tag{11}$$

I get the steady state valuables to solve the problem[9], and linearly approximate around the solution, as in the case of A.2.2,the convergence speed in endogenous growth model is witten as

$$\tilde{\lambda}_{end.} = \left(\frac{1-\beta}{\sigma} \right) (\delta + n + \alpha - \theta). \tag{12}$$

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