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Resource Curse, Overcommitment and Human Capital

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This paper attempts to provide a unifying and consistent perspective to British overcommitment and Latin American resource curse. Britain and Latin American countries overcommitted to a low productive, low technology intensive sector, including the primary resource sector. This paper sets up a multisectoral general equilibrium model with two kinds of human capital, general and specific human capital. Specific human capital represents specific skills, and general human capital increases the flexibility of economic agents. Combining empirical facts about the two empirical phenomena with theoretical implications of the model, we obtain the following result: Because Britain and Latin American countries had very strong primary sectors or traditional ones, which are less education demanding, they had not accumulated general human capital. Due to the lack of this capital, they could not easily move to more productive sectors.

I. Introduction

Quite a few economists are devoting much time to understand why many countries show diverse and distinct growth experiences, over time and across countries. Thus, it is difficult to present a unifying model which has the capacity to capture each and every unique aspect of many different growth experiences we can observe.

Among many interesting and nagging questions, the question why Latin American countries had been so slow to move to the more technology intensive, productive growth path, even with rich natural resources which had benefited them so much in the past, stands tall. Almost in every growth regression, it is easy to find a dummy variable standing for Latin America. In other words, Latin American growth experience is hard to understand and playing the role of an outlier.

Another question similar to the above is why Britain, an early starter of Industrial Revolution, failed to transform its economic structure to the more productive, human capital intensive one from the old technology such as cotton, coal, woolen and other sectors. It is generally believed that Britain had invested so much in (over-committed to) old sectors that it was impossible for it to move to the more productive path due to a huge cost of transformation.

In this paper, we derive interesting implications to understand the above two phenomena. The analysis of these phenomena will be performed in the following logical sequence. First, we will find out what are the important casual factors behind these phenomena. In other words, we will identify several elements constituting sufficient conditions for poverty trap. Second, from the quote of other papers and data, we will check whether these phenomena befit the

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theoretical model of this paper.

The analysis of poverty trap reveals us that two elements of economic state variables are essential to the poverty trap phenomena. These are relatively high level of certain specific human capitals and relatively low level of general human capital or education. The ingredient captures the overcommitment or resource curse, which will incur the high cost of creative destruction. The second one is related to the adaptability or flexibility of economic agents which lowers the cost of moving to more productive or technology intensive sectors.[1] What we find in the study of the above resource curse and overcommitment hypotheses is that these two elements are found to be important causal factors behind them in both theoretical and empirical context.

The paper proceeds as follows. In Section II, the model of poverty trap is outlined, and its existence and characterizations of equilibrium are analyzed. Section III derives relevant economic implications from the previous model. In addition, we try to explore causal factors underlying the above two phenomena and to see whether these are consistent with the model. Finally, Section IV concludes with an agenda of future research.

II. The model

In this section, brief discussion of two simplified versions of open and closed artificial economies is provided. Additionally, implications of poverty trap are analyzed and characterized with these models.[2]

2.1. The Closed Economy

This subsection presents an endogenous multisectoral growth model with two types of human capital in a closed economy. There are a large number of infinitely lived identical agents who consume n different types of goods, in this economy. The agents are maximizing the logarithmic utility function:

$$\max \sum_{t=1}^{\infty} \beta^t \sum_{i=1}^{n} \log c_t^i, \tag{1}$$

where c_t^i is the consumption of an i-th good in period t, and β is the discount rate.

There exist two kinds of human capital: One is n different types of specific human capitals (h_t^i), which are more related to production of specific commodities such as specific skills, techniques and know-how of production, and the other is general human capital (h_t^g) which is the general knowledge accumulated by education. We also assume that general human capital can be accumulated through formal education, and that new specific human capital

1. This kind of role of education is extensively studied in Kim and Kim (1998).
2. The models are based on Kim and Kim (1997). However, the analysis of the paper is more rigorous and its implications are new.

cannot be created directly by using inputs, but can be created only with the help of general human capital.

The specific human capital or the production technology can be changed by general human capital through the relationship of

$$h^i_{t+1} = \theta^i h^g_{t+1} \quad \text{at} \quad t+1,$$

where θ^i represents the efficiency of an i-th sector (industry) with which general human capital can be transformed into new specific human capital. High value of θ^i means that the i-th sector is a more knowledge and technology intensive sector.

We also assume that, once agents decide to change production technology through general human capital, this technology change should happen in all of the sectors. In other words, when agents change the technology at $t+1$,

$$h^i_{t+1} = \theta^i h^g_{t+1} \quad \text{for all} \quad i.$$

If they do not change specific human capital's,

$$h^i_{t+1} = h^i_t \quad \text{for all} \quad i.$$[3]

This assumption simplifies the analysis of poverty trap. And this does not seem to be extraordinary odd. It may be natural for all sectors to adopt modern technologies simultaneously, following the Big Push theory proposed by Rosenstein-Rodan (1961). However this assumption is not critical.

The accumulation of general human capital is assumed to be a linear function of time devoted to education (u_t) as:

$$h^g_{t+1} - h^g_t = Bu_t h^g_t, \tag{2}$$

where B represents the efficiency with which agents produce general human capital by investing time in education. And notice that when new specific human capital (h^i_{t+1}) is created using general human capital, the existing specific human capitals become one hundred percent obsolete. This aspect features Schumpeter's creative destruction.

The agent is endowed with one unit of non-leisure time in each period of his life, which is allocated for either education or work as:

$$u_t + \sum_{i=1}^{n} l^i_t = 1, \tag{3}$$

3. We can assume that specific human capital increase by learning by doing. However, as long as this effect is smaller than the effect of technology change *B*, the results will not change.

where l_t^i represents labor supply for an i-th industry in period t.

For simplicity, physical capital does not exist in this economy. Thus his current income is derived solely from the total supply of effective labor, which is the sum of the supply of l_t^i units of labor, quality adjusted by specific human capitals h_t^i over each industry. He spends this period's labor income on the current consumption of n different types of goods. Thus, the agent faces a budget constraint of

$$\sum_{i=1}^{n} p_t^i c_t^i = \sum_{i=1}^{n} w_t^i h_t^i l_t^i, \tag{4}$$

where p_t^i is the price of an i-th good and w_t^i is the real wage rate for one unit of effective labor in an i-th industry at time t.

For firms, we assume that the only input for the production of each commodity is the specific human capital related to that commodity. In particular, a constant returns to scale production function with respect to effective labor is assumed as follows:

$$y_t^i = A_t^i h_t^i l_t^i, \tag{5}$$

where A_t^i represents the marginal product of effective labor. To simplify the model, this stochastic variable A_t^i is not considered without changing the results. This is the description of the closed economy.

2.2. The Open Economy

The model of an open economy is identical to the previous model except an assumption of the perfect mobility of goods. Here, we assume immobility of labor.

In the open economy, we additionally assume that prices of n commodities p^{iW} are exogenously given from international commodity markets. Therefore, one county is forced to produce only one commodity of the most comparatively advantageous sector. Also assume that the economy specializes in the i^*-th industry. In other words, the i^*-th industry is the industry with a comparative advantage at time t. There are an infinite number of firms in each country, which allows competitive markets to work.

Due to the different assumptions of the open economy from the closed, we have, instead of Equations (3) and (4) above,

$$u_t + l_t^{i^*} = 1, \tag{6}$$

$$\sum_{i=1}^{n} p_t^{iW} c_t^i = w_t^{i^*} h_t^{i^*} l_t^{i^*}. \tag{7}$$

The solutions to the previous two models are very simple[4] as:

$$u_{t+1} = \frac{\beta(1+B)}{B},$$

$$l_t^j = \frac{1-u_t}{n}$$, for the closed economy, and

$$u_{t+1} = \beta\frac{(1+B)}{B},$$

$$l_t^{j*} = 1-u_t,$$ for the open economy.

At the steady state, an interior solution for u_{ss} is guaranteed by $\beta(B+1) > 1$, which is also the condition for a positive growth of the economy. At the steady state, $u_{t+1} > 0$ for all t and $h_t^j = \theta^j h_t^g$ for all i and t. And with this constant growth rate and a logarithmic utility function, the summability condition is guaranteed.

2.3. Poverty Trap

This subsection provides a more rigorous proof of existence and characterization of poverty trap. For this task, several propositions and theorems are in order. First, we will prove the continuity, strictly increasing property of the welfare function of a representative agent with respect to the state variables of general human capital and specific human capitals.

Proposition 1: *The welfare function is a weakly increasing (non-decreasing) function with respect to general and specific human capitals, respectively.*

This proposition is so obvious that we do not need any proof. This proposition says the more in resource endowment, the better the welfare.

Proposition 2: *The welfare function, the discounted summation of the momentary utility function over an infinite time horizon is continuous with respect to general human capital, given any fixed set of specific human capitals.*

Proof: See Appendix A.

Proposition 3: *The welfare function strictly increases in* h_0^g, *given any set of specific human capital's, in the first and third cases of Appendix A.*

4. Due to the logarithmic utility function, the solutions are very simple. The more patient economic agents are, the more they invest in education. And for the closed economy, they work for the equal amount of time for the whole sectors. It is because price and income effects cancel out in the case of the logarithmic utility function. Refer to Kim and Kim (1997) for more detailed analysis.

Proof: It can also be easily proved by applying the above ε-logic. Assume there are two economies, one with h_0^g and the other with $(1\pm\varepsilon)h_0^g$, with different initial general human capital and identical specific human capitals. The economy with $(1\pm\varepsilon)h_0^g$ can follow the optimal paths of state variables, consumption and investment of the economy with h_0^g, except the initial period, by investing less on general human capital (h_0^j) at time 0, by this amount of ε/B, thus increasing consumption at time 0. Thus, the welfare of the economy with $(1+\varepsilon)h_0^g$ is strictly larger than that with h_0^g./‍//

Theorem 1: *There exists exactly one cut off point h_0^{g*} above which the investment in h_t^g will be positive for all $t \geq 0$, and below which it will be zero for all $t \geq 0$, given a fixed distribution of specific human capital's.*

Proof: It is obvious that two curves in Graph 2 produce just one cutoff point h_0^{g*} by Proposition 1 and 3. Moreover, h_0^{g*} should be positive, because of the sufficient condition of poverty trap proved in Appendix B./‍//

The above propositions and Theorem 1 remain valid, irrespective of whether the economy is open or not. The simple intuition behind the poverty trap is: To move to the more productive and high growth path, economic agents should consider its cost and benefit: The higher level of general human capital they have, the less cost of input they need to build up general human capital and the more efficient specific human capital's they can create. Nonetheless, one of the important cost items is the opportunity cost of an old technology (or specific human capital) that should be discarded, once new technology is obtained and used. This is the cost of creative destruction that Schumpeter emphasizes in the process of development.

One more thing to note is that the critical cutoff value of general human capital is homogeneous of degree one with respect to $\{h_0^j\}_{j=1}^n$. Therefore, whether one is trapped in poverty or not dependends on the relative ratio of general to specific human capitals. From the above results, we have the following theorem.

Theorem 2: *If one country's general human capital level is small sufficiently, compared to the level of specific human capitals, then this country will be trapped in zero growth state when it maximizes its welfare. If this country tries to maximize growth, then she must invest in general human capital, sacrificing its welfare.*

III. Implications of the Model

This section pursues several economic implications from the previous model of poverty trap.

First the relationship between openness of an economy and possibility of poverty trap is studied. Second, the nagging question, why Britain could not move to the more productive industry, such as electric, chemical, motors and others, from old, low productive industries, such as woolen, cotton, steel and coal, around the end of 19th century and early 20th country, is analyzed.

Last, another interesting, being much studied, question, why Latin American countries have not shown any rapid growth of economy even with rich natural resources, while resource poor counties such as Singapore, Hong Kong, Taiwan and Korea have shown a remarkable rapid growth.

3.1. Openness of an Economy and Poverty Trap

This subsection provides two interesting cases to exemplify complicated relationships between openness of an economy and the poverty trap, depending on the distribution of general human capital and specific human capitals. This subsection will provide intuitions behind this complex relationship.[5]

Case 1: *One economy will remain in poverty trap under a closed economy regime forever, but can get out of poverty trap under an open economy.*

Note that it depends on the relative ratio of general to specific human capitals. Assume that this economy has initial endowments of general human capital and specific human capitals as in Graph 3. Graph 3 depicts that i^* sector or industry has low level of specific human capital, but this industry is knowledge intensive (θ^{i^*} is bigger than any other θ^{i}). Moreover, the level of general human capital is small compared that of all specific human capitals except one specific human capital of i^* industry.

Here is another assumption about world prices of n commodities. With Graph 3 and 4, the economy will not invest in general human capital under a closed economy, thus being trapped in poverty. It is because the relative ratio of general to specific human capital of all sectors but i^* is very small. However, if the country takes an export oriented industrialization policy (EOI), it will specialize in the i^*-th industry of comparative advantage, because

$$p^{Wi^*}\theta^{i^*}h_0^{i^*} > p^{Wj}h_0^{j}, \text{ for all } j,$$

where i^* is argmax $\{p^{Wi}\theta^{i}h_0^{i}\}$. Furthermore, this county will invest in education because $\theta^{i^*}h_0^{i^*}$ is relatively bigger than $h_0^{i^*}$.

Even though this example is exaggerated a little bit, this tells us: Even if a country has accumulated a very small amount of general human capital and specific human capital of i^* industry, and if i^* industry's world price is promising and its technology is knowledge intensive (effective), then opening up the market can push this country out of poverty trap.

5. The rigorous proofs for the result in this subsection will be easily established by using Equation (1) in the appendix.

Nonetheless, with the closed economy, the country will remain in poverty trap, because its traditional sectors' specific human capital is relatively high compared to general human capital.

Case 2: *One economy will remain in poverty trap under an open economy forever, but can get out of poverty trap with a closed economic policy.*

Assume that this economy's initial endowments of specific human capitals as Graph 5 shows. Graph 5 says that an i^* sector has a very high level of specific human capital, and this sector is not knowledge or technology intensive, because θ^{i^*} is low-valued. Moreover general human capital level is relatively high compared to specific human capitals expect an i^* sector.

Also assume the world prices of n commodities are given as in Graph 6. With initial endowments of specific human capitals in Graph 5, this economy will invest in education with a closed economic policy, because the level of general human capital is relatively high compared to that of specific human capitals of all sectors except i^*. However, if it opens up its market and participate in the world market, it will specialize in i^* sector through comparative advantage, and will not invest in education. It is because the ratio $\frac{\theta^{i^*} h_0^{g}}{h_0^{i^*}}$ is small and i^* sector is not knowledge intensive (low θ^{i^*}). This case well matches with the resource curse hypothesis. In the next two subsections, more detailed analysis about resource curse and overcommitment hypotheses will be provided.

3.2. British Overcommitment

This subsection will analyze the question, why Britain failed to transform its economic structure to the more productive and, accordingly, fast growing one in the early 20th century, by applying the poverty trap model in the previous section.

To answer the above question, the following sufficient condition that the previous analysis provides for poverty trap will be utilized. One specific sector's specific human capital, whose comparative advantage is strong in the world market, has been accumulated to a much higher level compared to the general human capital level.

To support our explanation of the British poverty trap, we will provide several quotes and data from Crafts (1985), supporting that the British economy had accumulated certain specific human capitals of traditional sectors (low θ^{i^*}) to such high levels that she had very strong comparative advantage in these sectors in the world market. This is the first element of poverty trap.

"Crafts and Thomas (1984) found that Britain's comparative advantage in goods in the use of human capital persisted through to the 1930s, and this may seem consistent with Harley and McCloskey's claim that Britain was right to stay heavily in the old industries before World War I. .... The results of Table 8.2 (Table 1 in this paper) confirm Harly and Mc Closkey's view that Britain had a very different comparative advantage from that of other advanced countries. In 1913 the 'old staples' dominate the rankings, whereas 'new' and technologically more prominent in the rankings for Germany, the United States and even France. .... Coal, iron and steel, cottons, and woolens were still the main exports, accounting for 51.0 percent in 1851 and 62.2 percent in 1873 (Michael and Deane (1962, p.305))."[6]

Table 1 Revealed Comparative Advantage in Manufacturing

	United Kingdom	Germany	United States	France
1913	Rail and Ship	Electricals	Non-ferrous Metals	Spirits/Tobacco
	Textiles	Cameras/Books	Agricultural Equipment	Motor Cars
	Iron and Steel	Leather/Wood	Industrial Equipment	Apparel
	Spirits/Tobacco	Industrial Equipment	Motor Cars	Cameras/Books
		Chemicals	Electricals	Finished Goods
		Metal Manufactures	Metal Manufacture	Leather/Wood
		Finished Goods	Leather/Wood	Textiles
		Iron and Steel	Rail and Ship	Chemicals
		Non-metal Materials	Iron and Steel	
		Apparel	Cameras/Books	
1937	Spirits/Tobacco	Metal Manufactures	Agricultural Equipment	Spirits/Tobacco
	Textiles	Finished Goods	Motors/Aircraft	Apparel
	Rail and Ship	Chemicals	Industrial Equipment	Textiles
	Finished Goods	Cameras/Books	Electricals	Iron and Steel
	Electricals	Non-metal Materials	Iron and Steel	Chemicals
		Rail and Ship	Non-ferrous Materials	Non-metal Materials
		Electricals	Cameras/Books	
		Industrial Equipment		

Source: Craft (1985b) based on data from Tyszynski (1951). Sectors are placed in rank order.

From the above quote and Table 1, we can easily infer that Britain had a distribution of human capitals around the end of 19th and the beginning of 20th century as in Graph 5.

Now, another essential element of the sufficient conditions for poverty trap, the existence of low level of general human capital accumulation, is well supported by the following quote.

"Nonetheless, arguments like this seem unlikely fully to answer the question as to why Britain failed to move to the higher growth path possible in the early twentieth century. There seem to be further feature of the economy which served to reduce its flexibility and underwrote the pattern of comparative advantage revealed in Cheaper 7 and Table 8.2 (Table 1 in this paper). Three points stand out: (1) Britain persistently had a relatively low rate of accumulation

6. pp.160-1, Crafts.

of human capital, and seems to have been exceptionally poor at producing scientists to work in industry. Although educational spending as a fraction of GDP rose, it fell further behind the United States and Germany such that in 1900, while Britain spent 1.3 percent of GDP on education, the U.S spent 1.7 percent, and Germany 1.9 percent."[7]

The above excerpt shares the same idea about education with this paper that it increases the flexibility for economy agents to move to the more productive sectors. The data from crafts also show poor accumulation of general human capital in Britain compared to general human capital in other countries, which is presented in Table 2. Finally, the following quote is consistent with the main idea of poverty trap mechanism of this paper.

"What we have seen in this chapter is that when a new range of problems and opportunities opened up in the years after 1890 the economy seemed to lack the flexibility easily to respond, and that the earlier experience of industrialization probably made the required adjustments more difficult."[8]

Table 2[9]

School Enrollment Ratio*	1870	1890	1910
European Norm	0.514	0.582	0.626
Britain	0.168	0.385	0.542

* The fraction of those aged 5-19 enrolled at primary or secondary school.
Source: Based on Chenery and Syrquin (1975, Table 3).

In a word, British overcommitment problem befits the previous Case 2 in Subsection 3.1 very well.

3.3. Resource Curse

We will analyze the resource curse hypothesis in the same way as in the previous subsection. We will check whether the two ingredients of poverty trap, high level of certain specific human capitals and low level of general human capital, exist in the problem of the slow growth of resource rich Latin American countries.

It is well known that Latin American countries, Argentina, Brazil, Mexico, and others, have been rich in primary resources, which does not need any supporting data. Anyway, this first element of poverty trap can be obviously verified by Table 3. Table 3 shows that, even until recently, Mexico and Brazil have been highly dependent on the primary sector in their export. This contrasts with Korea's and Taiwan case. Additionally, Table 4 shows the second element of the low level of general human capital of these countries.

7. pp.163-4, Crafts.
8. p.12 in Auty.
9. p.62-3, Crafts.

"The environmental factor is invoked by Mahon (1992) who argues that the reform of Latin American economies was blocked because the deployment of revenues from their primary products had initially been too successful in raising living standards and labor cost. He suggests that by the time the limits to the primary sector's capacity to generate foreign exchange became apparent, the cost of making the required switch to a competitive industrial policy (which he sees as necessarily based upon low-wage manufactured exports) were too high. ... Mahon's argument is a variant of the resource curse thesis which suggests that resource-rich countries may squander their resource advantage because an overly optimistic estimation of their prospects reads to the pursuit of lax economic policies. A corollary is that resource-poor countries, mindful of their marginal position, may compensate for their disadvantage by adopting firmer and more far-sighted policies."[10]

Table 3 Share of Total Export (%)

	Primary		Manufacturing	
Country	1960	1980	1960	1980
Korea	86	11	14	89
Taiwan	12	2	88	98
China	n.a.	51	n.a.	49
India	55	39	45	61
Mexico	88	61	12	39
Brazil	97	61	3	39

Source: Chenery *et al.* (1986), p.111 except Taiwan; Council for Economic Planning and Development.

Table 4 Secondary School Enrollment as a Share of Secondary School Age Population (ratios)[11]

	1971	1975	1980	1985	1990
Argentina	0.46	0.54	0.56	0.71	0.74
Bolivia	0.25	0.31	0.36	0.37	0.34
Brazil	0.17	0.26	0.34	0.36	0.40
Columbia	0.28	0.39	0.41	0.46	0.52
H.K	0.60	0.63	0.64	0.69	0.74
Korea	0.45	0.56	0.76	0.90	0.87
Mexico	0.24	0.34	0.46	0.53	0.53
Singapore	0.49	0.51	0.59	0.64	0.70
Taiwan	0.30	0.36	0.45	0.56	0.69
Uruguay	0.58	0.59	0.61	0.71	0.95
Venezuela	0.35	0.43	0.41	0.45	0.60

Source: David T. Coe, Elhanen Helpman, Alexander Hoffmaister, March, 1995.

10. p.12 in Auty.
11. p.41, Coe *et al.*

In our model, not only the resource factor but also education component is very important in explaining the resource curse hypothesis. Even though the resource curse hypothesis seems to be well explained by our model, we must be more cautious about our conclusion. It is because many relevant variables, such as exchange rate, the income and wealth distribution, the colonial experience and so forth, are not included. Therefore, as Auty warned us, our explanation of resource curse thesis may be a relatively robust, well-educated guess.

Here is the last quote revealing the first element of poverty trap very well.

"The inability of the emerging manufacturing sectors to earn foreign exchange. It maybe no coincidence that Mexico and Brazil, the best endowed of the six countries, were the last to embark on AIP reform. Both used their natural resources (oil in Mexico, minerals and hydro in Brazil) to delay reform further in the 1970's."[12]

IV. Conclusion

We can easily verify two common empirical features of British overcommitment and Latin American resource curse hypotheses: (1) overcommitment to the low productive, low technology intensive sector, including primary resource, and (2) low level of education of economic agents.

This paper attempts to provide a unifying and consistent perspective to these interesting phenomena, by incorporating these two common features above in a model. This paper constructs a multisectoral general equilibrium model with two kinds of human capital, general and specific human capital. In addition, we analyze the model and derive the characteristics consistent with the above features.

Combining empirical facts about the two empirical phenomena with theoretical implications of the model, we obtain the following results: Because Britain and Latin American countries had very strong primary sectors or traditional ones, which are less education demanding, they had not accumulated general human capital. Due to the lack of general human capital, they could not easily move to a more productive sector, neither could take export oriented industrialization policy.

The framework of this paper can also be applied to address the question of why many countries which had undergone colonial experiences show different paths of economic development. Especially, the contrast between two pairs, Britain-India and Korea-Japan experiences, can be possibly analyzed by our model. Japan had tried invest in education of the colonies, Taiwan and Korea, during the colonial period, for its own sake. Japan attempted to Japanize every one in the colonies. For this sake, Japan established many primary school institutions almost everywhere in the colonies. This aspect is quite different from the British policy toward India.

We should note that the British and Latin American countries are assumed to maximize their welfare, not growth in our model. However, if we introduce market failing features, such as an economy of scale or external learning by doing in the more productive modern

12. p.24 in Auty.

sectors, it can be welfare maximizing to maximize growth by helping move to the more productive sectors by government policy. This might be one of the next research topics.

Appendix A

Proof of Proposition 2

We must take three different cases into consideration one by one. At the steady state, it is easy to calculate the welfare function and its continuity with respect to general human capital. Just substitute the above solutions of u_{t+1} and $\{ h_t^g \}$ into the objective function, and check the continuity. In the second case of poverty trap, the welfare function itself is not a function of general human capital at all, thus is a continuous function in general human capital.

In the last case, where it takes time for economic agents to build up general human capital to reach the steady state, due to the relatively low level of the initial general human capital, agents invest positive amount of time in general human capital continuously. These three cases cover the whole cases.[13] It is because, if economic agents invest in general human capital today, then they will do tomorrow, thus, forever, and vice versa. The more general human capital they have with the given fixed distribution of specific human capitals today, there will be more incentive to build up general human capital in the future.

Now, let us prove the continuity of the welfare function with respect to general human capital in the third case. Due to the summability condition, the welfare function exists and is bounded everywhere.

Let us assume that the welfare function jumps at $h_0^{g'}$ as in Graph 1. We will prove that this jump does not exist. Take a sufficiently small ε and assume that the initial general human capital is $(1 \pm \varepsilon) h_0^g$, and that specific human capital's remain as given. Also assume that the investment path of general human capital of the economy with $(1 \pm \varepsilon) h_0^g$ is to be $\{ U_0^* \pm \varepsilon / B, u_1^*, u_2^*, \cdots u_n^* \}$, where u_t^* is the optimal investment path of the economy with h_0^g. Then these two economies will follow the same path of state variables $\{ h_t^g, h_t^1, h_t^2 \cdots h_t^n \}_{t=1}^{\infty}$ and, accordingly, optimal sequential decisions of consumption and investment except those at time 0. Therefore, the difference in the welfare of the above two economies, one with h_0^g and the other with $(1 \pm \varepsilon) h_0^g$, lies only in the difference of the initial period's momentary utilities.

Now, it is quite obvious that as ε converges to 0, the welfare function with $(1 \pm \varepsilon) h_0^g$ converges to that with h_0^g. Therefore, we prove the continuity of the welfare function in the third case, too. Moreover, noticing that the third case includes the first case, we can easily see that the continuity holds at the border line between the first and the third case. Continuity still holds at the border line between the second and the third case, which can be easily proved by the above ε-logic.///

13. With the specification $h_t^* = \max_i h_t = \max_i \{ \theta^i h_t^i \}$ for all i and t as in Kim and Kim (1997), the three cases cannot constitute the whole cases.

Appendix B

Sufficient Conditions for the Existence of Poverty Trap

Here, a sufficient condition for poverty trap in a closed economy is presented. The condition for an open economy is identical to the above one except one or two modifications of notations.

If we take the first order condition of the welfare function with resect to u_{t+1}, then we have, at the steady state,

$$\frac{w_t^i h_t^i u'(c_t^i)}{p_t^i} = \sum_{k=1}^{\infty} \frac{\beta^{t+k} u'(c_{t+k}^i)}{p_{t+k}^i} \sum_{j=1}^{n} \theta^j (w_{t+k}^j h_{t+k-1}^g l_{t+k}^j B). \tag{B1}$$

for $i = 1, 2, \cdots, n$.

To find sufficient conditions for poverty trap, Equation (B1) should be modified a little bit, because we are dealing with the equilibrium out of the steady state.

Assume that the inequality $h_N^{i^*} \leq \theta^{i^*} h_N^g$ holds *firstly* at time N and in the i^*-th sector. Then we have,

$$h_0^{i^*} \leq \theta^{i} h_0^{i^*} (1+B)^N \tag{B2}$$

$$\Rightarrow Z \equiv \log\left(\frac{h_0^{i^*}}{\theta^{i^*} h_0^g}\right) / \log(1+B) \leq N$$

Now, we have

$$LHS\ of\ (B1) = \sum_{k=1}^{\infty} \frac{\beta^k u'(c_{t+k}^i)}{p_{t+k}^i} \sum_{j=1}^{n} \theta^j (w_{t+k}^j h_{t+k-1}^g l_{t+k}^j B). \tag{B3}$$

Out of the steady state with positive investment in education, the RHS of (B1) should be modified as

$$\sum_{k=1}^{\infty} \frac{\beta^k u'(c_{t+k}^i)}{p_{t+k}^i} \sum_{j=1}^{n} \theta^j (w_{t+k}^j h_{t+k-1}^g l_{t+k}^j B), \text{ for } i = 1, 2, \cdots n, \tag{B4}$$

where $M \geq N$.

Now we have,

$$(B4) \leq nB \sum_{k=N}^{\infty} \beta^k \frac{\theta^{i'} h^{k}_{i+k-1} w^{i'}_{i+k} l^{i'}_{i+k}}{h^{i'}_{i+k} w^{i'}_{i+k} l^{i'}_{i+k}}, \tag{B5}$$

$$\leq Bn \sum_{k=N}^{\infty} \beta^k = \frac{Bn\beta^N}{1-\beta}$$

where $h^{i'}_{i+k} \geq \theta^{i'} h^{i}_{i+k-1}$ at $N-1$ for all i.

Therefore by (B2) and (B3), we have

$$\frac{Bn\beta^N}{1-\beta} \leq \frac{Bn\beta^z}{1-\beta}. \tag{B6}$$

Obviously, the sufficient condition for no investment in education is that the marginal benefit of investment of one unit of time is smaller than its marginal benefit. Thus this condition is,

$$n > \frac{Bn\beta^z}{1-\beta}, \text{ for all } l^{i}_{0} \in (0,1). \tag{B7}$$

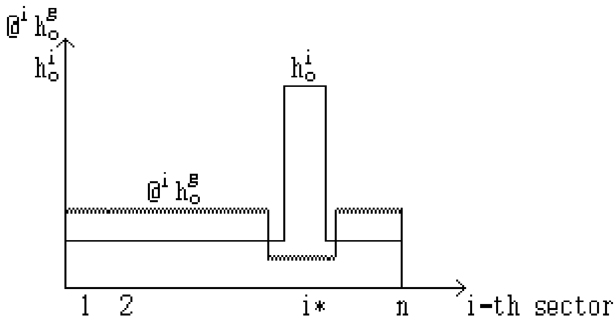
Now, we know that as $h^{i'}_0 \downarrow$, $Z \uparrow \infty$. Therefore, there exists a positive threshold ratio of $\frac{h^{i'}_0}{\theta^{i'} h^{i}_0}$ above which (B7) is satisfied with.

<Graph 1>

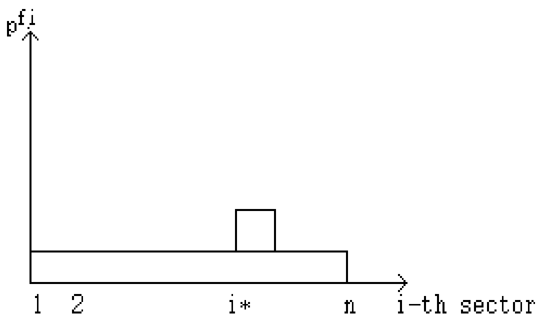
<Graph 2>

<Graph 3>

<Graph 4>



<Graph 5 >



<Graph 6>

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