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HUMAN CAPITAL DISTRIBUTION, GROWTH AND TRADE

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ABSTRACT

Distribution differences in human capital matter for a country's growth and trade. While the existing literature considers only the diversity difference in talent distribution, we argue that the kurtosis difference is also an important factor. In a two-sector equilibrium growth model, where the production function is supermodular for the consumption-good sector and submodular for the R&D sector, we prove that the diversity effect and kurtosis effect are opposite to each other. A country endowed with more diverse but leptokurtic talent distribution may have lower growth rate and import submodular goods, opposite to the conventional result from considering only the diversity difference.

Keywords: diversity, growth, kurtosis, trade

JEL classification numbers: F11, O41

I. INTRODUCTION

The impact of the diversity of human capital on the pattern of trade (POT) of an economy has in recent years received considerable attention. A large volume of international trade takes place between rich countries with similar technologies and endowments. In order to explain these observations,[1] in their pioneering work, Grossman and Maggi (2000) and Grossman (2004) have found that the distribution of human capital can matter for the POT, and prove that a country with less (more) diverse human capital will export the good produced by a supermodular (submodular) technology.[2] In addition, Bougheas and Riezman (2007) demonstrate that the POT of two countries with identical aggregate human capital endowments depends on not only the

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[1] The other theoretical studies, including Krugman (1979), Brander (1981) and Davis (1995), have accounted for these observations.

[2] Antrás and Rossi-Hansberg (2008) point out that Grossman and Maggi's (2000) model can be interpreted as the organizational design of the production process.

properties of the two human capital distributions but also the exact specification of preferences. In summary, the distribution of human capital plays a determinant role for the POT of an economy.

Growth theory typically holds that human capital can improve economic growth. There is a great deal of theoretical and empirical literature examining the impact of the level of human capital on economic growth, for example, Lucas (1988), Rebelo (1991), Mankiw *et al*. (1992), Barro (1991), Barro and Sala-i-Martin (1991, 1992) and Barro and Lee (1993). However, papers exploring the relationship between the diversity of human capital and growth are relatively few.[3] Whether an increase in diversity will enhance growth or not is an interesting and important issue. Bénabou (1996) and Takii and Tanaka (2009) prove that an increase in the diversity of human capital induced by heterogeneous ability may increase GDP. By adopting Grossman and Maggi's (2000) model in an endogenous growth scenario, Das (2005) shows that an increase in diversity is conducive to growth. In other words, the economic growth of a country with more diverse human capital is better than that of a country with less diverse human capital. While almost all the related literature proves a positive relationship between diversity and growth, it is unfortunately not consistent with the real world as addressed by Das (2005). A casual observation suggests that the economic performance of a country with more diverse human capital is not always the best among the developed countries. To explain the discrepancy between theoretical results and empirical observations, Das (2005) incorporates communication gaps among workers into the model to show that the growth rate may not be monotonically increasing in diversity. In addition, Lee (2009) proves that the deeper economic integration will lead to an increase in the diversity of talent, but may be detrimental to the advanced country's economic growth.

As a complement to the literature, this paper will provide an alternative explanation for the 'discrepancy' based upon the properties of the human capital distribution itself, including specifically not only the diversity but also the kurtosis. In other words, we will prove that the growth rate and POT will be affected not only by human capital's diversity but also by its kurtosis.

Intuitively, higher kurtosis indicates that more workers have ability around the mean level, implying that the economy has more comparative advantage in the supermodular sector, called the *kurtosis effect* hereafter. While the diversity is shown in the literature to be better for submodular goods than for supermodular goods (the *diversity effect*), the kurtosis effect is opposite. As a result, the conventional results for the relationship between diversity and POT/growth can hold only under certain conditions, especially when the effect of kurtosis difference is opposite to diversity.

We will prove that, in addition to diversity, the kurtosis also plays an important role in determining the POT and growth of an economy. Ignoring the kurtosis difference may lead to a misleading result. Therefore, we will consider a talent distribution difference with not only the diversity but also the kurtosis. With regard to the production side, we draw on the ideas of Grossman and Maggi (2000) and Das (2005), in which the assumption of heterogeneous human capital is introduced into an equilibrium growth model and consider the R&D sector producing new blueprints or ideas which provide the engine of growth, as in Romer (1990) and Jones (2005). In this paper, we suppose that the production technologies contain the supermodular and submodular technologies, as derived by Milgrom and Roberts (1990), Kremer (1993), Grossman and Maggi (2000) and Das (2005). The production process involves two tasks in each sector. The tasks are indivisible and each task is performed by exactly one worker. When the production technology is supermodular, a pair of workers performs complementary tasks. In contrast, when the production technology is submodular, the talent of the superior worker fully dominates the

[3] In the different contexts, Baumol (1990), Murphy *et al*. (1991) and Torvik (1993) explore the effects of the allocation of human capital on economic growth.

TABLE 1
Dispersion rates in literacy skills, persons aged 26–65, 1994–98

Prose			*Document*			*Quantitative*		
Country	*95th/5th**	*75th/25th***	*Country*	*95th/5th**	*75th/25th***	*Country*	*95th/5th**	*75th/25th***
CAN	2.72	1.31	CAN	3.09	1.32	CAN	2.65	1.33
AUS	2.71	1.30	CHE	2.97	1.28	AUS	2.64	1.30
USA	2.58	1.34	USA	2.90	1.36	USA	2.62	1.35
CHE	2.29	1.27	AUS	2.77	1.29	CHE	2.48	1.25
BEL	2.27	1.30	UK	2.55	1.36	IRL	2.45	1.38
UK	2.26	1.34	IRL	2.38	1.36	UK	2.44	1.37
IRL	2.24	1.33	BEL	2.16	1.28	BEL	2.35	1.32
FIN	1.78	1.24	FIN	1.95	1.27	FIN	1.82	1.23
SWE	1.75	1.23	NOR	1.80	1.23	SWE	1.77	1.23
DEU	1.74	1.24	SWE	1.77	1.24	NLD	1.76	1.21
NLD	1.72	1.22	NLD	1.74	1.22	NOR	1.72	1.21
NOR	1.65	1.19	DEU	1.72	1.22	DEU	1.67	1.21
DNK	1.55	1.19	DNK	1.69	1.23	DNK	1.65	1.20
Corr.	0.21	0.26	Corr.	0.15	−0.02	Corr.	0.26	0.07

Notes: Abbreviations of Countries: DNK, Denmark; DEU, Germany; IRL, Republic of Ireland; NOR, Norway; CHE, Switzerland; AUS Australia; BEL, Belgium; CAN, Canada; SWE, Sweden; FIN, Finland; NLD, the Netherlands; UK, United Kingdom.
*Literacy score ratio: 95th percentile/5th percentile.
**Literacy score ratio: 75th percentile/25th percentile.
Source: Benchmarking adult literacy in North America: an international comparative study (http://www.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=89–572-XIE&lang=eng).
Annual GDP average growth rates, UNCTAD Stat (http://unctadstat.unctad.org/TableViewer/tableView.aspx).

effective output, that is, the workers toil on substitutable tasks. Opposite to the conventional result, we find that a country endowed with a more diverse but leptokurtic talent distribution may have a lower growth rate and import submodular goods.

The rest of this paper is organized as follows. The detailed motivation with empirical observation on the relationship between the human capital distribution and economic growth is addressed in Section II. Section III establishes the equilibrium growth model with heterogeneous labour. Section IV considers the impact of the talent distribution difference on the POT and the equilibrium growth rate. Section V provides concluding remarks.

II. MOTIVATION

Some empirical observations will be addressed in this section. We observe that there is abundant evidence illustrating that countries differ not only in diversity but also in kurtosis of their distributions of human capital in the real world. Table 1 shows the dispersion rates of adult literacy for 13 countries on three different literacy scales over the years 1994–98, including prose, document and quantitative. For each country, two literacy score ratios, 95th/5th (representing the ratio of 95th percentile to 5th percentile) and 75th/25th (representing the ratio of 75th percentile to 25th percentile) on each literacy scale are reported.

By comparing the score ratios of 95th/5th and 75th/25th between any pair of countries, the distribution difference can be categorized into the following two types:

- Type 1: One of the countries has higher 95th/5th and higher 75th/25th than the other.
- Type 2: One of the pair of countries has higher 95th/5th but lower 75th/25th than the other.

Type 1 refers to the case of a country with more diverse human capital but with lower kurtosis than its pair country. From a statistical point of view, the cumulative distribution functions of two countries in the type cross just one time. Obviously, what the existing studies like Grossman and Maggi (2000), Grossman (2004) and Das (2005) have analysed is the Type 1 case, such as the USA vs. Germany (denoted as DEU in the table), in which the prose score of 95th/5th for the USA (2.58) is greater than that for DEU (1.74), and the 75th/25th score for the USA (1.34) is also greater than for DEU (1.24).

Type 2 represents the case of a country with not only more diverse human capital but also higher kurtosis than the other. Statistically, under this type the two cumulative distribution functions for the two countries will have at least three cross points. This type of distribution difference is seldom considered in the literature, despite the fact that many such cases can be found in the real world. In Table 1, the case of Canada vs. the USA illustrates this type. The prose score of 95th/5th for CAN (2.72) is greater than for the USA (2.58), and the 75th/25th score for CAN (1.31) is smaller than that for the USA (1.34).

Comparing the correlation between the 95th/5th score and growth rate, denoted as corr(95th/5th, g), and the correlation between 75th/25th score and the growth rate, corr(75th/25th, g), indirectly gives likely evidence on the opposite effect of the diversity and kurtosis on the growth rate. Reported in the last row of Table 1 is the correlation coefficient, which is computed based on the corresponding column's diversity score, designated as 95th/5th for the prose score in the 2nd column, and the corresponding average growth rate of the country, i.e., corr(95th/5th, g). Similarly, in the 3rd column, we have the corr(75th/25th, g) for the prose score. Clearly, we can observe that all the corr(95th/5th, g) are positive, that is, 0.21 for the prose score, 0.15 for the document and 0.26 for the quantitative. These results consistently support the conventional wisdom of positive diversity effect, that is, a country with a more diversified human capital distribution tends to have higher growth rate. On the other hand, we also find all the corr(75th/25th, g) for the three literacy scales, that is, 0.26 for the prose, −0.02 for document and 0.07 for quantitative. The positive results of corr(75th/25th, g) for the prose and quantitative scores, seems to indicate that high kurtosis of a country's human capital distribution is unfavourable to a country's growth, as we discussed earlier and would like to prove in the rest of the paper.

III. THE MODEL

Consider a small open economy with a fixed amount of workers, which for simplicity is normalized to one unit. Each worker is endowed with a fixed level of talent t which is assumed to be individual-specific, heterogeneous and perfectly observable to all the workers. To a certain degree, talent t can be understood as a worker's endowment and/or years of schooling. For simplicity, we assume further that the distribution of t is symmetric with mean $\bar{t}$ and probability density function $\phi(t)$ as below:

$$\phi(t) = \begin{cases} \dfrac{1}{2b}, & \text{if} \quad t \in \left[t_{\min}, \bar{t} - \dfrac{\varepsilon}{2}\right) \\ \dfrac{b+\varepsilon}{2b\varepsilon}, & \text{if} \quad t \in \left[\bar{t} - \dfrac{\varepsilon}{2}, \bar{t} + \dfrac{\varepsilon}{2}\right) \\ \dfrac{1}{2b}, & \text{if} \quad t \in \left[\bar{t} + \dfrac{\varepsilon}{2}, t_{\max}\right] \\ 0, & \text{otherwise,} \end{cases}$$

where $t_{\min} = \bar{t} - (b/2)$, $t_{\max} = \bar{t} + (b/2)$ and $0 < \varepsilon < b$. Clearly, $t_{\min}$ and $t_{\max}$ represent the minimum and maximum level of talent, respectively. Variable $b = t_{\max} - t_{\min}$ represents the spread of talent. The larger the variable b is, the more diverse the distribution of talent will be. Variable ε is to capture the kurtosis. A lower value of ε represents higher kurtosis, indicating more workers having talent around the mean.

There are two sectors in the economy, a consumption-good sector C and an R&D sector S. The production process for each sector involves two tasks, v and x. In addition, the production function is assumed to be supermodular in sector C and submodular in sector S. Supermodularity production indicates that the two tasks in C are complementary, and for simplicity we assume the complementarity is extreme, represented as $F_C(t_x, t_v) = \eta \min\{t_x, t_v\}$ in which task x is performed by a worker with talent t_x and task v by a worker with talent t_v, while η denotes the technology level for the economy generated by the R&D sector S. More specifically, sector S produces the new blueprints $\dot{\eta}$ (the time derivative of η), which accelerates technology improvement for producing the consumption-good C. The submodular production process in S sector implies that the two tasks are substitutable. Without losing generality we assume the substitution is extreme, and as in Romer (1990) and Das (2005), the level of existing technology or the stock of blueprints has a positive influence on the output of sector S. Mathematically, we let the production function of S be $F_S(t_x, t_v) = \eta \max\{t_x, t_v\}$.

By the properties of the supermodularity and submodularity, as proved by Kremer (1993) and Grossman and Maggi (2000), in equilibrium sector C employs workers with identical ability of t, so-called 'skill-clustering', and sector S attracts the most-talented and least-talented workers, i.e., 'cross-matching'. Accordingly, workers employed in C sector are those with t equal or closer to mean $\bar{t}$ than those working in sector S. Let $\hat{t}$ be the talent level of the least-talented workers in C sector. Obviously, $\hat{t} \leq \bar{t}$ and $m(\hat{t}) = 2\bar{t} - \hat{t}$ is the talent level of the most-talented workers in sector C. Corresponding to a given level of $\hat{t}$, the level of output for good C and good S (denoted by y_C and y_S, respectively) can be computed.

The results are derived under two cases: (i) $t_{\min} < \hat{t} < \bar{t} - \varepsilon/2$; and (ii) $\bar{t} - \varepsilon/2 \leq \hat{t} < \bar{t}$.

Case I: $t_{\min} < \hat{t} < \bar{t} - \varepsilon/2$

The level of output per capital of good C is

$$y_C = \int_{\hat{t}}^{m(\hat{t})} F_C(t, t)\phi(t)dt = \frac{\eta\bar{t}}{4b}(b + 2\bar{t} - 2\hat{t}) \tag{1}$$

As in Das (2005), we assume that the level of output per capital of good S must be equal to $\dot{\eta}$. Therefore, the level of output per capital of good S is

$$y_S = \dot{\eta} = \int_{t_{\min}}^{\hat{t}} F_S[t, m(t)]\phi(t)dt = \frac{\eta}{4b}\left(\frac{b}{2} - \bar{t} + \hat{t}\right)\left(\frac{b}{2} + 3\bar{t} - \hat{t}\right) \tag{2}$$

The production possibility frontier of Case I is strictly concave and its marginal rate of transformation (MRT^{I}) can be calculated as follows:

$$\text{MRT}^{\text{I}} = -\frac{\partial y_C}{\partial y_S} = -\frac{\partial y_C/\partial\hat{t}}{\partial y_S/\partial\hat{t}} = \frac{\bar{t}}{2\bar{t} - \hat{t}} \tag{3}$$

Equation (3) should be equal to the relative supply price of good S, say $1/p_{supply}$. That is,

$$\frac{1}{p_{supply}} = \frac{\bar{t}}{2\bar{t} - \hat{t}} \tag{4}$$

where p_{supply} represents the relative supply price of good C.

Following Das (2005), we assume that the government imposes an income tax and fully funds the new blueprints in a competitive market. Meanwhile, these new blueprints would be freely offered to the consumption-good sector. The tax proceeds equal $\tau[y_C + (1/p_{demand})y_S]$. Thus,

$\tau[y_C + (1/p_{demand})y_S] = (1/p_{demand})y_S$. Or,

$$\frac{1}{p_{demand}} = \frac{\tau}{(1-\tau)} \cdot \frac{y_C}{y_S} \tag{5}$$

where τ is the income tax rate. The variable p_{demand} is the relative demand price of good C and hence $1/p_{demand}$ represents the relative demand price of good S.

In the free-trade equilibrium, the world relative price of good C, p, is given and $p = p_{supply} = p_{demand}$. By substituting $p_{supply} = p$ into Equation (4), we obtain $\hat{t} = (2-p)\bar{t}$ (time-invariant) and then substituting $\hat{t} = (2-p)\bar{t}$ into Equations (1) and (2) can obtain the relative supply of good S (RS). Again, substituting $p_{demand} = p$ into Equation (5) can get the relative demand of good S (RD). Therefore, we have the export function of good S of Case I ($\Psi^{\mathrm{I}}(\cdot)$) as follows:

$$\Psi^{\mathrm{I}}(p, \tau, b, \bar{t}) \equiv RS - RD = \frac{[1 + (b/2\bar{t})]^2 - p^2}{2[p - 1 + (b/2\bar{t})]} - \frac{\tau p}{(1-\tau)} \tag{6}$$

By differentiating Equation (1) with respect to time, we can derive that the growth rate of consumption goods of Case I is $g^{\mathrm{I}} = \dot{\eta}/\eta$. Combining Equation (2) with $\hat{t} = (2-p)\bar{t}$ and eliminating $\hat{t}$ can find the growth rate of Case I as follows:

$$g^{\mathrm{I}} = \frac{\bar{t}^2}{4b}\left[\left(1 + \frac{b}{2\bar{t}}\right)^2 - p^2\right] \tag{7}$$

Substituting $\hat{t} = (2-p)\bar{t}$ into $t_{\min} < \hat{t} < \bar{t} - \varepsilon/2$ yields the range of p in Case I as follows:

$$1 + \frac{\varepsilon}{2\bar{t}} < p < 1 + \frac{b}{2\bar{t}} \tag{8}$$

Note that the kurtosis variable ε is an argument neither in the export function of Equation (6), nor in the growth function of Equation (7), indicating that the pattern of trade and growth rate are independent from the degree of kurtosis in this case. As will be shown later the conventional results of the diversity effect are duplicated in the case.

Case II: $\bar{t} - \varepsilon/2 \le \hat{t} < \bar{t}$

In Case II, by the same approach used in Case I, we can derive the corresponding y_C and y_S as below:

$$y_C = \int_{\hat{t}}^{m(\hat{t})} F_C(t, t)\phi(t)dt = \frac{\eta\bar{t}(b+\varepsilon)(\bar{t}-\hat{t})}{2b\varepsilon} \tag{9}$$

$$\begin{aligned} y_S = \dot{\eta} &= \int_{t_{\min}}^{\hat{t}} F_S[t, m(t)]\phi(t)dt \\ &= \frac{\eta}{4b}\left[(b-\varepsilon)\left(\bar{t} + \frac{b+\varepsilon}{4}\right) + \frac{(b+\varepsilon)}{\varepsilon}\left(\frac{\varepsilon}{2} - \bar{t} + \hat{t}\right)\left(\frac{\varepsilon}{2} + 3\bar{t} - \hat{t}\right)\right] \end{aligned} \tag{10}$$

Meanwhile, the export function of good S of Case II ($\Psi^{\mathrm{II}}(\cdot)$) can be obtained as follows:

$$\Psi^{\mathrm{II}}(p, \varepsilon, \tau, b, \bar{t}) = \frac{\Omega^2(b, \varepsilon, \bar{t}) - p^2}{2(p-1)} - \frac{\tau p}{(1-\tau)} \tag{11}$$

where

$$\Omega(b, \varepsilon, \bar{t}) = \left[1 + \frac{b\varepsilon(8\bar{t} + b + \varepsilon)}{4\bar{t}^2(b+\varepsilon)}\right]^{0.5}, \quad 1 + \frac{\varepsilon}{2\bar{t}} < \Omega(b, \varepsilon, \bar{t}) < 2$$

Similarly, the growth rate of Case II (g^{II}) can be derived as follows:

$$g^{\mathrm{II}} = \frac{(b+\varepsilon)\bar{t}^2}{4b\varepsilon}[\Omega^2(b, \varepsilon, \bar{t}) - p^2] \tag{12}$$

Finally, the corresponding range of p can also be derived as follows:

$$1 < p \leq 1 + \frac{\varepsilon}{2\bar{t}} \tag{13}$$

Clearly, the price in Case II is less than in Case I, as can be seen by comparing Equation (8) with Equation (13). In sum, at a given terms of trade, p, we can find a marginal worker with talent $\hat{t}$ and derive the corresponding export function and growth rate for each case.

IV. DIVERSITY, PATTERN OF TRADE AND GROWTH

Now we are ready to compare the POT and the growth rate between two small open countries, designated as home and foreign (denoted by an asterisk (*)), with different distributions of talent. To highlight that both the degree of diversity and kurtosis matter, we assume that the average talent level is the same in each country ($\bar{t}^* = \bar{t}$), but the talent distribution of the foreign country is not only more diverse but also more leptokurtic than that of the home country (i.e., $b^* = b + db$, $\varepsilon^* = \varepsilon + d\varepsilon$, and $db = -d\varepsilon > 0$).[4] Therefore, under a certain situation as will be considered in this paper, we will only discuss the impact of the variables b and ε on the POT and growth rate. Under this setup, comparing the POT and growth rate between home and foreign, is equivalent to conducting a comparative statics analysis of higher diversity accompanied with higher kurtosis on the equilibrium POT and growth rate for an economy.

Case I: $1 + \frac{\varepsilon}{2\bar{t}} < p < 1 + \frac{b}{2\bar{t}}$

Total differentiating Equation (6) by making use of $db = -d\varepsilon > 0$ yields

$$d\Psi^{\mathrm{I}} = \frac{\partial \Psi^{\mathrm{I}}}{\partial b}db + \frac{\partial \Psi^{\mathrm{I}}}{\partial \varepsilon}d\varepsilon = \frac{\partial \Psi^{\mathrm{I}}}{\partial b}db > 0 \tag{14}$$

in which $\partial\Psi^{\mathrm{I}}/\partial b = \{2(p-1)[1 + (b/2\bar{t})] + [p^2 - 1 + (b/4\bar{t}^2)]\}/\{4\bar{t}[p - 1 + (b/2\bar{t})]^2\} > 0$ and $\partial\Psi^{\mathrm{I}}/\partial\varepsilon = 0$. While $\partial\Psi^{\mathrm{I}}/\partial b > 0$ indicates a positive effect of diversity on the export of the R&D goods, S, as documented in the literature, the result of $\partial\Psi^{\mathrm{I}}/\partial\varepsilon = 0$ represents that there is no kurtosis in this case, which deserve a further explanation.

Intuitively, when the relative price of good C in the international market is high enough, a small open economy with more diverse and higher kurtosis (smaller ε) in its human capital distribution will be more likely to export more (or import less) of the submodular goods of S. There will be no kurtosis effect in this case, as denoted by $\partial\Psi^{\mathrm{I}}/\partial\varepsilon = 0$. This is because a sufficiently high relative price of goods C makes the sector large enough to employ a large number of workers with talent distributed around the mean talent level. In this situation, the property of enhancing the C sector due to high kurtosis has been developed to the extreme. Consequently, the marginal contribution of higher kurtosis on improving sector C becomes null.

Similarly, by totally differentiating the growth rate of Equation (7), we can derive

$$dg^{\mathrm{I}} = \frac{\partial g^{\mathrm{I}}}{\partial b}db + \frac{\partial g^{\mathrm{I}}}{\partial \varepsilon}d\varepsilon = \frac{\partial g^{\mathrm{I}}}{\partial b}db > 0 \tag{15}$$

[4] In terms of diversity, our assumptions are identical to Definition 1 of Grossman and Maggi (2000, p. 1264). While Grossman and Maggi allow the two cumulative distribution functions to cross only once, we permit these to cross three times, indicating that the distribution of human capital of the foreign country is more diverse and leptokurtic.

where $\partial g^{\mathrm{I}}/\partial b = \{\bar{t}^2[p^2 - 1 + (b/2\bar{t})^2]\}/4b^2 > 0$ and $\partial g^{\mathrm{I}}/\partial \varepsilon = 0$. That is, a rise in the talent diversity will stimulate the growth rate, as found in Das (2005). Again, there will be no kurtosis effect on the growth rate, for as elaborated in the POT effect, a marginal increase in kurtosis will have no effect on the production of goods C. However, the increase in diversity does increase the output of the R&D goods of S, which in turn will improve the growth rate.

In sum, when the relative price of good C is high enough, a country with a more diverse and leptokurtic talent distribution will have relatively higher output of the R&D good S, and thus have higher economic growth. Therefore, a conventional result of high diversity with high growth can be seen in Case I.

Case II: $1 < p \leq 1 + \dfrac{\varepsilon}{2\bar{t}}$

We now turn to Case II, in which the relative price of goods C to S in the world market is sufficiently low. By taking total differentiation of Equation (11) and making use of $db = -d\varepsilon > 0$, we have

$$d\Psi^{\mathrm{II}} = \frac{\partial \Psi^{\mathrm{II}}}{\partial b} db + \frac{\partial \Psi^{\mathrm{II}}}{\partial \varepsilon} d\varepsilon = \left(\frac{\partial \Psi^{\mathrm{II}}}{\partial b} - \frac{\partial \Psi^{\mathrm{II}}}{\partial \varepsilon}\right) db < 0 \tag{16}$$

in which $\partial \Psi^{\mathrm{II}}/\partial b = (\Omega\Omega_b)/(p-1) > 0$ represents the diversity effect on the excess supply of the R&D goods, and $-\partial \Psi^{\mathrm{II}}/\partial \varepsilon = -(\Omega\Omega_\varepsilon)/(p-1) < 0$ represents the kurtosis effect, where $\Omega_b = \partial \Omega(b, \varepsilon, \bar{t})/\partial b = \{\varepsilon[8\varepsilon\bar{t} + (b+\varepsilon)^2]\}/[8(b+\varepsilon)^2\bar{t}^2\Omega(b, \varepsilon, \bar{t})] > 0$ and $\Omega_\varepsilon = \partial \Omega(b, \varepsilon, \bar{t})/\partial \varepsilon = \{b[8b\bar{t} + (b+\varepsilon)^2]\}/[8(b+\varepsilon)^2\bar{t}^2\Omega(b, \varepsilon, \bar{t})] > 0$, and $\Omega_\varepsilon > \Omega_b$.

Although there is a positive diversity effect, the negative effect of higher kurtosis on the export of S-goods dominates the total effect. In other words, when the relative world price of the supermodular C-goods is sufficiently low, a small open economy with more diversified and more leptokurtic workers will produce less of the submodular S-goods. Intuitively, a small open economy facing a sufficiently low relative price of C, can only support a small scale of the supermodular C-industry, which in turn will hire a small portion of the workers distributed around the mean of talented workers. Therefore, the marginal effect of kurtosis change on the employment in C-sector will be large, i.e., a greater kurtosis effect on the expansion of the industry C.

Similarly, by total differentiation of Equation (12) and making use of $db = -d\varepsilon > 0$ yields

$$dg^{\mathrm{II}} = \frac{\partial g^{\mathrm{II}}}{\partial b} db + \frac{\partial g^{\mathrm{II}}}{\partial \varepsilon} d\varepsilon = \left(\frac{\partial g^{\mathrm{II}}}{\partial b} - \frac{\partial g^{\mathrm{II}}}{\partial \varepsilon}\right) db < 0 \tag{17}$$

where $\partial g^{\mathrm{II}}/\partial b = \{\bar{t}^2[p^2 - 1 + (b/2\bar{t})^2]\}/4b^2 > 0$ $\partial g^{\mathrm{II}}/\partial \varepsilon = \{\bar{t}^2[p^2 - 1 + (\varepsilon/2\bar{t})^2]\}/4\varepsilon^2 > 0$ and $\partial g^{\mathrm{II}}/\partial b < \partial g^{\mathrm{II}}/\partial \varepsilon$.

In Equation (17), $\partial g^{\mathrm{II}}/\partial b > 0$ denotes a positive effect of diversity on growth, while $-\partial g^{\mathrm{II}}/\partial \varepsilon < 0$ denotes a negative effect of kurtosis on growth, and the kurtosis effect is greater than the diversity effect as indicated by $\partial g^{\mathrm{II}}/\partial b < \partial g^{\mathrm{II}}/\partial \varepsilon$. In other words, Equation (17) shows that in the case of sufficiently low relative price of the supermodular goods, p, an economy with higher talent diversity accompanied with higher kurtosis of talent distribution is detrimental to economic growth. The intuition for this result is clear. As we have discussed earlier, in the case of low p, the marginal effect of an increase in kurtosis on the expansion of C-sector is large, and will dominate the diversity effect on the expansion of R&D S-sector. Thus the growth rate is lower for an economy with higher diversity and higher kurtosis of talent distribution.

Therefore, the results including Case I and Case II can be summarized as follows:

Proposition 1. When the relative price of good C is low (high) enough, a country with a more diverse and leptokurtic talent distribution will have relatively lower (higher) output *of the R&D good S, and thus be more likely to export good C (S) and import good S (C), which in turn will have lower (higher) economic growth in the free-trade equilibrium.*

V. CONCLUDING REMARKS

We set up an equilibrium growth model with heterogeneous labour to analyse the impact of the distribution difference in human capital on the POT and the equilibrium growth rate of an economy. Unlike the existing literature that considers the communication gaps among workers to explain that the growth rate may not be monotonically increasing with diversity, we provide an alternative explanation based upon the talent distribution itself. Namely, in a small open economy model, we elaborate that, in addition to the conventional diversity effect, the degree of kurtosis of the human capital distribution also plays an important role in determining the POT and economic growth of an economy. We prove that a country endowed with a more diverse but leptokurtic talent distribution may have a lower growth rate and import submodular goods, opposite to the conventional result from considering only the diversity difference.

Some policy implications can be drawn from our results. Without changing the talent distribution, the industrial policies beneficial to the submodular R&D sector can obviously improve the growth rate. However, the positive effect of education on the economic growth in the conventional belief may not be assured, depending on how the talent distribution is affected by the education policies. For countries with educational regimes more likely to enhance the kurtosis of human capital, the education may be detrimental to growth.

It should be worth noting here that the assumption of a small open economy is to simplify the analysis by fixing the terms of trade to highlight the role of kurtosis effect against the diversity effect. Releasing the assumption will make the terms of trade between the supermodular and submodular goods be endogenous, and complicate the analysis severely. Further extension study in this direction may be worthwhile.

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