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The Impact of Talent Distribution on Trade

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Abstract

In an equilibrium trade model, we prove that not only the diversity effect but also the kurtosis effect will affect the pattern of comparative advantage. Furthermore, we find that, against the conventional results, if the kurtosis effect dominates the diversity effect then a country with more (less) diversified talent may export the goods produced by supermodular (submodular) technology.

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1. Introduction

The relationship between the diversity of human capital and the pattern of trade (POT) of an economy has received considerable attention in recent years.[1] The existing studies including Grossman and Maggi (2000), Grossman (2004), Bougheas and Riezman (2007), and Ohnsorge and Trefler (2007) have proved that the diversity of human capital will affect the POT of an economy. They claim that a country with more (less) diverse human capital will export the goods produced by a submodular (supermodular) technology.[2] In other words, the existing studies argue that the diversity of human capital should play an important role in determining the POT.

In the real world, the evidence indicating that countries differ not only in diversity but also in kurtosis of their distributions of human capital can be observed. Table 1 reveals that the dispersion rates of adult literacy for three countries on three different literacy scales over the years 1994-1998, including prose, document and quantitative. For each country, we can compute two literacy score ratios, $95^{th}/5^{th}$ (referring to the ratio of 95^{th} percentile to 5^{th} percentile) and $75^{th}/25^{th}$ (representing the ratio of 75^{th} percentile to 25^{th} percentile) on each literacy scale.

Table 1: Dispersion Rates in Literacy Skills, Persons Aged 26-65

Prose			Document			Quantitative		
Country	$95^{th}/5^{th}$*	$75^{th}/25^{th}$**	Country	$95^{th}/5^{th}$*	$75^{th}/25^{th}$**	Country	$95^{th}/5^{th}$*	$75^{th}/25^{th}$**
CAN	2.72	1.31	CAN	3.09	1.32	CAN	2.65	1.33
USA	2.58	1.34	USA	2.90	1.36	USA	2.62	1.35
DEU	1.74	1.24	DEU	1.72	1.22	DEU	1.67	1.21

Notes: Abbreviations of Countries: CAN, Canada; DEU, Germany.

* Literacy Score Ratio: 95^{th} percentile/5^{th} percentile.

** Literacy Score Ratio: 75^{th} percentile/25^{th} 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).

Two different types of the talent distribution discrepancy can be obtained by

[1] This paper is concerned with what is called *diversity*, referring to the dispersion of skill, talent or human capital across workers in an economy, as discussed in Kremer (1993), Grossman and Maggi (2000), Grossman (2004), Das (2005), Bougheas and Riezman (2007), and Ohnsorge and Trefler (2007).

[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.

comparing the score ratios of $95^{th}/5^{th}$ and $75^{th}/25^{th}$ between any pair of countries. First, the case of the U.S.A. vs. Germany (denoted as DEU in the table), in which the prose score of $95^{th}/5^{th}$ for the U.S.A. (2.58) is greater than that for DEU (1.74), and the $75^{th}/25^{th}$ score for the U.S.A. (1.34) is also greater than for DEU (1.24), represents the situation of the U.S.A. with more diverse human capital but with lower kurtosis than Germany, which has been analyzed in the existing studies like Grossman and Maggi (2000), Grossman (2004), Bougheas and Riezman (2007), and Ohnsorge and Trefler (2007). They prove that a country like the United States with a more diverse population will export software produced by a submodular technology. In contrast, a country like Germany with a less diverse population will export passenger cars, industrial equipment and chemicals, produced by a supermodular technology.

Second, the case of Canada vs. the U.S.A. illustrates the other type of the talent distribution difference, in which the prose score of $95^{th}/5^{th}$ for CAN (2.72) is greater than for the U.S.A. (2.58), and the $75^{th}/25^{th}$ score for CAN (1.31) is smaller than that for the U.S.A. (1.34). The second type indicating that Canada is endowed with not only more diverse human capital but also higher kurtosis than the U.S.A. is seldom considered in the literature. However, some empirical studies address that the U.S.A. has comparative advantage in software industry and financial services produced by a submodular technology and that Canada has comparative advantage in the machine equipments, plastic products, and automotive products which are produced by a supermodular technology, for example, Solocha (1994), Head and Ries (2001), and Carter and Li (2004). That is to say, we observe that Canada with more diverse human capital exports the goods produced by a supermodular technology, while the U.S.A. with less diverse human capital exports the goods produced by a submodular. Obviously, the existing studies can’t explain the preceding observation.

To explain the preceding observation, we argue that, in addition to diversity, the kurtosis of human capital distribution should also be considered. The main reason can be stated as follows. Intuitively, higher kurtosis means that more workers have ability around the mean level of talent distribution, which will lead to an expansion in the supermodular sector, called the *kurtosis effect* hereafter. While the diversity is better for the submodular goods than for the supermodular goods (the *diversity effect*), which has been shown in the literature, the effect of kurtosis is opposite. As a result, the conventional impact of diversity on POT may be revised, especially when the effect of kurtosis is opposite to diversity.

As a complement to the literature, this paper will construct an equilibrium trade model incorporating the talent distribution differences not only in diversity but also in kurtosis to reexamine the impact of the talent distribution on the POT. Following

Milgrom and Roberts (1990), Kremer (1993), Grossman and Maggi (2000) and Grossman (2004), we suppose that the production technologies contain the supermodular and submodular technologies. Our main finding is that, in addition to diversity, the kurtosis also plays an important role in determining the POT of an economy. Unlike the existing results, we demonstrate that the country with a more (less) diverse talent distribution may export the goods produced by a technology with supermodularity (submodularity).

The rest of this paper is organized as follows. Section 2 establishes the equilibrium trade model with heterogeneous human capital. Section 3 considers the impact of the diversity in workers' talent on the POT. Section 4 provides concluding remarks.

2. The Model

There is a small open economy with fixed amount of workers (L). Each worker is endowed with a fixed level of talent t which is assumed to be heterogeneous and perfectly observable to all the workers. Hence, talent t can be viewed 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 shown below:

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

where

$$t_{\min} = \bar{t} - \frac{b}{2}, \;\; t_{\max} = \bar{t} + \frac{b}{2}, \text{ and } \;\; 0 < \varepsilon < b.$$

Clearly, $t_{\min}$ and $t_{\max}$ are the minimum and maximum level of talent respectively. Variable $b = t_{\max} - t_{\min}$ represents the spread of talent, indicating that the larger the variable b is, the more diverse the distribution of talent will be. Variable ε can capture the kurtosis. Lower ε represents higher kurtosis, indicating more of workers having ability around the mean.

There are two sectors in the economy, including the sector *C* and sector *S*. The production process for each sector involves two tasks, *x* and *v*. 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 complement. For simplicity we assume the complementarity is extreme, and hence the production function of sector *C* can be represented as $F_C(t_x, t_v) = \min\{t_x, t_v\}$ in which task *x* is performed by a worker with talent t_x and task *v* by a worker with talent t_v. On the other hand, submodular production process in *S* sector implies that the two tasks are substitute. Without losing generality, we assume the substitution is extreme, and mathematically, we let the production function of *S* be $F_S(t_x, t_v) = \max\{t_x, t_v\}$.

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", as proved by Kremer (1993) and Grossman and Maggi (2000). 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 least-talented worker in *C* sector. Obviously, $\hat{t} \le \bar{t}$ and $m(\hat{t}) = 2\bar{t} - \hat{t}$ be the most-talented worker 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) $\bar{t} - \varepsilon/2 \le \hat{t} < \bar{t}$.

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

The level of output of good *C* is

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

And, the level of output of good *S* is

$$Y_S = L\int_{t_{\min}}^{\hat{t}} F_S[t, m(t)]\phi(t)dt = \frac{L}{4b}(\frac{b}{2} - \bar{t} + \hat{t})(\frac{b}{2} + 3\bar{t} - \hat{t}). \tag{2}$$

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

$$\text{MRT}^{\text{I}} = -\frac{\partial Y_S}{\partial Y_C} = -\frac{\partial Y_S/\partial\hat{t}}{\partial Y_C/\partial\hat{t}} = 2 - \frac{\hat{t}}{\bar{t}}. \tag{3}$$

In the free-trade equilibrium, the world relative price of good *C*, *p*, is given. By making use of the equilibrium condition (p=MRT^{I}), we can find $\hat{t} = (2 - p)\bar{t}$ and then substituting $\hat{t} = (2-p)\bar{t}$ into equations (1) and (2) can obtain the equilibrium relative supply of good S of Case I ($RS^{\mathrm{I}}(\cdot)$) as follows:

$$RS^{\mathrm{I}}(p,b,\bar{t}) = \frac{[1+(b/2\bar{t})]^2 - p^2}{2[p-1+(b/2\bar{t})]}. \tag{4}$$

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

$$1+\frac{\varepsilon}{2\bar{t}} < p < 1+\frac{b}{2\bar{t}}. \tag{5}$$

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

In Case II, by using the analytical method of Case I, we can derive Y_C and Y_S of Case II as shown below:

$$Y_C = L\int_{\hat{t}}^{m(\hat{t})} F_C(t,t)\phi(t)dt = \frac{L\bar{t}(b+\varepsilon)(\bar{t}-\hat{t})}{2b\varepsilon}, \tag{6}$$

$$Y_S = L\int_{t_{\min}}^{\hat{t}} F_S[t,m(t)]\phi(t)dt = \frac{L}{4b}[(b-\varepsilon)(\bar{t}+\frac{b+\varepsilon}{4}) + \frac{(b+\varepsilon)}{\varepsilon}(\frac{\varepsilon}{2}-\bar{t}+\hat{t})(\frac{\varepsilon}{2}+3\bar{t}-\hat{t})]. \tag{7}$$

Meanwhile, the equilibrium relative supply of good S of Case II ($RS^{\mathrm{II}}(\cdot)$) can also be obtained as follows:

$$RS^{\mathrm{II}}(p,\varepsilon,b,\bar{t}) = \frac{\Omega^2(b,\varepsilon,\bar{t}) - p^2}{2(p-1)}, \tag{8}$$

where

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

Similarly, the extent of p in Case II can also be derived as follows:

$$1 < p \le 1+\frac{\varepsilon}{2\bar{t}}. \tag{9}$$

To proceed further, let us assume that the preference is homothetic, and thereby we can derive the equilibrium relative demand of good S, depending on the terms of trade (p). In summary, when the terms of trade is given, the small open economy can find the equilibrium relative supply and demand of good S, and then derive the POT.

3. Diversity and Pattern of Trade

In this section, we will describe the POT between two small open countries, said home and foreign (denoted by an asterisk (*)), each with different distribution of talent. Assume that preferences in the home and foreign countries are identical and homothetic. Suppose that the distribution of talent of foreign country is not only more diverse but also higher kurtosis than that of home country (i.e., $b^* = b + db$, $\varepsilon^* = \varepsilon + d\varepsilon$, and $db = -d\varepsilon > 0$) and the average talent level is the same in each country ($\bar{t}^* = \bar{t}$). Next, we will explore the impact of both diversity and kurtosis on the POT of an economy.

In Case I, taking the total differentiation of the equation (4) can obtain:

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

$$dRS^{\mathrm{I}} = \frac{\partial RS^{\mathrm{I}}}{\partial b} db + \frac{\partial RS^{\mathrm{I}}}{\partial \varepsilon} d\varepsilon$$

$$= \frac{\partial RS^{\mathrm{I}}}{\partial b} db > 0 .^{3} \tag{10}$$

Equation (10) shows that the relationship between the diversity of talent and the equilibrium relative supply of good *S* is positive, as proved in Grossman and Maggi (2000). As expressed in the first line in Equation (10), we find that the POT of a small open economy will be affected through two channels. The first is “the diversity effect”, whereby a rise in the diversity of human capital will lead to more aggregate talent allocated to the sector *S*, and thereby increases the output of sector *S*, which in turn will add the export of *S*. The second is “the kurtosis effect”, whereby higher kurtosis indicates more of workers having ability around the mean level, and hence increases the output of sector *C*, which in turn will reduce the export of *S*. It is obvious that the diversity effect dominates the kurtosis effect in Case I. In summary, the net effect which depends on these two channels is positive. Namely, when the diversity effect dominates the kurtosis effect, a country with more diverse and leptokurtic talent distribution will have relatively higher output of the good *S*, and thus have more comparative advantage in good *S*. That is, a conventional result of high diversity with high export of *S* can be seen in Case I.

Similarly, in Case II, by taking the total differentiation of the equation (8), we can obtain:

[3] We have $\partial RS^{\mathrm{I}} / \partial b = \{2(p-1)[1+(b/2\bar{t})] + [p^2 - 1 + (b/4\bar{t}^2)]\} / \{4\bar{t}[p-1+(b/2\bar{t})]^2\} > 0$ and $\partial RS^{\mathrm{I}} / \partial \varepsilon = 0$.

Case II: If $1 < p \le 1 + \dfrac{\varepsilon}{2\bar{t}}$, then

$$dRS^{\mathrm{II}} = \frac{\partial RS^{\mathrm{II}}}{\partial b} db + \frac{\partial RS^{\mathrm{II}}}{\partial \varepsilon} d\varepsilon$$

$$= \left(\frac{\partial RS^{\mathrm{II}}}{\partial b} - \frac{\partial RS^{\mathrm{II}}}{\partial \varepsilon}\right) db < 0 .^{4} \tag{11}$$

Equation (11) demonstrates a negative link between the diversity of talent and the export of good *S*. As mentioned above, the first line in Equation (11) reveals that the POT of a small open economy will be affected through two channels. The first is “the diversity effect”, and the second is “the kurtosis effect”. Obviously, the kurtosis effect dominates the diversity effect in Case II. Hence, the net effect which depends on these two channels is negative. Namely, when the kurtosis effect dominates the diversity effect, a country with more diverse and leptokurtic talent distribution will have relatively lower output of the good *S*, and thus lower export of *S*. That is, the conventional result for the relationship between diversity and POT will reverse in Case II. Therefore, the results including Case I and Case II will be summarized as below:

Proposition 1. *When the diversity effect dominates the kurtosis effect, a country with more diverse and leptokurtic talent distribution will have relatively higher output of the good S, and thus export good S and import good C in the free-trade equilibrium. On the contrary, when the kurtosis effect dominates the diversity effect, a country with more diverse and leptokurtic talent distribution will have relatively lower output of the good S, and thus export good C and import good S in the free-trade equilibrium.*

4. Concluding Remarks

In an equilibrium trade model, this paper explores the impact of the talent distribution on the POT of an economy. Grossman and Maggi (2000) stress the effects of the diversity on trade. We claim that not only the diversity but also the kurtosis of talent distribution can matter for the POT. We also demonstrate that, in the free-trade equilibrium, if the kurtosis effect dominates the diversity effect then the country with a more (less) diverse distribution of talent may export the goods produced by a technology with supermodularity (submodularity), a result being different from Grossman and Maggi (2000).

[4] We have $\partial RS^{\mathrm{II}} / \partial b = (\Omega\Omega_b)/(p-1) > 0$ and $\partial RS^{\mathrm{II}} / \partial \varepsilon = (\Omega\Omega_\varepsilon)/(p-1) > 0$, where $\Omega_b = \partial\Omega(b,\varepsilon,\bar{t})/\partial b = \{\varepsilon[8\varepsilon\bar{t} + (b+\varepsilon)^2]\}/[8(b+\varepsilon)^2 \bar{t}^2 \Omega(b,\varepsilon,\bar{t})] > 0$, $\Omega_\varepsilon = \partial\Omega(b,\varepsilon,\bar{t})/\partial\varepsilon = \{b[8b\bar{t} + (b+\varepsilon)^2]\}/[8(b+\varepsilon)^2 \bar{t}^2 \Omega(b,\varepsilon,\bar{t})] > 0$, and $\Omega_\varepsilon > \Omega_b$.

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