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Kunieda, Takuma

Nishimura, Kazuo

Shibata, Akihisa

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Specializations, Financial Constraints, and Income Distribution

Takuma Kunieda*
School of Economics, Kwansei Gakuin University

Kazuo Nishimura†
Kobe University, RIEB

Akihisa Shibata‡
Institute of Economic Research, Kyoto University

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Abstract

We investigate how financial frictions affect across- and within-country income distributions by using a three-country dynamic general equilibrium model. In our model, the first and second countries specialize in producing (country-specific) intermediate goods and face financial constraints. The third country produces the final goods by using its own labor and intermediate goods purchased from the first and second countries. The financial markets of these countries are perfectly separated from each other, and the interest rates differ across countries. Our finding is that if the elasticity of substitution between the two intermediate goods is sufficiently high, the relaxation of financial constraints in the first (second) country decreases the second (first) country's income, whereas if the elasticity of substitution is sufficiently low, the relaxation of financial constraints in the first (second) country increases the second (first) country's income. We also find that the income inequality across the three countries is widened by the further relaxation of financial constraints in the country with higher financial development, regardless of the ranking of the per capita income between the first and second countries. Furthermore, the income inequality within the first or second country is reduced as the financial constraints in that country are relaxed.

*School of Economics, Kwansei Gakuin University, 1-155 Uegahara Ichiban-Cho, Nishinomiya, Hyogo, 662-8501, JAPAN, Phone: +81 798 54 6482, Fax: +81 798 51 0944, E-mail: tkunieda@kwansei.ac.jp

†Corresponding author: Kazuo Nishimura. Research Institute for Economics and Business Administration, Kobe University, 2-1 Rokkodaicho, Nadaku, Kobe, 657-8501, JAPAN, Phone&Fax: +81 78 803 7005, E-mail: nishimura@rieb.kobe-u.ac.jp

‡Institute of Economic Research, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan, Phone: +81-75-753-7126, Fax: +81-75-753-7158, E-mail: shibata@kier.kyoto-u.ac.jp

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1 Introduction

The progress of globalization causes drastic changes in the industrial structures of many countries. The production process has been internationally specialized in different stages across countries, and global value chains have organized international production worldwide. Firms often outsource the production stages to different countries. In such a situation, the terms of trade, which affect the allotment of final goods as income, are subject to the production environments in the outsourced countries. In this paper, we investigate how the interaction of international trade and financial development (which is one of the key determinants of the production environments) impacts across- and within-country income distributions by applying a multi-country dynamic general equilibrium model.

There are many earlier works on trade and across- and within-country income distributions. Matsuyama (1996, 2004, 2013) demonstrated that when there are financial market imperfections or increasing returns to scale, international trade always divides ex ante symmetric countries into the rich and the poor. Manasse and Turrini (2001), Yeaple (2005), Sampson (2014), Blanchard and Willmann (2016), Helpman et al. (2016), and Furusawa and Konishi (2016) investigated the effects of international trade on within-country income inequality. In contrast to these studies, our focus is on the effect of financial constraints on across- and within-country income distributions that result from international trade.[1]

In our model, there are three countries. The first and second countries specialize in producing (country-specific) intermediate goods that are exported to the third country. Both intermediate goods are produced from capital with a linear technology. The third country produces the final goods by using its own labor force and the intermediate goods purchased from the first and second countries. The first and second countries import the final goods from the third country by selling all their products to the third country.

[1]In the literature of finance and trade, many researchers study how financial constraints affect trade patterns and production specializations. See, among others, Antrás and Caballero (2009), Ju and Wei (2011), and Manova (2013). Moreover, several authors analyzed the effect of income distribution on production and trade structure. See, for example, Fajgelbaumet al. (2012) and McCalman (2018).

The production function for the final goods in the third country is of the CES (Constant Elasticity of Substitution) type. The elasticity of substitution between the two intermediate goods is the key factor in determining the allotment of the final goods. In each period, agents in the first and second countries (who are potential entrepreneurs) receive idiosyncratic productivity shocks. Agents who draw lower productivity shocks become lenders, and agents who draw higher productivity shocks become capital producers (borrowers): Lenders and borrowers are endogenously determined in equilibrium. The financial markets in the three countries are segmented from each other and each market clears within each country. Agents in the first and second countries face financial constraints. Because of the financial constraints, agents in the first and second countries can borrow only up to a certain proportion of their own funds, and this proportion can be regarded as the degree of financial development, as in Aghion and Banerjee (2005) and Aghion et al. (2005). If the financial constraints are relaxed in a country, more production resources are intensively used by higher-productivity capital producers, and the aggregate productivity in that country rises. In this model setting, we investigate how the final goods are distributed across the three countries.

Our findings are as follows. Consider the first and second countries. If the elasticity of substitution between the two intermediate goods is sufficiently high, the relaxation of financial constraints in the home country harms the opponent country. In contrast, if the elasticity of substitution is sufficiently low, the relaxation of financial constraints in the home country benefits the opponent country. Across-country income inequality is widened by the further relaxation of financial constraints in a country where the financial sector is more developed than in the opponent country, regardless of the ranking of per capita income. Lastly, the within-country income inequality is reduced as the financial sector is well developed.

The rest of the paper is organized as follows. In the next section, a three-country model is presented in which the first and second countries produce intermediate goods and the third country produces final goods. In section 3, we derive the equilibrium. In section 4, we obtain each country's total income and income share in the steady state and study income distribution by performing comparative statics for per capita income and income shares. Section 5 provides concluding remarks.

2 Model

There are three countries in the world: country 1, country 2, and country 3. The final goods are produced in country 3 by using labor and intermediate goods that are imported from countries 1 and 2. The intermediate goods indexed by j are produced in country j ($j = 1, 2$) and sold to a representative firm in country 3.

The population in country j ($j = 1, 2$) is normalized to one. Agents in country 1 and 2 receive idiosyncratic productivity shocks in each period. They are subject to financial constraints, and thus, they can borrow resources only up to some proportion of their own funds in the financial market. The population of agents (who are homogeneous workers) in country 3 is equal to L. Each worker inelastically supplies a unit of labor to the representative firm in each period. The financial markets in the three countries are segmented from each other, each of which clears within each country.

2.1 Production

The production function for the final goods in country 3 is given by

$$Y_t = \left[(Y_t^1)^\gamma + (Y_t^2)^\gamma\right]^{\frac{\alpha}{\gamma}} L_t^{1-\alpha}, \quad 0 < \alpha < 1, \quad \gamma < 1, \tag{1}$$

where Y_t is the final goods produced in period t, Y_t^j is the intermediate goods produced in country j, and L_t is the labor in country 3, which is equal to a constant population L in equilibrium. Note that γ is related to the elasticity of substitution between the two intermediate goods, which is given by $1/(1-\gamma)$. As γ increases, the elasticity of substitution also increases.

The profit maximization problem of the representative firm in country 3 is expressed as in the following:

$$\max_{Y_t^1, Y_t^2, L_t} \Pi_t := \left[(Y_t^1)^\gamma + (Y_t^2)^\gamma\right]^{\frac{\alpha}{\gamma}} L_t^{1-\alpha} - p_t^1 Y_t^1 - p_t^2 Y_t^2 - w_t L_t, \tag{2}$$

where the numeraire is the final goods, p_t^j is the price of the intermediate goods, and w_t is a wage rate. The first-order conditions for the maximization problem are obtained as follows:

$$w_t = (1-\alpha)\left(\frac{Y_t}{L_t}\right), \tag{3}$$

$$p_t^1 = \frac{\alpha (Y_t^1)^\gamma}{(Y_t^1)^\gamma + (Y_t^2)^\gamma}\left(\frac{Y_t}{Y_t^1}\right), \tag{4}$$

and

$$p_t^2 = \frac{\alpha (Y_t^2)^\gamma}{(Y_t^1)^\gamma + (Y_t^2)^\gamma}\left(\frac{Y_t}{Y_t^2}\right). \tag{5}$$

2.2 Agents in country j ($j = 1, 2$)

2.2.1 Timing of events

Consider the timing of the events that agent $i \in \Omega^j$ in country j experiences in period t, where Ω^j is the whole set of agents in country j. At the beginning of period t, i) each agent earns an income from her savings, ii) the consumption market in period t is opened, iii) she decides how much to consume and save in this period, and iv) the consumption market is closed.

At the end of period t, i) an idiosyncratic productivity shock $\Phi_t^j(i)$ is realized; this shock is associated with the production of the intermediate goods in period $t+1$. ii) Upon knowing $\Phi_t^j(i)$, agent i makes a decision about the portfolio allocation of her savings (i.e., whether to invest in a project for intermediate goods production or lend her funds in the financial market).

Productivity $\Phi_t^j(i)$ is a random variable. No one can insure against low productivity because no insurance market exists for the productivity shocks. $\Phi_t^j(i)$ is independent and identically distributed across agents, time, and countries (the i.i.d. assumption). The cumulative distribution function of $\Phi_t^j(i)$ is given by $G(\Phi)$, which is time-invariant and common across countries 1 and 2. The support of the distribution is a closed interval $[d, \eta]$, where $d, \eta \in \mathcal{R}_+$, and thus, $G'(\Phi)$ is well defined over the support.

2.2.2 Utility maximization

Agent i in country j in period t solves the following utility maximization problem:

$$\max E_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \ln c_\tau^j(i) \right]$$

subject to

$$c_\tau^j(i) + s_\tau^j(i) = p_\tau^j \Phi_{\tau-1}^j(i) k_{\tau-1}^j(i) + (1 + r_\tau^j(i)) b_{\tau-1}^j(i) \tag{6}$$

$$b_\tau^j(i) \geq -\lambda^j s_\tau^j(i) \tag{7}$$

$$k_\tau^j(i) \geq 0, \tag{8}$$

for $\tau \geq t$, where $\beta \in (0,1)$ is a subjective discount factor, $c_\tau^j(i)$ is consumption, $r_\tau^j(i)$ is the (net) interest rate, and $E_t[.]$ is an expectation operator given the information in period t. In Eq. (6), $s_\tau^j(i) := b_\tau^j(i) + k_\tau^j(i)$ is agent i's savings in period τ, where $b_\tau^j(i)$ is borrowing if $b_\tau^j(i) < 0$ and lending if $b_\tau^j(i) > 0$, and $k_\tau^j(i)$ is capital used for intermediate goods production, which depreciates entirely in one period. A linear technology is available to produce intermediate goods: $\Phi_{\tau-1}^j(i) k_{\tau-1}^j(i)$ is the intermediate goods produced by agent i. Eq. (6) is a flow budget constraint that is effective for $\tau \geq 1$ and the flow budget constraint in period 0 is $c_0^j + s_0^j = p_0^j Y_0^j$, where Y_0^j is the initial intermediate goods that agents in country j are commonly endowed with. Inequality (7) is the financial constraint.[2] Agents can borrow in the financial market in their home country only up to a partial proportion of their own funds. The extent of financial constraints is measured by $\lambda^j \in (0, \infty)$ with smaller values implying a more severe financial constraint. One can consider λ^j as the degree of financial development in country j, as in

[2]Many researchers such as Aghion et al. (1999), Aghion and Banerjee (2005), and Aghion et al. (2005) employ this type of financial constraint.

Aghion and Banerjee (2005) and Aghion et al. (2005). Inequality (7) can be rewritten as $b_\tau^j(i) \geq -\mu^j k_\tau^j(i)$, where $\mu^j = \lambda^j/(1+\lambda^j) \in (0,1)$. Capital, $k_\tau^j(i)$, should be nonnegative, and thus, we impose inequality (8). Without the loss of generality in the analysis, we assume that the financial constraint in country 1 is more relaxed than that in country 2.

Assumption 1. $\mu^1 > \mu^2$.

We define $\phi_t^j := (1+r_{t+1}^j)/p_{t+1}^j$. Then, we obtain the following portfolio program for investment, borrowing, and lending.

$$k_t^j(i) = \begin{cases} 0 & \text{if } \Phi_t \leq \phi_t^j \\ \frac{s_t^j(i)}{1-\mu^j} & \text{if } \Phi_t > \phi_t^j, \end{cases} \tag{9}$$

and

$$b_t^j(i) = \begin{cases} s_t^j(i) & \text{if } \Phi_t \leq \phi_t^j \\ -\frac{\mu^j}{1-\mu^j} s_t^j(i) & \text{if } \Phi_t > \phi_t^j. \end{cases} \tag{10}$$

The portfolio program given by Eqs. (9) and (10) rewrites the flow budget constraint (6) as

$$c_\tau^j(i) + s_\tau^j(i) = R_\tau^j(i) s_{\tau-1}^j(i), \tag{11}$$

where $R_\tau^j(i) := \max\{1+r_\tau^j, [p_\tau^j \Phi_{\tau-1}^j(i) - (1+r_\tau^j)\mu^j]/(1-\mu^j)\}$. The maximization of the agent's lifetime utility subject to Eq. (11) yields the Euler equation as follows:

$$\frac{1}{c_t^j(i)} = \beta E_t \left[\frac{R_{t+1}^j(i)}{c_{t+1}^j(i)} \right]. \tag{12}$$

The necessary and sufficient optimality conditions for the lifetime utility maximization problem consist of the Euler equation (12) and the transversality condition given by $\lim_{\tau\to\infty} \beta^\tau E_t[s_{t+\tau}^j(i)/c_{t+\tau}^j(i)] = 0$.

Lemma 1. *The law of motion of agent i's savings is given by*

$$s_t^j(i) = \beta R_t^j(i) s_{t-1}^j(i). \tag{13}$$

Proof. See the Appendix.

2.3 Agents in country 3

A representative agent in country 3 solves a maximization problem for her lifetime utility given in the following:

$$\max \sum_{\tau=t}^{\infty} \beta^{\tau-t} \ln c_{\tau}^{3}$$

subject to

$$c_{\tau}^{3} + b_{\tau}^{3} = (1 + r_{\tau}^{3}) b_{\tau-1}^{3} + w_{\tau} \tag{14}$$

for $\tau \geq t$, where c_{τ}^{3} is consumption, r_{τ}^{3} is the interest rate and b_{τ}^{3} is an asset that the agent holds. The Euler equation of this maximization problem is given by

$$\frac{1}{c_{t}^{3}} = \beta(1 + r_{t+1}^{3}) \frac{1}{c_{t+1}^{3}}. \tag{15}$$

The necessary and sufficient optimality conditions for the lifetime utility maximization problem consist of the Euler equation (15) and the transversality condition given by $\lim_{\tau \to \infty} \beta^{\tau} b_{t+\tau}/c_{t+\tau}^{3} = 0$.

3 Equilibrium

A competitive equilibrium is expressed by sequences of prices: $\{w_t, p_t^1, p_t^2, r_{t+1}^1, r_{t+1}^2, r_{t+1}^3\}$ for all $t \geq 0$ and allocation: $\{Y_t^1, Y_t^2, L_t\}$ for all $t \geq 0$ and $\{c_t^1(i), c_t^2(i), c_t^3, s_t^1(i), s_t^2(i), k_t^1(i), k_t^2(i), b_t^1(i), b_t^2(i), b_t^3\}$ for all $t \geq 0$ and $i \in \Omega^j$ $(j = 1, 2)$, so that (i) consumers in all countries maximize their lifetime utility; (ii) the representative firm in country 3 maximizes its profits in each period; and (iii) the final and intermediate goods markets, the financial markets in country 1 and 2, and the labor market in country 3 clear.

3.1 Market clearing conditions

3.1.1 Counties 1 and 2

Intermediate goods are produced by high-productivity agents in countries 1 and 2 who draw productivity such that $\Phi_t^j(i) > \phi_t$. Then, the market clearing condition for intermediate goods is given by

$$Y_{t+1}^j = \int_{i \in \Omega^j \setminus E_t^j} \Phi_t^j(i) k_t^j(i) di, \tag{16}$$

where $E_t^j = \{i \in \Omega^j | \Phi_t(i)^j \leq \phi_t^j\}$. All lending and borrowing are canceled out within country j ($j = 1, 2$). Thus, the financial market clearing condition is given by

$$\int_{i \in \Omega^j} b_t^j(i) di = 0. \tag{17}$$

Each agent in country j becomes a lender with probability $G(\phi_t^j)$ and becomes a borrower with probability $1 - G(\phi_t^j)$. Therefore, in period t, the population of lenders is $G(\phi_t)$ and that of borrowers is $1 - G(\phi_t^j)$ in country j. Eqs. (10) and (17) and the i.i.d. assumption for productivity shocks yield

$$G(\phi_t^j) \times S_t^j = \frac{\mu^j (1 - G(\phi_t^j))}{1 - \mu^j} \times S_t^j. \tag{18}$$

or equivalently,

$$G(\phi_t^j) = \mu^j, \tag{19}$$

where $S_t^j := \int_{i \in \Omega^j} s_t^j(i) di$. Note from Eq. (19) that the cutoff ϕ_t^j is determined by the extent of financial constraints, μ^j. Eq. (19) defines the cutoff in equilibrium as $\phi^{j*} := G^{-1}(\mu^j)$.

3.1.2 Country 3

Because the population of workers in country 3 is L, the labor-market clearing condition in country 3 is given by

$$L_t = L. \tag{20}$$

In country 3, all agents are homogeneous and the aggregate assets are equal to zero. Then, it holds that $b_t^3 = 0$ for all $t \geq 0$. From Eq. (14), we have the final-good market clearing condition,$c_t^3 = w_t$, in country 3. Then, it follows from Eq. (15) that

$$\frac{1}{w_t} = \beta(1 + r_{t+1}^3)\frac{1}{w_{t+1}}. \tag{21}$$

Substituting Eq. (3) into Eq. (21) yields the equilibrium interest rate in country 3 as follows:

$$r_{t+1}^3 = \frac{Y_{t+1}}{\beta Y_t} - 1. \tag{22}$$

3.2 Aggregation

In this section, the aggregate variables are derived. The i.i.d. assumption with regard to the productivity shocks simplifies the aggregation of variables.[3]

Lemma 2. *The aggregate income and the aggregate savings in country j ($j = 1, 2$) are given by*

$$I_t^j := p_t^j Y_t^j = \int_{i \in \Omega^j} R_t^j(i) s_{t-1}^j(i) di \tag{23}$$

and

$$S_t^j = \beta p_t^j Y_t^j, \tag{24}$$

respectively.

Proof. See the Appendix.

From Eq. (9), an agent in country j who draws a productivity greater than ϕ^{j*} produces intermediate goods. Then, from Eq. (9) and the i.i.d. assumption with respect

[3]We followed Kunieda and Shibata (2016) in aggregating variables.

to productivity shocks, we can compute the total intermediate goods as follows:

$$Y_{t+1}^{j} = \frac{H(\phi^{j*})}{1-\mu^{j}} S_{t}^{j}, \tag{25}$$

where $H(\phi^{j*}) = \int_{\phi^{j*}}^{\eta} \Phi^{j} dG(\Phi^{j})$. Eqs. (1), (4), (5), and (24) transform Eq. (25) into

$$Y_{t+1}^{1} = \alpha\beta M^{1} L^{1-\alpha} \left[(Y_{t}^{1})^{\gamma} + (Y_{t}^{2})^{\gamma}\right]^{\frac{\alpha}{\gamma}-1} (Y_{t}^{1})^{\gamma} \tag{26}$$

and

$$Y_{t+1}^{2} = \alpha\beta M^{2} L^{1-\alpha} \left[(Y_{t}^{1})^{\gamma} + (Y_{t}^{2})^{\gamma}\right]^{\frac{\alpha}{\gamma}-1} (Y_{t}^{2})^{\gamma}, \tag{27}$$

where $M^{j} := H(\phi^{j*})/(1-\mu^{j})$. A useful lemma is obtained in the following.

Lemma 3. *$\partial M^{j}/\partial \mu^{j} > 0$ for $j = 1, 2$.*

Proof. See the Appendix.

As seen in Eq. (25), M^{j} is the aggregate productivity in country j. Lemma 3 implies that as the financial constraint in country j is relaxed, the aggregate productivity in country j increases because production resources are used intensively by high-productivity agents as the financial constraint is relaxed.

4 Steady state and income distribution

In this section, we investigate how the relaxation of financial constraints in countries 1 and 2 affect the income distribution between the three countries in the steady state.

4.1 Steady state

From Eqs. (26) and (27), the non-trivial steady-state values of Y_{t}^{1}, and Y_{t}^{2} are obtained as follows:

$$Y^{1*} = (\alpha\beta)^{\frac{1}{1-\alpha}} (M^{1})^{\frac{1}{1-\gamma}} \left[(M^{1})^{\frac{\gamma}{1-\gamma}} + (M^{2})^{\frac{\gamma}{1-\gamma}}\right]^{\frac{\alpha-\gamma}{\gamma(1-\alpha)}} L, \tag{28}$$

and

$$Y^{2*} = (\alpha\beta)^{\frac{1}{1-\alpha}} (M^2)^{\frac{1}{1-\gamma}} \left[(M^1)^{\frac{\gamma}{1-\gamma}} + (M^2)^{\frac{\gamma}{1-\gamma}} \right]^{\frac{\alpha-\gamma}{\gamma(1-\alpha)}} L, \tag{29}$$

where the asterisks stand for the steady-state values. The output of final goods in the steady state Y^* is computed from Eqs. (1), (28), and (29) as in the following:

$$Y^* = (\alpha\beta)^{\frac{\alpha}{1-\alpha}} \left[(M^1)^{\frac{\gamma}{1-\gamma}} + (M^2)^{\frac{\gamma}{1-\gamma}} \right]^{\frac{\alpha(1-\gamma)}{\gamma(1-\alpha)}} L \tag{30}$$

We confirm that the relaxation of financial constraints in both countries 1 and 2 increases the output of final goods.

Lemma 4. *As the financial constraint is relaxed in country j ($j = 1, 2$), the output of final goods in the steady state increases (i.e, $\partial Y^*/\partial \mu^j > 0$).*

Proof. From Eq. (30), we have $\partial Y^*/\partial M^j > 0$. Then, from Lemma 3, we obtain $\partial Y^*/\partial \mu^j = (\partial Y^*/\partial M^j)(\partial M^j/\partial \mu^j) > 0$. $\square$

In what follows, we investigate how the fruit of the relaxation of financial constraints is distributed to the three countries.

4.2 Comparative statics for per capita income and income share

From Eqs. (4), (5), (28) and (29), we derive the per-capita income in countries 1 and 2 as follows:

$$I^{1*} := p^{1*} Y^{1*} = \frac{\alpha (M^1)^{\frac{\gamma}{1-\gamma}}}{(M^1)^{\frac{\gamma}{1-\gamma}} + (M^2)^{\frac{\gamma}{1-\gamma}}} Y^*, \tag{31}$$

and

$$I^{2*} := p^{2*} Y^{2*} = \frac{\alpha (M^2)^{\frac{\gamma}{1-\gamma}}}{(M^1)^{\frac{\gamma}{1-\gamma}} + (M^2)^{\frac{\gamma}{1-\gamma}}} Y^*, \tag{32}$$

where I^{j*} and p^{j*} are per capita income and the intermediate-good price in country j in the steady state, respectively. From Eq. (3), per capita income in country 3 is obtained as follows:

$$I^{3*} := w^* = \frac{1-\alpha}{L} Y^*. \tag{33}$$

Throughout the following analysis, we focus on the case in which the amount of labor force in country 3 is so large that the per-capita income in that country is the smallest among the three countries.

Assumption 2. *L is sufficiently large so that $I^{3*} < \min\{I^{1*}, I^{2*}\}$.*

The income shares in countries 1 and 2, I^{j*}/Y^* ($j = 1, 2$), are subject to the financial constraints in these countries. Define $Q^j = (M^j)^{\frac{\gamma}{1-\gamma}}/[(M^1)^{\frac{\gamma}{1-\gamma}} + (M^2)^{\frac{\gamma}{1-\gamma}}]$ for $j = 1, 2$. Then, from Eqs. (31) and (32), the income shares in countries 1 and 2 are given by $I^{j*}/Y^* = \alpha Q^j$ ($j = 1, 2$). The following theorem provides the comparative statics for the income shares of countries 1 and 2 with respect to the relaxation of financial constraints.

Theorem 1. *The income shares in countries 1 and 2 in the steady state are affected by the relaxation of financial constraints as in the following.*

- $\partial(\alpha Q^j)/\partial\mu^j > (<)0$ *if and only if* $\gamma > (<)0$ *for* $j = 1, 2$.
- $\partial(\alpha Q^j)/\partial\mu^{j'} < (>)0$ *if and only if* $\gamma > (<)0$ *for* $(j, j') = (1, 2),\ (2, 1)$.

Proof. See the Appendix.

Theorem 2. *The per-capita income in the three countries in the steady state is affected by the relaxation of financial constraints in countries 1 and 2 as in the following.*

- $\partial I^{j*}/\partial\mu^j > (<)0$ *if and only if* $(M^j/M^{j'})^{\gamma/(1-\gamma)} > (<) - \gamma(1-\alpha)/[\alpha(1-\gamma)]$ *for* $(j, j') = (1, 2),\ (2, 1)$.
- $\partial I^{j*}/\partial\mu^{j'} > (<)0$ *if and only if* $\gamma < (>)\alpha$ *for* $(j, j') = (1, 2),\ (2, 1)$.
- $\partial I^{3*}/\partial\mu^j > 0$ *for* $j = 1, 2$.

Proof. See the Appendix.

Note from the first claim in Theorem 2 that if $\gamma > 0$ (i.e., if the elasticity of substitution between the two intermediate goods is greater than one), the relaxation of financial constraints in the home country increases per capita income in that country. However, if γ is negative and sufficiently small and if the financial constraints in the home country are more relaxed than in the opponent country (i.e., $M^j > M^{j'}$), the further relaxation of financial constraints in the home country can decrease per capita income in that country. This is because the relaxation of financial constraints in the home country decreases the income share in that country if $\gamma < 0$ (the first claim in Theorem 1), and the decrease in the income share in the home country surpasses the increase in Y^* (see Eq. (31) or (32)). In this case, the fruit of the relaxation of financial constraints in the home country leaks out to the opponent country. In contrast, if $\gamma > 0$, the relaxation of financial constraints in the home country decreases the income share in the opponent country (the second claim in Theorem 1). If γ is so large that $\gamma > \alpha$, the relaxation of financial constraints in the home country harms the opponent country (the second claim in Theorem 2).

Whereas Theorems 1 and 2 present the marginal effects of the relaxation of financial constraints on the income shares and the per capita income, Remark 1 below presents a direct comparison of per capita income between country 1 and country 2.

Remark 1. *Under Assumption 1, the ranking of the per capita income between country* 1 *and country* 2 *is given as in the following.*

- *Suppose that* $0 < \gamma < 1$*. Then, it holds that* $I^{1*} > I^{2*}$*.*
- *Suppose that* $\gamma < 0$*. Then, it holds that* $I^{1*} < I^{2*}$*.*

Proof. Both claims immediately follow from Lemma 3 and Eqs. (31) and (32) under Assumption 1. □

The second result in Remark 1 is a bit surprising since the per capital income in the country with higher financial development is less than that in the country with lower financial development. However, one can note from Theorem 1 that when the elasticity of substitutions between the two intermediate goods is sufficiently low, the income share in the country with higher financial development becomes smaller, and that in the country with lower financial development becomes larger. Therefore, the ranking of the per capita income is overturned.

4.3 Within-country income inequality

It is difficult to directly compute the Gini coefficient of income distribution within country 1 and country 2 since our model is a dynamic model with infinitely lived agents.[4] As seen in the right-hand side of Eq. (11), the individual income in a certain period is equal to the return to savings times the savings in the previous period, which means that income inequality within a country is subject to the accumulation of savings. Thus, in this section, we compute the Gini coefficient of the returns $R_t^j(i)$. The Gini coefficient of $R_t^j(i)$ can measure whether income inequality within a country shrinks or widens when the financial constraint in that country is changed.

To derive an analytical solution for the Gini coefficient, we parameterize the productivity distribution in this section.

Assumption 3. *Φ_t^j is uniformly distributed over $[0,1]$.*

Under Assumption 3, the cutoff becomes $\phi^{j*} = \mu^j$ for $j = 1, 2$. Then, we obtain the Lorenz curve in Lemma 6 below.

Lemma 5. *Suppose that Assumption 3 holds. The Lorenz curve with respect to the individual returns $R_t^j(i)$ is given as in the following.*

$$L^j(x) := \begin{cases} \frac{2\mu^j x}{1+\mu^j} & \text{if } 0 \le x < \mu^j \\ \frac{(\mu^j)^2 - 2(\mu^j)^2 x + x^2}{1-(\mu^j)^2} & \text{if } \mu^j \le x < 1 \end{cases} \tag{34}$$

Proof. See the Appendix.

We can compute the Gini coefficient by applying the formula, $\Gamma^j := 1 - 2\int_0^1 L^j(x)dx$, and thus, it is given by

$$\Gamma^j = \frac{-2(\mu^j)^2 + \mu^j + 1}{3(\mu^j + 1)}. \tag{35}$$

[4] Agents in country 3 are homogeneous and there is no income inequality between them.

The Gini coefficient given by Eq. (35) exhibits the same form as that derived by Kunieda et al. (2014). However, the Gini coefficient in Eq. (35) is related to the return to savings whereas that in Kunieda et al. (2014) is directly related to the income obtained by agents.

Theorem 3. *Under Assumption 3, it holds that* $\partial \Gamma^j / \partial \mu^j < 0$.

Proof. The claim is straightforward because $d\Gamma^j/d\mu^j = -2\mu^j(\mu^j+2)/[3(\mu^j+1)^2] < 0$.
$\square$

Income inequality within a country tends to shrink as the financial constraint is relaxed in that country. Note that the within-country Gini coefficient is independent from the financial constraints in the opponent country. This is because our model assumes that there is no international financial market.

4.4 Across-country income inequality

In this section, we investigate how income inequality is affected by the relaxation of financial constraints by comparing the per-capita income in the three countries. Suppose that an average person in country j ($j = 1, 2, 3$) earns an income I^{j*}, which is the per-capita income in the steady state. We consider the income inequality between the three average persons. The Lorenz curve that graphically represents income inequality is obtained in Lemma 6 below.

Lemma 6. *Suppose that Assumptions 1 and 2 hold. Depending upon whether* $0 < \gamma < 1$ *or* $\gamma < 0$*, the Lorenz curve with respect to the three average persons in the three countries is given as in the following.*

- *If* $0 < \gamma < 1$*, it holds that* $I^{1*} > I^{2*}$ *and the Lorenz curve is given by*

$$L(x) := \begin{cases} \frac{3(1-\alpha)}{1+(L-1)\alpha} x & \text{if } 0 \le x < \frac{1}{3} \\ \frac{1-\alpha}{1+(L-1)\alpha} + \frac{3L\alpha Q^2}{1+(L-1)\alpha}\left(x - \frac{1}{3}\right) & \text{if } \frac{1}{3} \le x < \frac{2}{3} \\ \frac{1-\alpha+L\alpha Q^2}{1+(L-1)\alpha} + \frac{3L\alpha Q^1}{1+(L-1)\alpha}\left(x - \frac{2}{3}\right) & \text{if } \frac{2}{3} \le x \le 1 \end{cases} \tag{36}$$

- *If $\gamma < 0$, it holds that $I^{1*} < I^{2*}$ and the Lorenz curve is given by*

$$L(x) := \begin{cases} \frac{3(1-\alpha)}{1+(L-1)\alpha} x & \text{if } 0 \leq x < \frac{1}{3} \\ \frac{1-\alpha}{1+(L-1)\alpha} + \frac{3L\alpha Q^1}{1+(L-1)\alpha}\left(x - \frac{1}{3}\right) & \text{if } \frac{1}{3} \leq x < \frac{2}{3} \\ \frac{1-\alpha+L\alpha Q^1}{1+(L-1)\alpha} + \frac{3L\alpha Q^2}{1+(L-1)\alpha}\left(x - \frac{2}{3}\right) & \text{if } \frac{2}{3} \leq x \leq 1. \end{cases} \tag{37}$$

Proof. See the Appendix.

[Figure 1 around here]

The Lorenz curve is illustrated in Figure 1. The Gini coefficient is equal to the proportion of the tetragonal area $OACD$ to triangle OAB. Therefore, it is straightforward to compute the Gini coefficient Γ as follows:

$$\Gamma := \begin{cases} \frac{2}{3}\left(1 - \frac{L\alpha Q^2 + 2(1-\alpha)}{1+(L-1)\alpha}\right) & \text{if } 0 < \gamma < 1 \\ \frac{2}{3}\left(1 - \frac{L\alpha Q^1 + 2(1-\alpha)}{1+(L-1)\alpha}\right) & \text{if } \quad \gamma < 0. \end{cases} \tag{38}$$

Theorem 4. *Under Assumptions* 1 *and* 2, *the Gini coefficient is affected by the relaxation of financial constraints in countries* 1 *and* 2 *as in the following.*

- $\partial\Gamma/\partial\mu^1 > 0$.
- $\partial\Gamma/\partial\mu^2 < 0$.

Proof. See the Appendix.

The important point in Theorem 4 is that regardless of the ranking of per capita income between I^{1*} and I^{2*}, the further relaxation of financial constraints in a country where the financial constraints are already more relaxed than the opponent country widens the income inequality, whereas the relaxation of financial constraints in a country where the financial constraints are less relaxed than the opponent country reduces the income inequality.

5 Concluding remarks

Nowadays, global value chains link the different stages of a production process that are located in different countries and promote international specializations. In this paper, we investigate how the final output is distributed across countries as income under international specializations.

We find from our model that the relaxation of financial constraints in the home country is harmful (beneficial) to the opponent country if the elasticity of substitution between the two intermediate goods is sufficiently high (low). We also find that the further relaxation of financial constraints in a country with the financial development than in the opponent country widens the income inequality across the three countries, regardless of the ranking of income between the first and second countries. Moreover, the income inequality within a country is reduced as the financial sector in that country is well developed. In particular, the income inequality within a country is independent of the financial constraints in the opponent country. This result crucially depends upon the fact that there is no international financial market in which agents in the first and second countries can lend and borrow with each other internationally. The extension to introduce an international financial market is left for future research.

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Appendix

Proof of Lemma 1

From Eq. (11), it follows that

$$\frac{s_t^j(i)}{c_t^j(i)} + 1 = \frac{R_t^j(i) s_{t-1}^j(i)}{c_t^j(i)}.$$

Taking an expectation $E_{t-1}[.]$ for both sides of this equation yields

$$E_{t-1}\left[\frac{s_t^j(i)}{c_t^j(i)}\right] + 1 = s_{t-1}^j(i) E_{t-1}\left[\frac{R_t^j(i)}{c_t^j(i)}\right]. \tag{A.1}$$

Substituting Eq. (12) into Eq. (A.1) yields

$$\frac{s_{t-1}^j(i)}{c_{t-1}^j(i)} = \beta + \beta E_{t-1}\left[\frac{s_t^j(i)}{c_t^j(i)}\right] \tag{A.2}$$

By iteratively using Eq. (A.2), we obtain

$$\begin{aligned}
\frac{s_t^j(i)}{c_t^j(i)} &= \beta + \beta E_t\left[\frac{s_{t+1}^j(i)}{c_{t+1}^j(i)}\right] \\
&= \beta + \beta^2 + \cdots + \beta^\tau + \beta^\tau E_t\left[\frac{s_{t+\tau}^j(i)}{c_{t+\tau}^j(i)}\right] \\
&= \frac{\beta}{1-\beta} + \lim_{\tau\to\infty} \beta^\tau E_t\left[\frac{s_{t+\tau}^j(i)}{c_{t+\tau}^j(i)}\right].
\end{aligned} \tag{A.3}$$

From the transversality condition, we have $\lim_{\tau\to\infty} \beta^\tau E_t[s_{t+\tau}^j(i)/c_{t+\tau}^j(i)] = 0$. Therefore, from Eq. (A.3), we obtain

$$\frac{s_t^j(i)}{c_t^j(i)} = \frac{\beta}{1-\beta},$$

or equivalently,

$$s_t^j(i) = \frac{\beta}{1-\beta} c_t^j(i). \tag{A.4}$$

Substituting Eq. (A.4) into Eq. (11) yields Eq. (13). □

Proof of Lemma 2

Using the intermediate-good market clearing condition (16) and the financial market clearing condition (17), one can aggregate Eq. (6) across all agents in country j as follows:

$$C_t^j + S_t^j = p_t^j Y_t^j, \tag{B.1}$$

where $C_t^j = \int_{i\in\Omega^j} c_t^j(i)di$ and $S_t^j = \int_{i\in\Omega^j} s_t^j(i)di$. Moreover, the aggregation of Eq. (11) yields

$$C_t^j + S_t^j = \int_{i\in\Omega^j} R_t^j(i) s_{t-1}^j(i)di. \tag{B.2}$$

From Eqs. (B.1) and (B.2), one obtains

$$p_t^j Y_t^j = \int_{i\in\Omega^j} R_t^j(i) s_{t-1}^j(i)di,$$

which is Eq. (23). By aggregating Eq. (13) across all agents with the use of $p_t Y_t^j = \int_{i\in\Omega^j} R_t^j(i) s_{t-1}^j(i)di$, one obtains Eq. (24). $\square$

Proof of Lemma 3

$\text{sign}[\partial M^j/\partial\mu^j] = \text{sign}[-(1-\mu^j)\phi^{j*}G'(\phi^{j*})(\partial\phi^{j*}/\partial\mu^j) + H(\phi^{j*})]$. Because of the inverse function theorem, it follows that $G'(\phi^{j*})(\partial\phi^{j*}/\partial\mu^j) = 1$, and thus, the inside of the bracket in the right-hand side becomes $-(1-\mu^j)\phi^{j*} + H(\phi^{j*})$. Moreover, from this equation and Eq. (19), it follows that $-(1-G(\phi^{j*}))\phi^{j*} + H(\phi^{j*}) > 0$. $\square$

Proof of Theorem 1

From Lemma 3, it follows that $\partial(M^j)^{\frac{\gamma}{1-\gamma}}/\partial\mu^j > (<)0$ if and only if $\gamma > (<)0$. Therefore, from Eqs. (31) and (32), we have $\partial(\alpha Q^j)/\partial\mu^j > (<)0$ and $\partial(\alpha Q^j)/\partial\mu^{j'} < (>)0$ if and only if $\gamma > (<)0$ for $(j, j') = (1,2), (2,1)$. $\square$

Proof of Theorem 2

Regarding the first claim, it suffices to show that $\partial I^{1*}/\partial\mu^1 > (< 0)$ if and only if $(M^1/M^2)^{\gamma/(1-\gamma)} > (<) -\gamma(1-\alpha)/[\alpha(1-\gamma)]$. From Eqs. (30) and (31), we have

$$I^{1*} = \alpha^{1/(1-\alpha)}\beta^{\alpha/(1-\alpha)}L\left[(M^1)^{\frac{\alpha\gamma}{\alpha-\gamma}} + (M^2)^{\frac{\gamma}{1-\gamma}}(M^1)^{\frac{\gamma^2(1-\alpha)}{(1-\gamma)(\alpha-\gamma)}}\right]^{\frac{\alpha-\gamma}{\gamma(1-\alpha)}}. \tag{C.1}$$

Because $\partial I^{1*}/\partial\mu^1 = (\partial I^{1*}/\partial M^1)(\partial M^1/\partial\mu^1)$ and $(\partial M^1/\partial\mu^1) > 0$ (from Lemma 3), it follows that $\text{sign}(\partial I^{1*}/\partial\mu^1) = \text{sign}(\partial I^{1*}/\partial M^1)$. For $\text{sign}(\partial I^{1*}/\partial M^1)$, we have

$$\begin{aligned}\text{sign}(\partial I^{1*}/\partial M^1) &= \text{sign}(\partial \ln(I^{1*})/\partial M^1)\\ &= \text{sign}\left(\frac{\alpha}{1-\alpha}(M^1)^{\frac{\gamma}{1-\gamma}} + \frac{\gamma}{1-\gamma}(M^2)^{\frac{\gamma}{1-\gamma}}\right).\end{aligned} \tag{C.2}$$

The first claim follows from Eq. (C.2). Regarding the second claim, it suffices to show that $\partial I^{1*}/\partial\mu^2 > (<)0$ if and only if $\gamma < (>)\alpha$. We have $\partial I^{1*}/\partial\mu^2 = (\partial I^{1*}/\partial M^2)(\partial M^2/\partial\mu^2)$. From Eq. (C.1), it holds that $\partial I^{1*}/\partial M^2 > (<)0$ if and only if $\gamma < (>)\alpha$. Additionally, we have $\partial M^2/\partial\mu^2 > 0$. Then, the second claim holds. Regarding the third claim, $\partial I^{3*}/\partial\mu^j = (\partial Y^*/\partial\mu^j)(1-\alpha)/L > 0$ for $j = 1, 2$ from Lemma 4. □

Proof of Lemma 5

From the definition of $\phi_t^j := (1 + r_{t+1}^j)/p_{t+1}^j$ ($j = 1, 2$), it follows that

$$R_t^j(i) = (1 + r_t^j)\max\left\{1, \frac{\Phi_{t-1}^j(i)/\phi^{j*} - \mu^j}{1-\mu^j}\right\}$$

Then, under Assumption 3, the aggregate return in country j is computed as follows:

$$\begin{aligned}\int_{i\in\Omega^j} R_t^j(i)di &= \int_0^1 R_t^j(i)d\Phi^j \\ &= (1+r_t^j)\left[\int_0^{\phi^{j*}} d\Phi^j + \int_{\phi^{j*}}^1 \frac{\Phi_{t-1}^j(i)/\phi^{j*}-\mu^j}{1-\mu^j}d\Phi^j\right] \\ &= \frac{(1+r_t^j)(1+\mu^j)}{2\mu^j}. \end{aligned} \tag{D.1}$$

We have used $\phi^{j*}=\mu^j$ to derive the last equality. By using Eq. (D.1), we can derive the Lorenz curve as follows:

$$\begin{aligned} L^j(x) &= \begin{cases} \frac{1+r_t^j}{\int_{i\in\Omega^j} R_t^j(i)di}x & \text{if } 0\le x<\mu^j \\ \frac{2(\mu^j)^2}{1+\mu^j} + (1+r_t^j)\frac{\int_{\mu^j}^x \frac{\Phi_{t-1}^j(i)/\phi^{j*}-\mu^j}{1-\mu^j}d\Phi^j}{\int_{i\in\Omega^j} R_t^j(i)di} & \text{if } \mu^j\le x<1 \end{cases} \\ &= \begin{cases} \frac{2\mu^j x}{1+\mu^j} & \text{if } 0\le x<\mu^j \\ \frac{(\mu^j)^2-2(\mu^j)^2x+x^2}{1-(\mu^j)^2} & \text{if } \mu^j\le x<1, \end{cases} \end{aligned}$$

which is Eq. (34). $\square$

Proof of Lemma 6

It follows that $(I^{1*}+I^{2*}+I^{3*})/3 = [\alpha Q^1+\alpha Q^2+(1-\alpha)/L]Y^*/3 = [\alpha+(1-\alpha)/L]Y^*/3 =: \Psi$.

Case 1: $0<\gamma<1$

In this case, it holds that $I^{3*}<I^{2*}<I^{1*}$ from Remark 1 and Assumptions 1 and 2. Then, the Lorenz curve is computed as follows:

$$L(x) := \begin{cases} \frac{I^{3*}}{\Psi}x & \text{if } 0\le x<\frac{1}{3} \\ \frac{I^{3*}}{3\Psi}+\frac{I^{2*}}{\Psi}\left(x-\frac{1}{3}\right) & \text{if } \frac{1}{3}\le x<\frac{2}{3} \\ \frac{I^{3*}+I^{2*}}{3\Psi}+\frac{I^{1*}}{\Psi}\left(x-\frac{2}{3}\right) & \text{if } \frac{2}{3}\le x\le 1 \end{cases} \tag{E.1}$$

Eq. (36) follows from eq. (E.1).

Case 2: $\gamma < 0$

In this case, it holds that $I^{3*} < I^{1*} < I^{2*}$ from Remark 1 and Assumptions 1 and 2. Then, the Lorenz curve is computed as follows:

$$L(x) := \begin{cases} \frac{I^{3*}}{\Psi}x & \text{if } 0 \leq x < \frac{1}{3} \\ \frac{I^{3*}}{3\Psi} + \frac{I^{1*}}{\Psi}\left(x - \frac{1}{3}\right) & \text{if } \frac{1}{3} \leq x < \frac{2}{3} \\ \frac{I^{3*}+I^{1*}}{3\Psi} + \frac{I^{2*}}{\Psi}\left(x - \frac{2}{3}\right) & \text{if } \frac{2}{3} \leq x \leq 1 \end{cases} \tag{E.2}$$

Eq. (37) follows from eq. (E.2). $\square$

Proof of Theorem 4

Suppose that $0 < \gamma < 1$. Then, because $\partial\Gamma/\partial Q^2 < 0$ and $\partial Q^2/\partial\mu^1 < 0$, it follows that $\partial\Gamma/\partial\mu^1 = (\partial\Gamma/\partial Q^2)(\partial Q^2/\partial\mu^1) > 0$. Additionally, because $\partial Q^2/\partial\mu^2 > 0$, it follows that $\partial\Gamma/\partial\mu^2 = (\partial\Gamma/\partial Q^2)(\partial Q^2/\partial\mu^2) < 0$. Suppose that $\gamma < 0$. Then, because $\partial\Gamma/\partial Q^1 < 0$ and $\partial Q^1/\partial\mu^1 < 0$, it follows that $\partial\Gamma/\partial\mu^1 = (\partial\Gamma/\partial Q^1)(\partial Q^1/\partial\mu^1) > 0$. Additionally, because $\partial Q^1/\partial\mu^2 > 0$, $\partial\Gamma/\partial\mu^2 = (\partial\Gamma/\partial Q^1)(\partial Q^1/\partial\mu^2) < 0$. $\square$

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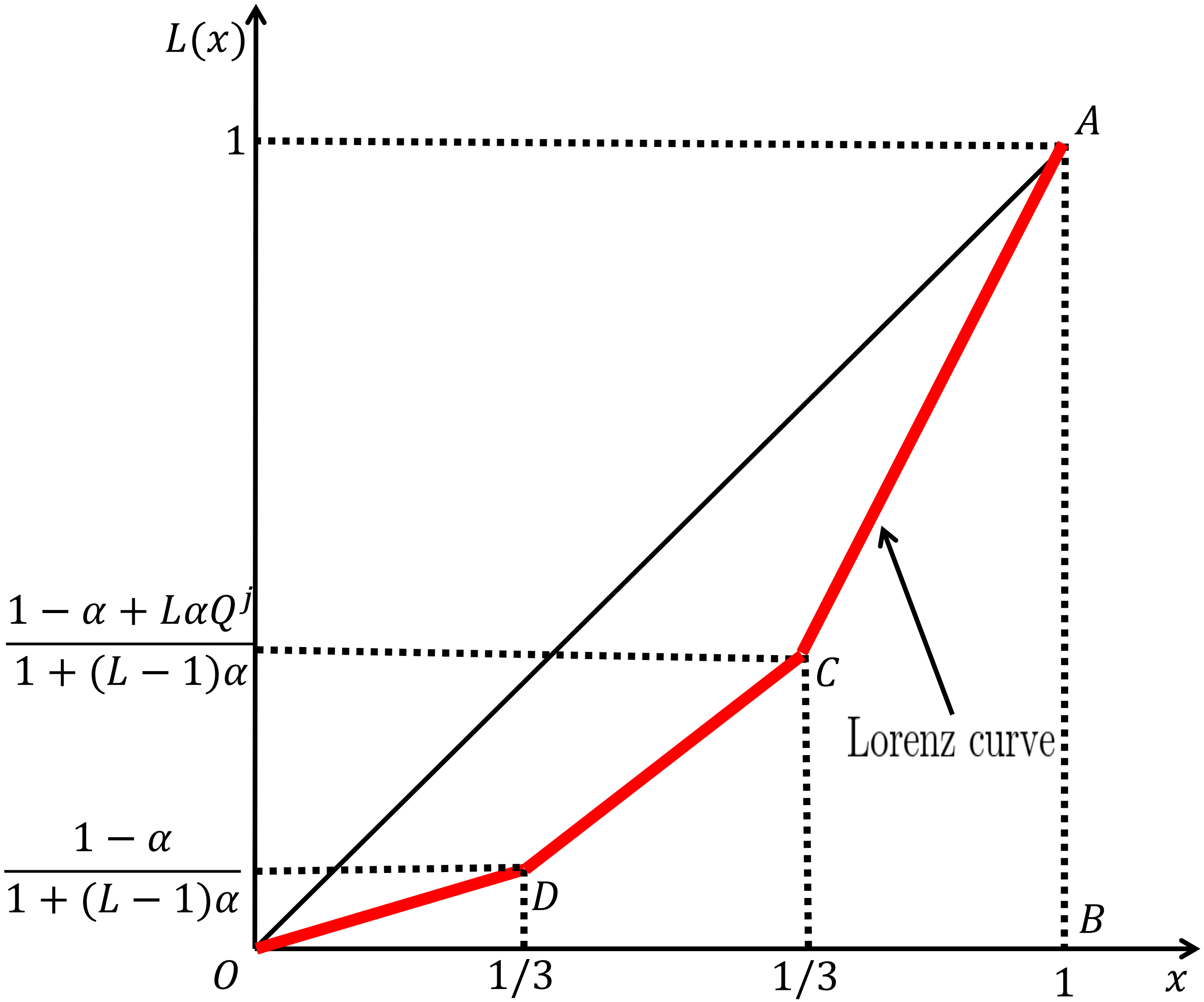

Figure 1. Lorenz Curve