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# Population, Technological Progress and the Welfare of the North-South Trade: A Revisit of the Classic Ricardian Model

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# Population, Technological Progress and the Welfare of the North-South Trade: A Revisit of the Classic Ricardian Model

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**Population, Technological Progress and the Welfare of the North-South Trade: A Revisit of the Classic Ricardian Model**

**Abstract.** This paper analyzes how the technology progress of the South country affects the welfare of the North country in a free trade world. Using the standard Ricardian model of the North-South trade, we show that, import biased technological progress of the South will undermine the welfare of the North, once the cumulative technological progress of the South exceeds a threshold. The relative population size of the South to North affects the threshold. Generally, a relatively larger South country has a lower threshold and the technological difference between the two countries remains even beyond the threshold. To a certain extent, the findings of the paper offer an theoretical explanation about the concerns of rising China in an integrated world economy.

**Keywords:** Free trade, Comparative advantage, Technological progress, Population, Welfare

**JEL Classification:** F1

# 1 Introduction

International trade and globalization offer opportunities for developing countries to learn from and catch-up developed countries. Many developing countries have gradually shortened technological distances with developed countries by imitation, reversal engineering, and technology transfers. International trade and corresponding benefits depend on the disparity of countries in productivity and resource endowments. The convergence theory predicts that the disparity between developing and developed countries in both income and technology continue to shrink and eventually disappear as developing nations gradually catch-up developed nations. An interesting question is whether the technology progress of developing countries is always welfare enhancing for developed countries in a free trade world. In particular, whether the technological improvement of developing countries in the areas where developed countries have comparative advantage, would undermine the welfare of developed countries.

The China threat's argument is a typical example. The rise of China as a world economic powerhouse has caused a lot of anxieties among industrialized countries. It is politician, business people and ordinary citizen who visualize the threat of emerging developing countries on the living standard of developed countries. Mainstream economists supporting free trade, however, refute the concerns as questionable on conceptual grounds and wholly implausible in terms of data (Krugman, 1994).

A few studies, however, suggest that it is plausible that the catch-up of developing nations could undermine the welfare of developed countries in the

world of free trade. Dornbusch, Fisher and Samuelson (1977) showed that the international transfer of the least cost technology from the high-wage country to the low-wage country would reduce the income of the former. Grossman (1995) argued that, technological catch-up by the less developed country should improve its welfare while the advanced country might suffer from the narrowing of the technological lead. The article by Paul Samuelson (2004), "Why Ricardo and Mill Rebut and Confirm argument of Mainstream Economists Supporting Globalization" in the Journal of Economic Perspective, presents an example justifying the argument. Samuelson employed a numerical example illustrating how the US suffered after China experienced substantial technological progress in the sector where the US initially had both absolute and comparative advantage. He argued that the example was a proof that the United States suffered permanent measurable loss in per capita real income when China enjoyed exogenous productivity gains in the sector where the US initially had comparative advantage. Samuelson's proposition challenges the conventional wisdom who believes that free trade always leads to a win-win scenario for both parties involved.

However, some critics (e.g., Panagariya, 2005) pointed out that the negative welfare effect was induced by the deterioration of the US's terms of trade, which has been known to trade economists since the publication of Johnson (1955). However, Samuelson (2005) argued that his conclusion was analytically distinct from the point about self immiserizing trade made cogently by Bhagwati (1958) and Johnson (1955) and the numerical example broke new ground in providing a novel money-metric-utility that measured precisely gains of winners and losses of losers.

Samuelson's proposition is derived from a special numerical example, in which the cumulative productivity growth in China wiped out all the difference in productivity between the two countries so that the basis for trade vanished. But, no country has comparative advantage and absolute advantage/disadvantage is rare and a matter of coincidence (Salvatore, 2004).

In this paper, we attempt to generalize the analysis of Samuelson (2004) by using the classic Ricardian model of North-South trade and investigate whether the win-lose scenario exists under general conditions. The Ricardian model is the simplest and most basic general equilibrium model of international trade and provides the platform for the introduction of new ideas (deardorff). We examine whether the technological progress in the South–developing nation will undermine the welfare of the North–developed nation even before the comparative advantage between the two nations completely vanishes because of the catching-up of the South.

Our analysis shows that, once the import biased technological change of the South exceeds a threshold, any further technological advancement of the South in the sector where the North initially has comparative advantage will undermine the welfare of the North. That there is no comparative advantage between the two countries is not a necessary condition for the North suffers from the import biased technological changes. Additionally, the relative population size between the South and the North affects the threshold. Generally, a relatively larger South country has a lower threshold. To a certain extent, the findings

of the paper explain why industrialized countries, especially the US, feel unconformtable about the rise of China, the largest developing country with 1.4 billion population.

The paper is organized as follow. In section 2, we set up the model and present the closed form solutions of the equilibria in both autarky and free trade. In section 3, we analyze the welfare impact of the technological progress and the role of the relative population size between the South and the North. Finally, we briefly summarize the findings of the paper.

# 2 The Model

Following the classical Ricardian model, we consider a world economy with two countries: country 1 (South) and country 2 (North). In each country, there are two sectors: sector 1 and sector 2, which produce good 1 and good 2 respectively. Labor is the only input for both sectors. The North is developed country and has absolute advantage in both sectors compared with the South– developing nation. Each country has many but limited number of homogeneous firms, seeking profit maximization, and country $i$ has $L_i > 0$ homogeneous rational individuals, seeking utility maximization under their budget constraint, each with a unit labor endowment, for all $i = 1, 2$.

We assume a consumer has the utility function

$$U(c_1, c_2) = c_1^{\alpha} c_2^{\beta},$$

where $\alpha \in (0, 1)$, $\beta = 1 - \alpha$, and $c_1, c_2$ denote the consumption quantities of good 1 and good 2 respectively.

For any $i = 1, 2$, $j = 1, 2$, the production function of a firm in sector $j$ of country $i$ is

$$Y_{ij} = A_{ij} Lij,$$

where $Y_{ij}$ is the output of good $j$ in country $i$, $L_{ij}$ is the labor input, and $A_{ij} > 0$ is a constant, which stands the technology of sector $j$ in country $i$.

Labor is mobile freely within each country but not cross-country and all markets are perfectly competitive. We make a convention that all variables in the paper are nonnegative.

For convenience, we denote

$$\theta = \frac{\beta L_1}{\alpha L_2}, \quad \kappa = \alpha^{\alpha} \beta^{\beta},$$

$$\theta_j = \frac{A_{2j}}{A_{1j}}, \quad \forall j = 1, 2.$$

Throughout this paper, we assume that

$$\theta_1 < \theta_2. \tag{1}$$

It implies that the North has comparative advantage in good 2 while the South has comparative advantage in good 1.

In the following sections, we will first calculate the welfare of both countries in autarky and free trade accordingly, and then apply comparative static analysis to exam welfare impacts of relevant parameters.

This model can be considered as a proxy of China-US trade. The South country represents China and the North the US. Good 1 and good 2 are, say, T-shirt and computer respectively. The US has comparative advantage in computer production while China in T-shirt production.

When the South and North trade with each other, there are four markets: international market for good 1, international market for good 2, and two isolated domestic labor markets.

Let $p_j$ denote the price of good $j$, $\omega_i$ the wage of country $i$, $c_{ij}$ the consumption of good $j$ at country $i$ and $l_{ij}$ the share of labor employed in sector $j$ of country $i$. Now, we define the free trade equilibrium explicitly.

**Definition.** We say $\{p_j, \omega_i, l_{ij}, c_{ij}\}_{i=1,2;j=1,2}$ is a free trade equilibrium, if
(i) for any $i = 1, 2$,

$$(c_{i1}, c_{i2}) \in \arg\max_{x,y}\{x^\alpha y^\beta\},$$

s.t.

$$p_1 x + p_2 y \leq \omega_i;$$

(ii) for any $i = 1, 2, j = 1, 2$,

$$l_{ij}L_i \in \arg\max_{L}\{p_j A_{ij} l_{ij} L_i - \omega_i l_{ij} L_i\},$$

(iii) for any $j = 1, 2$,

$$\sum_{i=1}^{2} c_{ij}L_i = \sum_{i=1}^{2} A_{ij} l_{ij} L_i;$$

and for any $i = 1, 2$,

$$\sum_{j=1}^{2} l_{ij} = 1.$$

It is straightforward to verify that if $\{p_j, \omega_i, l_{ij}, c_{ij}\}_{i=1,2;j=1,2}$ is a free trade equilibrium, then, $p_1 > 0$, $p_2 > 0$, $\omega_1 > 0$, $\omega_2 > 0$.

With regards to the equilibrium, we have following results.

**Lemma.** The equilibrium exists and is unique, and is determined as follows.
(i) if $\theta < \theta_1$, then,

$$\theta_1 \omega_1 = \omega_2 = p_1 A_{21} = p_2 A_{22},$$

$$l_{11} = 1, \quad l_{12} = 0,$$
$$l_{21} = \alpha - \alpha\theta/\theta_1, \quad l_{22} = \beta + \alpha\theta/\theta_1,$$

$$c_{11} = \alpha A_{11}, \quad c_{12} = \beta A_{22}/\theta_1,$$
$$c_{21} = \alpha A_{21}, \quad c_{22} = \beta A_{22}.$$

(ii) if $\theta \in [\theta_1, \theta_2]$, then,

$$\theta p_1 A_{11} = \theta\omega_1 = \omega_2 = p_2 A_{22},$$

$$l_{11} = 1, \quad l_{12} = 0,$$
$$l_{21} = 0, \quad l_{22} = 1,$$

$$c_{11} = \alpha A_{11}, \quad c_{12} = \beta A_{22}/\theta,$$
$$c_{21} = \alpha\theta A_{11}, \quad c_{22} = \beta A_{22}.$$

(iii) if $\theta > \theta_2$, then,

$$\omega_1 = p_1 A_{11} = p_2 A_{12} = \omega_2/\theta_2,$$

$$l_{11} = \alpha + \beta\theta_2/\theta, \quad l_{12} = \beta - \beta\theta_2/\theta,$$
$$l_{21} = 0, \quad l_{22} = 1,$$

$$c_{11} = \alpha A_{11}, \quad c_{12} = \beta A_{12},$$
$$c_{21} = \alpha\theta_2 A_{11}, \quad c_{22} = \beta A_{22}.$$

The above lemma gurantees that the free trade equilibrium exists and is unique. But, the pattern of trade and specialization varies.

(i)if $\theta < \theta_1$, the South specializes in good 1 while 1 the North produces both goods. Feenstra (2003) and Deardorff (2007) mentioned this free trade equilibrium and explained that, it happened simply because the North was much bigger than the South and the demand of the North would not be met if it specialized in one good. Examining the condition suggests that, if the North productivity is much higher in both sectors than the South, it is also possible that the North produces both goods while the South specializes in just one when the sizes of both countries are roughly same. The extremely low productivity of the South could not produce enough to meet the global consumption if the North specialized in good 2. In this case, the North gains nothing from trading with the South. It is highly likely that the North does not trade with the South. This equilibrium explains why many low income countries cannot export any manufacturing products but resources to advanced countries.

Their low productivity in manufacturing industry hinders the possibility to trade with developed countries in spite of the existence of comparative advantage.

(ii) if $\theta \in [\theta_1, \theta_2]$, the South produces only goods 1 while the North produces only good 2. This is the typical trade pattern derived from the Ricardian model. Both countries benefit from the free trade.

(iii) if $\theta > \theta_2$, the South produces both goods while the North produces only good 2. In this case, the South does not benefit from the trade and only the North does. This trade pattern is possible if the South is much bigger than the North and the technological disparity between the South and the North is relatively small.

In the free trade equilibrium, the corresponding welfare of country 1 and country 2 are as following respectively:

$$\begin{aligned} U_1 &= \kappa A_{11}^{\alpha} \left( \frac{\theta_2}{\omega} A_{12} \right)^{\beta}, \\ U_2 &= \kappa \left( \frac{\omega}{\theta_1} A_{21} \right)^{\alpha} A_{22}^{\beta}, \end{aligned} \tag{2}$$

where

$$\omega = \max\left(\theta_1, \min(\theta, \theta_2)\right),$$

which is just the ratio of wages.

Similarly, we can define the autarky equilibrium and prove that in autarky equilibrium, the welfares of country 1 and country 2 are as following respectively:

$$U_1^* = \kappa A_{11}^{\alpha} A_{12}^{\beta}, \quad U_2^* = \kappa A_{21}^{\alpha} A_{22}^{\beta}.$$

Furthermore, we can prove that if the condition (1) is replaced with $\theta_1 = \theta_2$, that is, no country has any comparative advantage, then, there exist a continuum of free trade equilibria, under which the welfare of any country is the same as in autarky. Hence, if the comparative advantage disappears, no country has the incentive to trade.

# 3 The Welfare Impact of Exogenous Technological Progress

Comparing the welfare of the two countries in autarky with that in free trade, we can derive the results below:

$$U_1 \geq U_1^*, \quad U_2 \geq U_2^*,$$

and,

$$\begin{aligned} U_1 = U_1^* &\iff \theta \geq \theta_2, \\ U_2 = U_2^* &\iff \theta \leq \theta_1. \end{aligned}$$

We summarize these results in proposition 1.

**Proposition 1.** Comparing with in autarky, any country is better off in free trade. Moreover, if

$$\theta \leq \theta_1,$$

then, only country 1 is strictly better off; if

$$\theta_1 < \theta < \theta_2,$$

then, both countries are all strictly better off; if

$$\theta \geq \theta_2,$$

then, only country 2 is strictly better off.

Now, we examine how the catching-up of the South affects the welfare of the North. Specifically, we analyze whether the productivity growth of the South in sector 2, where the North has comparative advantage at the beginning of the free trade would make the North better or worse off.

From (2), we know that if

$$\theta \leq \theta_1,$$

then, $U_2$ is independent of $A_{11}$ and $A_{12}$. So, in this case, technological changes of the South have no impacts on the North.

The interesting case is $\theta > \theta_1$. We focus on two scenarios:

Scenario I:

$$\theta_1 < \theta < \theta_2;$$

Scenario II:

$$\theta_1 < \theta_2 \leq \theta.$$

In scenario I, the South specializes in producing good 1 while the North in good 2. So, the South exports good 1 and imports good 2. As the South experiences significant import biased technological progress, the productivity $A_{12}$ increases. Once $A_{12}$ exceeds a threshold, the world economy enters into scenario II, where the South starts to produce both goods while the North continues to specialize in good 2. The threshold is

$$A_{12}^* = \frac{A_{22}}{\theta}. \tag{3}$$

From (2), we derive the welfare of the North in Scenario I as

$$U_2 = \kappa \left(\theta A_{11}\right)^{\alpha} A_{22}^{\beta},$$

which is independent of $A_{12}$. In other words, the productivity growth of the South in sector 2 has no impacts on the welfare of the North in scenario I.

In Scenario II, however, the welfare of the North is

$$U_2 = \kappa \left( \frac{A_{11}}{A_{12}} \right)^{\alpha} A_{22}. \tag{4}$$

It implies that the welfare of the North is an decreasing function of $A_{12}$. Any further productivity improvement of the South in sector 2 will result in a decrease in the welfare of the North.

We summarize the result in the following proposition.

**Proposition 2.** Once the technological progress of the South in sector 2 crosses a threshold so that the South starts to produces two goods and the North produces good 2 only, any further technological progress of the South in sector 2 will undermine the welfare of the North, other things being equal.

It is important to notice that, if there exists a uniform technological progress in both sectors of the South and other factors are held constant, the welfare of the North remains the same.

In fact, based on (4), we can easily give a more general result about the welfare impact of the technological progress of the South in sector 2 in Scenario II: The North will be strictly worse off, if and only if $\alpha b > a$, where $a$ is the growth rate of the productivity in the sector 2 of the North, and $b$ is the growth rate of the productivity in the sector 2 of the South minus that of the South in sector 1.

Regarding the magnitude of the threshold, equation (3) implies that the threshold $A_{12}^*$ is strictly decreasing with respect to the population ratio of the South to the North.

Therefore, with a given North country, a relatively large (small) South country has a relatively low (high) threshold.

Compared with China, Vietnam, for example, has a quite higher threshold to cross before its technological progress in high-tech sector becomes harmful to the welfare of the US.

From the proposition 2, we know that even before the South completely catches up the North in sector 2 and has the same productivity as the North in the sector, the welfare of the North will begin to decrease as the South improves its productivity in producing good 2.

Samuelson (2004) argued that, the US welfare would decrease if China caught up the US so that no country had comparative advantage in any sectors. However, our analysis suggests that, the welfare of the North would be undermined by the technological advancement of the South even before the comparative advantage disappears. The relative size of the two trading nations plays a critical role in determining the welfare effect of the technological progress of the South .

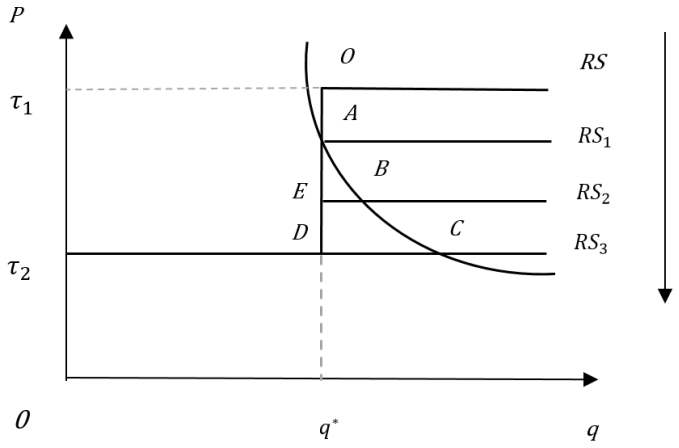


Figure 1: The Equilibria of Free Trade with Exogenous Technology Progress

The results of proposition 2 can be explained by the world relative demand (RD) and relative supply (RS) curves.

Following Krugman et al. (2015), we draw a diagram of RD and RS curves under different technologies in Figure 1.

The RD curve is

$$p = \frac{\beta/\alpha}{q},$$

and the RS curve is

$$p = \tau_2 I(q \leq q^*) + \tau_1 I(q > q^*),$$

where $p = p_2/p_1$ the relative price, $q = q_2/q_1$ the relative quantity, $q_i$ is the total quantity of production of good $i$ for $i = 1, 2$, and

$$q^* = \frac{A_{22}L_2}{A_{11}L_1}, \quad \tau_i = \frac{A_{i1}}{A_{i2}}, \quad \forall i = 1, 2.$$

Point A marks the initial world market equilibrium, in which the South specializes in producing good 1 and the North in producing good 2. Associated with the technological progress in good 2, Labor productivity $A_{12}$ increases. Consequently, $\tau_1$ decreases, and the ORS part of the RS curve shifts downward.

Once the ORS is below $ARS_1$, at the free trade equilibrium, the South produces both goods, and the welfare of the North decreases.

For example, at the position of ERS, the RD curve intersects with the RS curve at point B, where the South produces both goods.

Once ORS overlaps with $DRS_3$, the relative productivity between the two countries is equalized, i.e. $\tau_1 = \tau_2$, and neither the South nor the North has comparative advantage over the other.

It is worthy to mention that there exists a substantial distance between $ARS_1$ and $DRS_3$. The distance indicates that the negative effect on the welfare of the North will emerge far before the relative productivity equalization occurs.

In our model, that no country has comparative advantage is not a prerequisite for the North's welfare being undermined by the South's technological progress. Therefore, our result is more general than that of Samuelson (2004).

Actually, the world market equilibrium defined by point C represents the special case employed by Samuelson(2004). At point C, $\tau_1 = \tau_2$, neither the South nor the North has comparative advantage. The incentive for trade does not exist. Thus, both countries move back to autarky. The South's welfare increases with the improved productivity while the North suffers.

No technical progress in the sector 2 of the North is another unrealistic assumption in the Samuelson's numerical example. Our model could accommodate the technological progress of the US. The results will hold providing that the growth of the South's productivity in sector 2 is much higher than that of the North. As the North is the leader in producing good 2 at the beginning of the free trade and the South is a follower, improving technology through imitation, reversal engineering and technology spillover is far easier than making a new breakthrough. It is a reasonable and realistic assumption that the South's labor productivity generally grows quite faster than that of the North.

# 4 Concluding Remarks

Using the standard Ricardian model, we generalize the result of Samuelson (2004). Our analysis shows that, once the technological progress of the South in the sector where the North has comparative advantage, has accumulated to a certain level, the South will switch from the complete specialization to producing two goods, thus giving rise to a decrease in the welfare of the North. The win-lose scenario (comparing with the initial state of the free trade) induced by the technological improvement occurs even before comparative advantage between the two countries is eliminated completely. Even though the welfare of the North decreases as the South starts to produce both goods, free trade remains a better choice than autarky for the North.

The analysis also suggests that the negative welfare impact depends on the relative size of the South. For a relative small developing country, the damage to the North will not be materialized until it crosses over a very high productivity threshold. To a certain extent, the results explain why the rise of China, the largest developing country with 1.4 billion population causes much more concerns than any other emerging developing countries.

# References

[1] Deardorff, A. V. (2007). "The Ricardian Model," Discussion Paper No. 564, Gerald R. Ford School of Public Policy, the University of Michigan.

[2] Dornbusch, R., Fisher, S. and Samuelson P. A. (1977). "Comparative Advantage, Trade, and Payments in A Ricardian Model with a Continuum of Goods," The American Economic Review, Vol. 67(5): 823-839.

[3] Grossman, G. M. (1995). "Technology and Trade," Chapter 25 in Handbook of International Economics, Vol. III edited by G. Grossman and K. Rogoff.

[4] Johnson, H.G. (1955). "Economic Expansion and International Trade", Manchester School of Economic and Social Studies, May, 23, 95-112.

[5] Krugman, P. (1994). "Does Third World Growth Hurt First World Prosperity?", Harvard Business Review, July-August, 1994: 113-121.

[6] Krugman P., Obstfeld M., Melitz M. (2015). International Economics. Theory and Policy. 10th edition, Pearson.

[7] Panagariya, A. (2005). "Why the Recent Samuelson Article is NOT about Offshore Outsourcing", mimo.

[8] Salvatore, D. (2004). International Economics, 8th edition, New York: John Wiley & Sons, Inc.

[9] Samuelson, P.A. (2005). "Comments: Response from Paul A. Samuelson", Journal of Economic Perspective, 19(3): 242-43.

[10] Samuelson, P.A. (2004). "Where Ricardo and Mill Rebut and Confirm Arguments of mainstream Economists Supporting Globalization", The journal of Economic Perspective, 18(3): 135-46.

# Appendix

**Proof of Lemma.** One can verify directly that in any one of the three cases, the given $\{p_j, \omega_i, l_{ij}, c_{ij}\}_{i=1,2;j=1,2}$ is really an equilibrium.

In the sequel, we prove the uniqueness. Or, equivalently, we prove that if $\{p_j, \omega_i, l_{ij}, c_{ij}\}_{i=1,2;j=1,2}$ is an equilibrium, then, it must be of the form given in this lemma.

First of all, we show that it can not happen that $l_{11} > 0, l_{12} > 0, l_{21} > 0, l_{22} > 0$. In fact, otherwise, we would have that

$$\omega_1 = p_1 A_{11} = p_2 A_{12},$$
$$\omega_2 = p_1 A_{21} = p_2 A_{22},$$

which yields $\theta_1 = \theta_2$, we get a contradiction.

Next, we prove that it can not happen that $l_{11} = 0, l_{12} > 0, l_{21} > 0, l_{22} > 0$. Otherwise, we would have that

$$\omega_1 = p_2 A_{12} \geq p_1 A_{11},$$
$$\omega_2 = p_1 A_{21} = p_2 A_{22},$$

which yields $\theta_1 \geq \theta_2$, we also get a contradiction.

Similarly, one can prove that it can not happen that $l_{11} \geq 0, l_{12} > 0, l_{21} > 0, l_{22} = 0$.

Then, there are left only three cases: $l_{11} > 0, l_{12} = 0, l_{21} > 0, l_{22} > 0$; $l_{11} > 0, l_{12} = 0, l_{21} = 0, l_{22} > 0$; $l_{11} > 0, l_{12} > 0, l_{21} = 0, l_{22} > 0$.

Now, suppose that $l_{11} > 0, l_{12} > 0, l_{21} = 0, l_{22} > 0$. Then, we have that

$$\omega_1 = p_1 A_{11} = p_2 A_{12},$$
$$\omega_2 = p_2 A_{22} \geq p_1 A_{21},$$

$$p_1 c_{i1} = \alpha \omega_i, \quad p_2 c_{i2} = \beta \omega_i, \quad i = 1, 2,$$

$$c_{11} L_1 + c_{21} L_2 = A_{11} l_{11} L_1,$$
$$c_{12} L_1 + c_{22} L_2 = A_{12} l_{12} L_1 + A_{22} L_2,$$

which yields the solution, coinciding with that given in the case, where $\theta > \theta_2$.

Other two cases can be treated similarly. The lemma is proved.