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Abstract

One of the main criticisms of the modern trade theories is that they are based on the assumption of equivalent technologies in the trading countries. These theories explicitly assume that the trading partners possess identical technologies, and the difference in the amount of goods produced is solely due to the differences in factor endowments. In effect, opening to trade between two countries with different factor endowments is an optimization problem that redistributes labor and capital between the types of goods produced to maximize the world output. In this optimization problem both trade participants benefit from free trade, and it is possible to make everybody win. But if the two countries possess different technologies, the result is quite opposite. The optimization problem leads to the destruction of capital in the country with less efficient technology. While the main conclusions of the theory – the owners of export-oriented factor of production win and capital-abundant country will export capital-intensive goods and vice versa – will hold, the country with less efficient pre-trade technology will lose the technology altogether, and the total output of that country will fall as a result of free trade.

Introduction

The development of modern trade theory stands on three pillars. Ricardo's comparative advantage[1] uses labor as the only input. Samuelson's specific factors model[2,3] adds capital to labor, but capital is industry specific. Heckscher-Ohlin factors proportions model relaxes the industry-specificity assumption and allows capital to move across industries in the long run.

All the three pillars lead economists to conclude that free trade between countries benefits all participants. How do we get to that? Well, in the labor-only Ricardo's model we *postulate* that the value of both traded goods (high-tech vs low-tech, for example) is virtually the same if they both require the same number of hours worked. Then we can prove, quite rigorously at that, that a country can benefit by giving up high-tech industries and specializing in low-technology products.[4] In the specific factors model we postulate that countries have identical technologies, and trade helps redistribute labor in the most optimal way. The same assumption about technologies is used in the Heckscher-Ohlin model, which then becomes the problem of optimization of distribution of available to countries capital and labor in the long run.

In our previous publications[5,6] we considered situations where the value of labor is different in high-technology versus low-technology industries in the Ricardian model and where technologies are different in efficiency in the two trading partners in the specific factors model. As expected, to an unindoctrinated by abstract economic theory person at least, a country that gives up its high-technology (or most advanced) industries in favor of low-technology exports loses as a result of free trade. In the case of specific factors model, the country whose technology is less efficient, is also worse off in free trade where it must sacrifice its most advanced industry in favor of commodity products exports.

In this paper we consider the Heckscher-Ohlin model, but in the context of different technologies between the trading parties. The standard Heckscher–Ohlin model assumes that the production functions, and thus, technologies, are identical for all countries concerned. The main criticism of this model is that it ignores this crucial factor when considered in regard to the development of poor countries in the international context.[7]

We provide a simple numerical illustration that when countries have different technologies, there is no way to redistribute resources – labor and capital – in such a way that both countries win. Our example also shows that the factor price equalization that occurs in the standard equivalent-technologies scenario, does not apply when technologies are different. Both factors, and the economy as a whole, lose in the country that gives up its most advanced industry to specialize in commodity products.

Results

Definition of capital. The crucial concept we want to introduce is the definition of capital in terms of input of labor into its creation and maintenance. In the modern production system, the capital is machines and apparatuses, together with materials and intermediate products, that are used in the production process. The capital is not an endowment given by the nature. Rather, it is composed of goods created and manufactured in the production. Capital is a production power accumulated by the past investment, research and development, and maintained by the current research, engineering and production personnel. Therefore, we want to define capital as the work, past and present, of human personnel – researchers, engineers, workers and the providers of financing – necessary to create and operate the machinery. Labor is defined as workers who are using the machines and apparatuses to produce final goods. With this definition, both capital and labor will be measured in the number of personnel, or work hours. But the output, or income, of personnel involved in capital and personnel involved production will be different. The income of personnel in capital, with this definition, corresponds to capital rental rate. And the income of personnel involved in production, corresponds to wages.

In the simple two-commodities, US-Russia Ricardian model,[5] we defined the input in terms of the number of "American workers" and "Russian workers." Here with our definition of capital we will also use the number of personnel as input, but the personnel will be divided into the number of persons involved in capital creation and maintenance, and the number of persons involved in production. We will also use terms "skilled" and "unskilled" workers for these two types of human resources respectively.

Heckscher-Ohlin model when technologies are the same. Consider the autarky production table we used for illustration in our previous publication:[5]

Products	American personnel	American output	Russian personnel	Russian output	World output
Chairs	200	100,000	200	100,000	200,000
Laptop PCs	300	60,000	300	18,000	78,000

Table 1. Autarky production of two commodities, laptop PCs and chairs, by the United States and Russia

In this table 300 people are required to produce 60,000 laptop PCs in the US. But electronics is capital-intensive industry, and most components are produced with highly mechanized and automated machinery, while final assembly requires relatively few workers. We therefore assume that most of the 300 persons involved in the production pipeline raw materials – finished PC are involved in creation and maintenance of the equipment to manufacture chips and other components. That is, most of these 300 persons are involved in capital creation and maintenance.

For our illustration we will take that number to be 285 and leave 15 people to work in final assembly. Therefore, the breakdown of the 300 persons in the laptop production in the US will be 285 skilled + 15 unskilled workers.

Furniture production, by contrast, is labor-intensive. While some engineers and some investment money are required to create machinery to make some parts of the furniture, most of the work in the industry is manual. For our illustration we will assume that out of 200 persons involved in the furniture industry in Russia, 10 are skilled persons involved in tools and machinery creation, and 190 are unskilled workers involved in final assembly.

Further, assume that the US is capital-abundant and labor-scarce, and Russia is labor-abundant and capital-scarce. The implication of this is that in the US there is shortage of labor in furniture, and in Russia there is shortage of capital in electronics. The shortage of labor in the furniture industry in the US must be compensated by extra engineers, and the shortage of capital in Russia must be compensated, at least partially, but extra labor in electronics. Assume, therefore, that in the US the chair production utilizes 100 skilled plus 100 unskilled workers, instead of a more optimal 10 plus 190. In Russia, on the other hand, only 80 skilled workers represent the capital used in electronics, and some of the shortage of capital is compensated by extra blue-collar workers, so the 300 personnel in electronics in Russia are 80 skilled plus 220 unskilled personnel.

To summarize the above assumptions, the human resources are split into capital + production personnel as follows:

Products	**American personnel**	**American output**	**Russian personnel**	**Russian output**	**World output**
Chairs	100 + 100	100,000	10 + 190	100,000	200,000
Laptop PCs	285 + 15	60,000	80 + 220	18,000	78,000

Table 2. Autarky production of two commodities, laptop PCs and chairs, by the United States and Russia, and the number of skilled and unskilled workers employed in each industry

Suppose the price of a laptop in the US is \$750, and in Russia is ₽1500, while the price of a chair is \$220 and ₽90 in the US and Russia respectively. The output in local currencies is as follows:

Products	American workers	American output	Russian workers	Russian output
Chairs	100+100	$22,000,000	10 + 190	₽9,000,000
Laptop PCs	285 + 15	$45,000,000	80 + 220	₽27,000,000
Total	385 + 115	$67,000,000	90 + 410	₽36,000,000

Table 3. Autarky production of two commodities, laptop PCs and chairs, by the United States and Russia and the output in local currencies

The US is capital-abundant, because we have 100 + 285 = 385 capitalists (or skilled or white-collar) workers, and 100 + 15 = 115 production workers. Russia is labor-abundant, with 90 skilled and 410 production workers. Notice that, for this reason, the relative price of a laptop PC is higher in Russia than in the US.

The average wages are found as a solution of a system of two linear equations with two unknowns for each of the countries in the above table and are as follows:

Country	Skilled	Unskilled
United States	$154,400.00	$65,600.00
Russia	₽242,300.00	₽34,600.00

Table 4. Autarky wages in local currencies

As we have stated above, Russia is capital-scarce, and must compensate the shortage of capital in the capital-intensive electronics by sending extra workers from furniture. The US, on the other hand, is labor-scarce and needs to compensate the shortage of labor in furniture by using some of the electronics engineering force. Free trade would allow both countries to use the resources more efficiently and increase the World production of both laptop PCs and chairs.

If the technologies in the countries are the same, then, by definition, the same number of engineers + the same number of workers will produce the same number of laptops or chairs in either country. The optimal free-trade World output would look, up to rounding the number of skilled and unskilled personnel to the nearest integer, as follows:

Products	**American workers**	**American output**	**Russian workers**	**Russian output**	**World output**
Chairs	5+95	50,000	20+405	212,500	262,500
Laptop PCs	380+20	80,000	70+5	15,000	95,000

Table 5. Optimal free-trade output and the distribution of engineering and worker resources (corresponding to capital and labor)

Notice the exact same number of engineers + workers (up to rounding to integer) required per 1000 laptops in both the US and Russia, and the exact same number of engineers + workers required per 1000 chairs in both countries.

In free trade, the prices of goods become the same and the relative price of a laptop increases in the US and decreases in Russia. Assume, for illustration, the free-trade prices of $1000 for a laptop and $100 for a chair.

Now, taking the dollar as the reference currency, the output in the free-trade world is as follows:

Products	American personnel	American output	Russian personnel	Russian output	World output
Chairs	5+95	$5,000,000	20+405	$21,250,000	$26,250,000
Laptop PCs	380+20	$80,000,000	70+5	$15,000,000	$95,000,000
Total	385+115	$85,000,000	90+410	$36,250,000	$121,250,000

Table 6. Optimal free-trade output in terms of the reference currency

And the wages are:

Country	Skilled	Unskilled
United States	$208,300.00	$41,700.00
Russia	$211,300.00	$42,000.00

Table 7. Free-trade wages in reference currency

In the case of equivalent technologies factor prices do equalize (the difference is due to rounding off the number of personnel). Also, both countries benefit. Suppose the two countries consume a share of laptops and chairs proportional to their share of global GDP. Russia can now consume 36.25/121.25 = 30% of the increased output, or 28400 laptops and 78480 chairs, as opposed to 18,000 laptops and 100,000 chairs, which at any relative price in the range from autarky to free trade is better. The US can consume the remaining 61600 laptops and 183520 chairs.

Case when technologies are not equivalent. The above illustration was just a demonstration of the standard Heckscher-Ohlin model with equivalent technologies. The only novelty that we introduced was the representation of the amount of capital by the number of people involved in its creation. The technology was identical in both trading partners, and the difference was in the amount of available personnel and accumulated knowledge involved in tools and machinery creation. In autarky the shortage of accumulated knowledge and capital in Russia was being partially compensated by abundant labor. This inefficiency was resolved in free trade by redistribution of workers and engineers to the most optimal level between the two trading partners. The key point of this optimization, from the perspective of Russia, for example, was that removing a significant number of unskilled personnel from electronics does not proportionally hurt laptop production, while re-employing them in furniture increases the chairs production significantly. If the technologies are the same, then only one unskilled worker is required per approximately 10 skilled workers in the electronics industry. 220 unskilled per 80 skilled workers (**Table 2**) will increase the production only by a small amount compared to 5 unskilled per 70 skilled (**Table 5**), which is why we were able to redistribute workers to greater efficiency between the two countries.

The situation is crucially different if the technologies are not equivalent. Less efficient Russian tools and machinery in the electronics industry does not allow to free a large number of unskilled workers without significantly reducing the production of computers. Essentially, let us assume that the Russian electronics industry does require almost three blue collar workers per one engineer to function, so 220 workers per 80 engineers are needed to produce 18,000 laptops, as in **Table 2**. If in free trade Russia does move, say, three quarters of workers from laptops to furniture, then three quarters of engineers are also not required in electronics anymore, and laptop production falls from 18,000 units to 4,500. The workers and engineers moved to furniture increase the chair production to 212,500.

Assume the US production, after redistribution of US workers and engineers, is the same as in the previous section. The free-trade production table is now as follows:

Products	American workers	American output	Russian workers	Russian output	World output
Chairs	5 + 95	50,000	70 + 355	212,500	262,500
Laptop PCs	380 + 20	80,000	20 + 55	4,500	84,500

Table 8. Free-trade output when the Russian electronics industry is less efficient than American under the assumptions in the text

In dollar terms

Products	American workers	American output	Russian workers	Russian output	World output
Chairs	5 + 95	$5,000,000	70 + 355	$21,250,000	$26,250,000
Laptop PCs	380 + 20	$80,000,000	20 + 55	$4,500,000	$84,500,000
Total	385 + 115	$85,000,000	90 + 410	$25,750,000	$110,750,000

Table 8. Free-trade output when the Russian electronics industry is less efficient than American under the assumptions in the text – in dollar terms

The wages become:

Country	Skilled	Unskilled
United States	$208,300.00	$41,700.00
Russia	$131,900.00	$33,800.00

Table 10. Wages under free trade when technologies are different

Unlike in the case of equivalent technologies, the factor prices actually *diverge* when technologies are not the same. Furthermore, the share of Russia in World output is now smaller than it was under autarky, so Russia loses from free trade. There is no way to redistribute the output so that everyone gains, like it is in the case of equivalent technologies.

Schematic representation of production possibilities frontier. **Figure 1** shows the classical PPF of the two trading partners when technologies are the same.

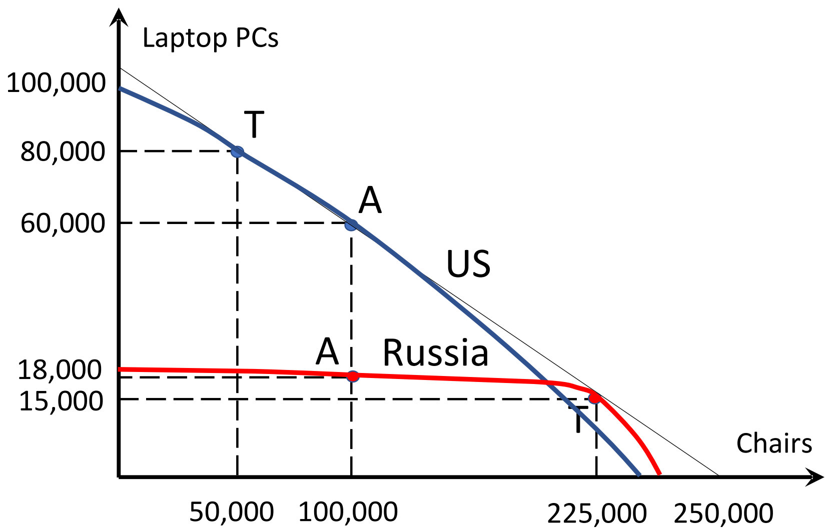

Figure 1. Production possibilities frontiers for the US and Russia in the Heckscher-Ohlin framework. The autarky production numbers are denoted by points A for the US (blue) and Russia (red). The *crucial* difference in the case of the same versus different technologies, from Russia's perspective, is the behavior of PPF in the rightmost part of the plot. When technologies are the same, part of the Russia's PPF has a steeper slope than the US PPF (segments of the red and blue lines near the 225,000 chairs). In the case of different technologies, the red line would have a shallower slope than blue line, as in Figure 2 below.

At the autarky production point in Russia, the slope is much shallower than in the US for the same number of chairs. The significance of this is that at that point Russia's use of capital and labor (engineering and worker) resources is inefficient. Russia achieves slightly higher production of electronics by trying to compensate scarcity of capital (engineering resources) with extra workers who could more efficiently be employed in furniture. Free trade allows Russia to send these resources to furniture while importing more computers in exchange for furniture exports.

When technology is different – less efficient in Russia – the PPF is very different (**Figure 2**).

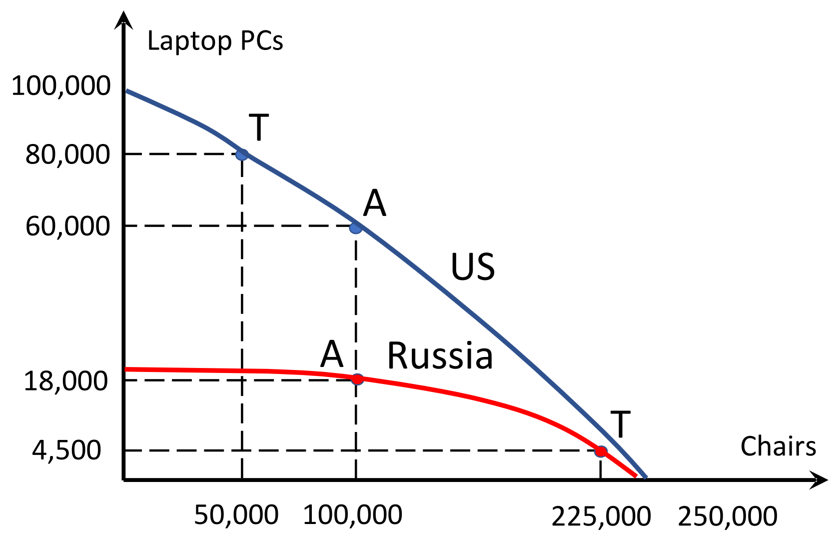

Figure 2. Production possibilities frontiers for the case of different technologies.

The workers that were employed in electronics were not overcompensating for shortage of engineers. Moving some of these workers to furniture would significantly lower computer production. Russia would not be able to produce enough chairs for export to compensate for far lower electronics production. And will, therefore, lose from free trade and redistribution of production.

Conclusions

We have considered Heckscher-Ohlin model of international trade under two different scenarios – a case of equivalent technologies in the trading partners and a case when technology in one of the countries is less efficient than in the other. We have illustrated the classical conclusions of the model under equivalent technologies – convergence of factor prices and mutual gains from trade. In the case of different technologies, on the other hand, we have demonstrated the opposite effect. The country with the less efficient technology loses from opening to trade with a more advanced partner, which in turn leads to divergence of factor prices – capital rental rage and wages – in favor of the latter.

The most important idea to demonstrate the above effect is the definition of capital in terms of input of labor into its creation and maintenance. This has important implications for the concept of capital mobility and foreign investment, especially in developing countries.

Who is the owner of capital and what is capital mobility? It has been argued that capital mobility is infinite since any investor any place in the world can buy shares of stock of any company. But from development economics perspective, is physical capital used in production of goods and services, mobile? The answer is a definite NO! The physical capital mobility is ZERO. To understand this, consider the following example. A manager at AvtoVAZ, the manufacturer of Russian Lada cars, is thinking, "The Russian engineers produce inefficient production machines and equipment, so I will exchange rubles for oil dollars, go out and buy a production line in Korea or Germany." Will the aforementioned AvtoVAZ manager be the owner of the capital? No, the owners of capital will remain those who created it. They will be paid in full for the use of this capital by AvtoVAZ either up front or over the years with interest. Obviously, the only thing AvtoVAZ will own is the present value of the expected value added that AvtoVAZ is hoping to receive in the future by selling cars assembled with the use of the acquired machines. What is the effect of this on Russia's economic development? The Lada's manufacturer (a Russian entity) will pay foreign creators of the production line (the real owner of capital) in full, Russian provider of car assembly lines will go out of business; Russia will fall back in economic development.

Do rich countries invest in poor countries? Consider an example, touted as "the largest foreign direct investment in Russia" – the purchase of a stake in a Russian oil company TNK by British Petroleum[8]. What is the actual value of foreign direct investment in Russia in this case? Correct! Zero! British Petroleum will contribute to this "investment" by purchasing oil drilling equipment outside of Russia and then using this equipment in Russia only to drill oil. Russia will not see a dime of this "investment," all the money will go to the real owners of capital – manufacturers of oil drilling equipment outside of Russia. The only thing that Russia will eventually receive is, obviously, money for crude oil extracted by BP.

Notice that the situation is different in trade between developed countries. Suppose Volkswagen sets up an assembly line in the US. It will probably use some machinery from German manufacturers, but also may purchase some process automation software, for example, from US suppliers. Similarly, if Ford sets up an assembly line in Germany it will probably buy some equipment or software from US vendors but also some machinery from German suppliers. In total, the amount of money spent on US-based and Germany-based suppliers may well equal the amount of money "invested in Germany" by Ford *plus* the amount of money "invested in the US" by Volkswagen. Therefore, the formally defined "foreign direct investment" by rich countries in rich countries may well reflect the actual investment. But if Ford sets up an assembly line in Russia, it will highly unlikely buy much from Russian suppliers of high-technology equipment. And clearly, the investment *in Russia* by Ford will be close to zero.

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