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Technology Unemployment and Productivity Improvement of Industrial Robot

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Abstract

The world is going through a big change called the fourth industrial revolution. Many articles have discussed the effect caused by this technology. In Keynes's work, the definition of technology unemployment has firstly been pointed out. The work of this paper is based on this and talking about the different effects between developed countries and developing countries. It is found that the industrial robot can enlarge the comparative advantage which can make the global division of labor clearer. Besides, There is also a new way to relieve the pressure of unemployment. It is better to control the robot by humans since it creates some extra posts.

Keywords

Global Trade, Technology development, R&D, Robot Technology.

1. Introduction

Nowadays the whole world is experiencing a big change called the Fourth Industrial Revolution. Unlike the First industrial revolution that used water and steam power to mechanize production, and the Second used electric power, Schwab (2017) [1] describe it as based on the third digital revelation and linked the physical, digital and biological spheres.

First, McKinsey company (2019) [2] point out that in the context of the Fourth Industrial Revolution, production is at the cusp of a paradigm shift driven by three technological megatrends: connectivity, intelligence and flexible automation. Connectivity is widely used in technology, which means connected devices together. Artificial intelligence, advances in computing power and the availability of big data are allowing machine learning algorithms to excel. Automation technology can currently automate 60% of all manufacturing tasks.

The second important part is Human-Machine-Interaction (HMI). In some case they are called robots. However, robots are not the whole part of HMI. Rosheim (2006) [3] pointed out that indeed, Leonardo da Vinci sketched a mechanical man around 1495, which has been evaluated for feasibility in modern times, which can be seen as the earliest example of a human-like machine. Goodrich and Schultz (2007) [4] says that emerging from the early work in robotics, human factors experts have given considerable attention to two paradigms for human–robot interaction: teleoperation and supervisory control.

Thirdly, a hot technology called 5G is also included in this paper. World Economic Forum (2020) [5] has pointed out a question 'How 5G and the Internet of Things can create a winning business?' 5G is powering the Fourth Industrial Revolution in the same way that steam, electricity and silicon powered the previous three. Outfitted with superpowers such as capacity, speed and lightning-fast response time, 5G provides a solid foundation for this the Forth Industrial Revolution. With faster and more reliable connectivity, industries can digitally transform their businesses and manufacture their products in much smarter ways. 5G are expected to become more widespread in the future, and bring enormous promotion to business.

Furthermore, impact on the high education has been paid lots of attention. There are more changes of curriculum. First, STEM becomes more and more important, and some new subjects appear. Secondly, Computer science will become one of the primary subjects in order to form the literacy of the fourth industrial revolution. Thirdly, New branches of basic subjects appear. Fourthly, some primary subjects integrate.

However, there are not only the benefit brought by technological development, but also several problems people should pay attention to.

First and foremost, unemployment risk raises with technological development. The most traditional view is that robot will replace some people's work. Automation is invading the economy at a fast and pervasive pace. Every conceivable activity that is codifiable and translatable into an algorithm is an activity that sooner or later is withdrawn from the hands of workers to be executed in a fast and precise way by robots. However, new research disagreed with this opinion, Borland and Coelli (2017) [6] find that the total amount of work does not appear to be decreasing; and the pace of change in the labour market is not accelerating. Lambert (2019) [7] carried forward this research by pointing out that Job losses will vary greatly across countries and regions, with the toll falling disproportionately on lower-skilled workers and on poorer local economies, aggravating social and economic stresses. This is also the motivation of this paper.

Besides, is technological progress always synonymous with pervasive economic prosperity? Gomes (2018) [8] pointed out that technological progress is the booster of economic prosperity. New ideas and their implementation have always been the engines of increased market activity. However, it is known that technological progress brings change, so even if the expected net effect is positive, there will certainly be fears and anxieties that should be carefully weighted and that cannot be overlooked.

Thirdly, the influence of the fourth industrial revolution on international relations. With the proceeding of development, the unprecedented technological transformation is taking place today and a period of exponential change labelled the Fourth Industrial Revolution is the name of this period. The world economic forum, the existence of the fourth industrial revolution will distort international relations. And there are three major determinants contributed to this field (mainly the geopolitical aspect): innovation, talent, and resilience. Mentioned by Klaus Schwab (2017) [9], the world economic forum, apart from the undeniable benefits brought by this technology breakthrough, threats cannot be neglected. One of the threats from this development on the international relations is on the international security aspect as it has changed the nature of conflict and it seems to exacerbate the inequality around the world.

The main problem this paper wants to find out is that the different effects in different aspects such as unemployment, education and R&D in different countries. By this way this paper want to find out the changes Fourth Industrial Revolution taken to the whole world, not only the countries that benefit from it.

2. Data analysis

Mentioned in the introduction, the fourth industrial revolution is driven by the cutting-edge technologies such as the introduction of robotics, this unprecedented development has brought a huge impact on the world in disparate aspects including both of the developed countries and developing countries. Here, we mainly intend to find out how the utilization of robots affects unemployment and productivity based on data.

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Since 2010, demand for industrial robots has risen considerably due to the ongoing trend toward automation and continued technical innovations in industrial robots, which can be represented from the figures below:

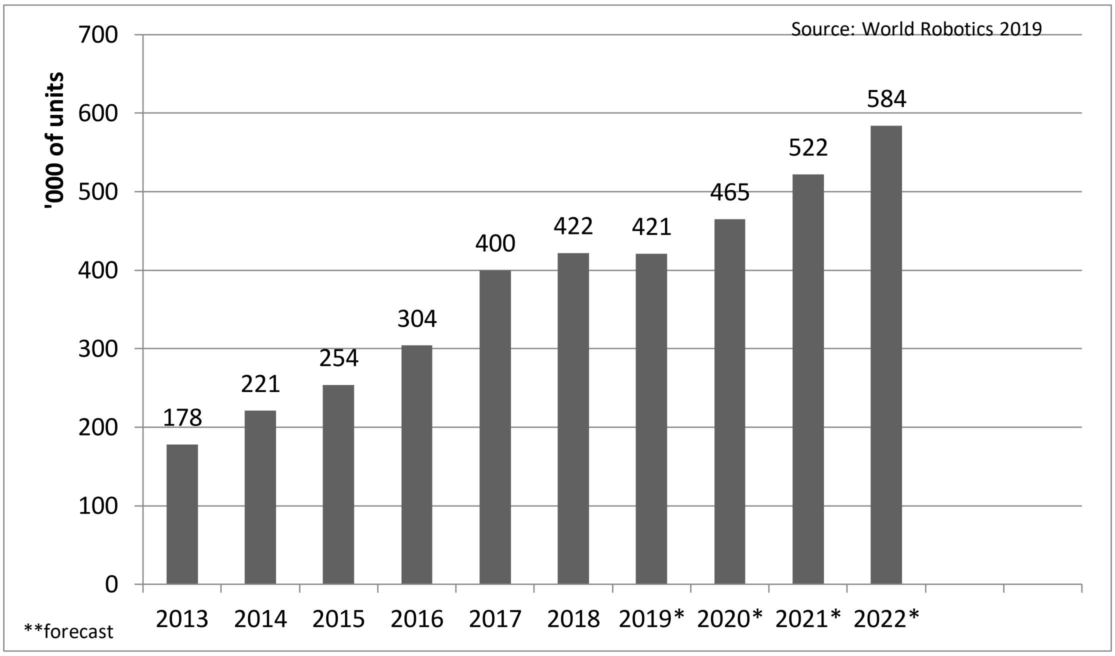

Figure 1 Annual installations of industrial robots 2013-2018 and 2019*-2022

Illustrated by Figure 1, there is a steady growth of global annual installations of industrial robots and the trend is projected to continue in the near future. Starting from 2013 to 2018, by calculation, the percentage growth of annual installations of the industrial robots is 19 on average per year. Though it was predicted to plateau in 2019 and the pace of increment might slow down, there is still an estimated 12% growth average per year in the near future. (IFR,2019)

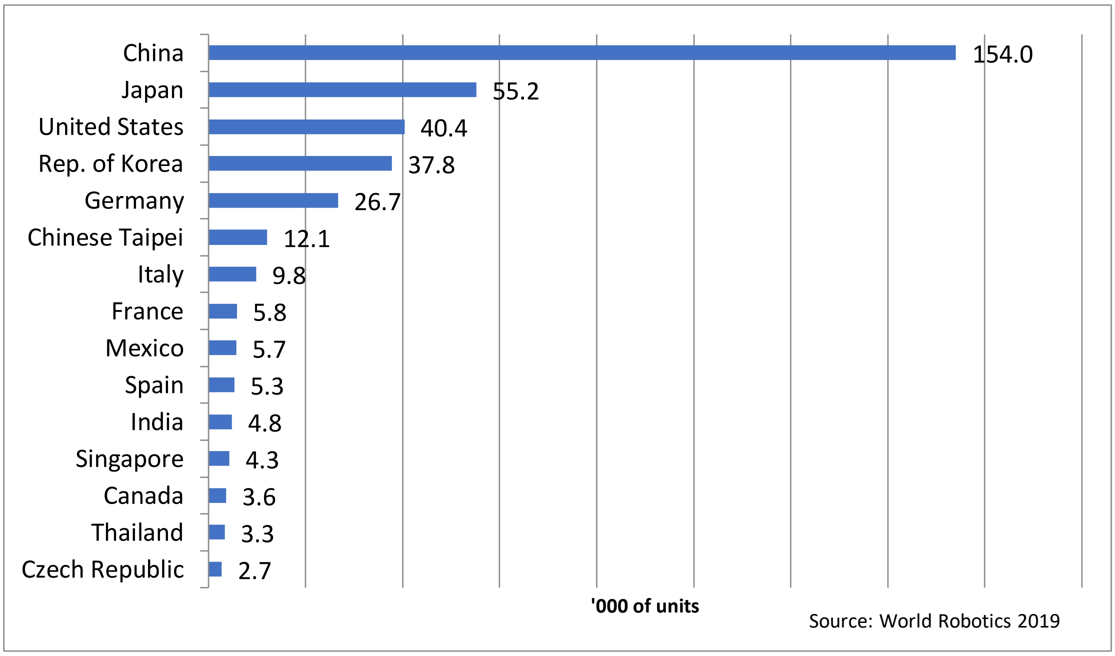

Figure 2 Annual installations of industrial robots 15 largest markets 201

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Throughout the world, we have witnessed an increase in the annual installations of industrial robots. Nevertheless, the utilization of robots varies by countries and the distribution of robots around the world is indeed unequal. Figure 2 has revealed that, by continents, Asia remains the highest industrial robot market including 7/15 top 15 largest markets for robots whereas according to table 1, using robots in the manufacturing process is still not prevalent in Africa. Specifically making an insight into countries, we discover that China remains the world´s largest industrial robot market with a share of 36% of total installations and the overall installation is more than the number of robots installed in Europe and the Americas together. Followed by China, Japan´s robot sales increased year by year, which has generated the highest value ever for the country. The average annual growth rate of 17% since 2013 is remarkable for a market with an already highly automated industrial production and causes Japan to be the second-largest market for robots. (IFR,2018) It's apparent that apart from the US and Germany, European countries and American countries are in the bit laggard positions around the world. Concerning African countries, focus on table 1, the usage of robots is less than 1% that of in Asia. Hence, due to the insufficient installation of robots in Africa, we might conclude that Africa is still not ready for the imminent march of robots and this also causes an imbalance of productivity around the world

In order to find out how the use of robotics influences productivity, we may have to pick out the most representative industry as a typical example to draw a conclusion. As disparate industries have the different annual installation of robots in accordance with the statistics conducted by the International Federation of Robotics, using the highest ranking industry which is the automotive industry, the correlation between productivity and robots might be the most direct. However, we have to use the countries which produce automobiles themselves and hardly import from others. Also we intent to compare the productivity between the African countries which do not have much robot utilization rate and a developed country which have a high ratio of using robots to manufacture cars, hence South Africa and Japan seem to be the appropriate countries to research on as Japan has 300 per 10000 manufacturing workers (IFR) whereas South Africa only has 28 per 10000 manufacturing workers.(though still quite high compare with other African countries) (consultant.co.za) In addition, to obtain how productivity is affected by robots, we use the year 1999 when robots were not so prevalent in production in Africa and 2018 when mechanization was already popular in both countries.

Table 1. numbers of automobiles produced in Japan and South Africa in 1999 and 2018

Countries / Years	Japan/per units produced	South Africa/per units produced
1999	9,895,476	317,367
2018	9,728,528	610,854

Source: Extracted from OICA

Vertically comparing the data for both countries, as Japan introduced robots in manufacturing in the early 1980s (IFR),the number of robots produced in both years had not played much of the differences by checking the Table 1. Nevertheless, unlike Japan, the vehicles produced nearly doubled in South Africa and that might be attributed to the usage of robots.

By conducting Horizontal comparison between the data for dual countries in 2018, it's evident that though South Africa commenced using massive robots in automobile industry, the automobiles produced were still a mere 6% of that manufactured in Japan and this might pertain to the huge differences in the disparity of robot per 10000 labor, which have shown us that productivity at least in the automobile industry has a positive relationship with the number

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of robots used in manufacturing. Moreover, we have also seen that Africa was trying its best to enlarge the scale of robots used in each industry.

However, another issue has aroused by this phenomenon. As robots may be regarded as the substitutes of labor in several low skilled industries, the introduction of robotics will cause the unemployment of labor. Represented by table 3 below about the unemployment of people who previously employed in skill level 1 jobs, which are the jobs involve repetitive and simple physical or manual tasks such as cleaning and vegetable picking according to ISCO made by the International Labor Office. As these jobs are most likely to be replaced by robots, we may implicitly conclude the trend of how the introduction of robots impacts on the unemployment through the comparison of the data pertaining to different countries in these jobs. (Japan and South Africa) in disparate years in table 2.

Table.2. the unemployment of people who previously employed in skill level 1 jobs

Area	Time	Unemployment of people who previously had skill level 1(low) jobs (thousands)
Japan	2009	19.0000
Japan	2015	140.0000
South Africa	2000	763.2777
South Africa	2019	876.0798

Source: Extracted from ILO.

It is evident that with time forward, there were notable increments in the unemployment of low skilled workers in both countries. For Japan, we've witnessed a 600% increase in unemployment for the low skilled workers from 2009 to 2015 as this revolution became more and more prevalent. As for South Africa, which is the country with the highest unemployment rate, was also deeply hurt by this revolution. Though the increment in percentage was not comparable with that in Japan, on the basis of high unemployment in the whole country, an additional 100 thousands of unemployment of people with low skills exacerbated this phenomenon. Also, both trends seemed to be maintained in the future unless feasible measures could be enacted.

Robots can also generate jobs as they displace the human workers and it was estimated that 133 million new roles would be created by robots as 75 million jobs displaced by them. (WEF, 2018) Nonetheless, these incoming new jobs might be more skillful, so reeducating the labor with low skills would be an alternative to opt for the governments around the world to reduce this issue in the long run.

3. Model

Consider the classical model with two countries, two goods setting. Labor is the only factor of production used and labor productivities are constant. Labor productivities are different between the two countries in an industry. And there is perfect competition in the product and factor markets. In this section, we want to find out the different effect made by industrial robots between developing countries and developed countries. So that we assume that the home country is a developing country and the foreign country is a developed country. In the traditional model, two countries will produce goods and services which they have comparative advantages, and it is normal for developing countries to specialized production. However, the foreign country's market is too large so that home country cannot satisfy. It means in this case, the foreign also need to produce both product 1 and 2.

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Let L be the fixed labor endowment in the home country and $L_j$be the employment of labor in industry j in the home country. Denote $a_{L_i} = \frac{L_j}{S_j}$, which means the labor hours per unit of good j needed in the home country. w is the money wage rate in home the country. The foreign counterparts are denoted with an asterisk.

3.1. Basic model without robot

In the traditional model, we made the assumption of constant returns to scale. In this model, it is also an important assumption because we want to use it to present the effect of the industrial robot. Firstly, we consider a market without the industrial robot. A competitive firm in an industry is a price taker. It chooses output to maximize profit facing constant product and factor price. The profit function in industry j is:

$$\pi_j = p_j S_j - wL_j = p_j a_{L_j}^{-1} L_j - wL_j, j = 1,2 \tag{1}$$

Maximization of π_j with respect to L_i yields the first-order condition.

$$\mathrm{w} a_{L_j} = p_j, j = 1,2 \tag{2}$$

It shows that the marginal cost is equal to the marginal revenue, which is the condition for any profit-maximizing firm. It also shows that the average cost is equal to the average revenue. With free entry and exit, a competitive industry can only earn zero profit in the long run. Also, the foreign country's counterparts are

$$w^* a_{L_j}^* = p_j^*, \mathrm{j} = 1,2 \tag{3}$$

In the Ricard system, the autarkic relative prices are readily obtained from the zero-profit conditions:

$$\frac{p_1}{p_2} = \frac{w a_{L_1}}{w a_{L_2}} = \frac{a_{L_1}}{a_{L_2}}, \frac{p_1^*}{p_2^*} = \frac{w^* a_{L_1}^*}{w^* a_{L_2}^*} = \frac{a_{L_1}^*}{a_{L_2}^*} \tag{4}$$

Since we have made the assumption of full employment, we get:

$$L_1 + L_2 = L_H \tag{5}$$

It can be written as:

$$a_{L_1} S_1 + a_{L_2} S_2 = L_H \tag{6}$$

Once the trade is opened up, it is commonly thought that the foreign country is dominated in both goods and therefore cannot compete. However, in the conclusion of Ricardian theory, with the existence of comparative advantage, the home country will choose to specialized product goods 1 when:

$$\frac{\mathrm{a}_{L_1}}{\mathrm{a}_{L_2}} < \frac{a_{L_1}^*}{a_{L_2}^*} \tag{7}$$

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In this case, since home country chooses to specialize in producing goods 1, the full employment condition can be written as:

$$a_{L_1} S_1 = L_H \tag{8}$$

3.2. Basic model with robot

Now if we take industrial robot into consideration, we assume that foreign chooses to do R&D for the industrial robot, since the small country is lack of technology to make R&D by itself. Since in this model labor is the only factor and keeps the same across industries. So R&D is from exogenous technology shock that brings robots rather than created by high-skilled labor.

We use a_R to show the number of robots needed to produce the product i. to find out this technology revolution to the small country, we assume that the robot can only be used in industry 1. Besides, we assume that the home country and the foreign country utilize robot at the same rate:

$$a_{L_1} \rightarrow \alpha a_{L_1} + (1-\alpha) a_R \tag{9}$$

$$a_{L_1}^* \rightarrow \alpha a_{L_1}^* + (1-\alpha) a_R^* \tag{10}$$

We make these three assumptions:

I) The foreign country will consume ${L_R}^*$ of labor to do the R&D. ${L_R}^*$ is a general function of α and a_R. We assume that $\frac{\delta {L_R}^*}{\delta \alpha} < 0$, which means the more investment in R&D, the more robot will replace the human. And $\frac{\delta {L_R}^*}{\delta a_R} < 0$, which means the more investment in R&D, the more efficient the product will be.

II) The same rate of the robot is exogenous determined. In our paper, we do not consider the case that the small country can decide the rational rate of the robot. This can be a further research direction in further discussion.

III) The productivity of robots is larger than humans, which can be written as $a_R < a_{L_i}$. This assumption makes it meaningful for countries to replace humans with the robot.

Now we consider the new profit function in industry 1 in the home country is:

$$\pi_1 = p_1 S_1 - w L_1 = p_1 \left[\alpha a_{L_1} + (1-\alpha) a_R\right]^{-1} - w L_1 \tag{11}$$

Maximization of π_1 with respect to L_1 yields the first-order condition.

$$\mathrm{w}\left[\alpha a_{L_1} + (1-\alpha) a_R\right] = p_1 \tag{12}$$

And the full employment condition is changed into:

$$L_1 + L_2 = L_H \tag{13}$$

$${L_1}^* + {L_2}^* = L_F - {L_R}^* \tag{14}$$

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And now we get the first question. Since the productivity of industry 1 has improved because the foreign country chooses to do R&D. In this case, the foreign country should have the motivation to produce goods 1 by itself. To find out this we begin our analysis.

4. Analysis

Our analysis will begin at the comparative advantage. We want to find out if this kind of shock will change the trade condition between these two countries. And then we will discuss the advantage home country can get from the R&D. Finally, we will talk about the difference between robot-replacing-human and human-robot interaction.

Proposition 1: The technology development will enlarge the comparative advantage, it means that the small country will be more motivated to produce the goods 1 and take part in the global trade.

Proof:

$$\frac{\alpha a_{L_i} + (1-\alpha)a_R}{\alpha a_{L_i}{}^* + (1-\alpha)a_R{}^*} < \frac{a_{L_1}}{a_{L_1}^*} < \frac{a_{L_2}}{a_{L_2}^*} \tag{15}$$

This proposition solved the first question we have just put forward. With the increase in productivity, the foreign country may have the motivation to produce goods 1 by itself. However, we have proved that the comparative advantage will increase. For a profit-maximize firm in the foreign country, the best choice is to import goods 1 from developing countries since they have a larger increase in the productivity of goods 1. This case is really common in many countries since a small country has a better land or managerial condition in some traditional industries. They can benefit more from technological development in these industries.

In this proposition, we proved that one of the advantages of R&D is that it can help to make the global division of labor clearer. However, it also causes another problem called Prebisch-Singer dilemma. The traditional goods small country produced mostly are the raw material. If developed countries did R&D in this industry, and there is a more obvious comparative advantage, the developing country may hard to jump out of the poverty trap.

Before we begin our discussion of proposition 2. It is necessary for us to introduce the difference between human-machine-interaction and robot-replace-human. If our robot needed to be controlled by humans, then we call it human-machine-interaction, which means the total labor will hold L_H. But if the robot will replace the human, and then the total labor of small country will change to $L_H - L_U$, where L_U means the unemployment caused by industrial robots. And now we get proposition 2:

Proposition 2: Whether what kind of robot the small country use, only if the total value of the rest of employment persons are higher than before can the small country benefit from this technology development.

Proof: Since the small country can only produce the goods 1, the gain of it can be written as:

$$G_1 = \frac{L_H - L_U}{\alpha a_{L_1} + (1-\alpha)a_R} p_1^t \tag{16}$$

Where the subscribe 't' means the new price when the trade is opening. With the maximize profit condition we also have:

$$p_1^t = w_1^t\left[\alpha a_{L_1} + (1-\alpha)a_R\right] \tag{17}$$

With the (16) and (17), we can get:

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$$G_1 = (L_H - L_U)w_1^t \tag{18}$$

This is also true when we change L_H to $L_H - L_U$

This function provided a new way for us to evaluate whether the robot is worth buying. To make sure that the small country can gain from the technology, it must make sure that $(L_H - L_U)w_1^t > L_H w_1$, where L means the human labor of the small country, w_1^t means the equilibrium wage of the labor when import the robot. The importance of this proposition is that the traditional view of robot always forces the value of robots and the human being it can replace. However, when considering the rest of the employment people, we should also take care that their wages may be increase or decrease.

Proposition 3: The human-machine-interaction is always better than the robot-replace-human if they can improve the same rate of productivity since they will reduce the pressure of unemployment.

The proof of this proposition is obvious so we omit it. The reason is that if we choose to control the robots by humans, the pressure of unemployment will decrease. The problem of technology unemployment has been discussed in many researchers' work, which firstly is raised by Keynes (1930). Just like the discussion before, there are many different views of it. Some say that technology unemployment is a big problem while some say that the total number of workers does not decrease.

The proposition 3 of us wants to provide another way to solve this problem. If these industrial robots can be controlled by humans, those who are supposed to lose their job can choose to learn how to control the industrial robot so that to decrease the risk of unemployment. In our discussion, it means the $L_H - L_U$ finally comes back to the L_H. There is another reason why we should use the human-machine-interaction robot, we may also cut off the R&D cost since it seems that the human-machine-interaction robot is less expensive.

5. Summary

This article is based on the work of Lambert (2019), in his article he says the job losses caused by robots will vary greatly across countries and regions. So, in our model, we discuss a market with a developing country and a developed country. With the basic set of Richerad model, we discuss the comparative advantage with the existence of robots, the gain from the robot and the comparison between two kinds of the robot.

The first finding is that the comparative advantage will enlarge so that there is a more obvious global division of labor. It seems that the small country can enjoy a better efficiency in their advantage industry since its basis in this country is better. The next finding gives us a new way to assess whether we should use the industrial robot or not. If the industrial robot can increase the total value of the rest of the employment, it is valuable. Finally, we proved that the human-machine-interaction is always better than the robot-replace-human robot. The former can solve the problem of unemployment in this way.

Our further discussion can force on a market with two factors. Because it is not obvious for us to present the developing country and developed country, if we want to let this model more general, we should discuss a labor-intensive country and a capital-intensive country. In this setting, we can explain our analysis more clearly. The industrial robot can replace the worker so that it will have a severer effect on the labor-intensive country.

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