Research on the Substitution Effect of Industrial Robot for Labor—Evidence from J Auto Company

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Keywords: Manufacturing Enterprises, Industrial Robot, Substitution Effect for Labor, Case Study.

Abstract. Based on the theory of technical substitution rate and the Life Cycle Cost theory, this research designs the measurement model of robot substitution effect and analyzes the dynamic costs of industrial robot and labor. Then, by using welding robot of J auto company’s R model as an example, validates the effectiveness of this method. Finally the paper concludes that robots have a competitive advantage in the manufacturing process.

Introduction

Since the 1970s, robot has been widely used in various fields in the industrialized countries. In recent years, with labor costs soaring, more enterprises begin the large-scale use of industrial robots. According to reports, the robot utilization in some positions of Foxconn reached up to 70\%\textsuperscript{[1]}, but the rate was only 0.23\% in China, far from the international average of 0.58\% \textsuperscript{[2]}. It only reflects to the lost jobs due to the robot production, but how to analyze the new production mode, especially the complex dynamic cost, the production efficiency and so on, remains to be discussed in this paper.

Literature Review

The Substitution Effect of Industrial Robots

The substitution effect refers to the demand of commodities changes with relative prices, to explain the effects of price changes on consumer demand preference. With the wide application of industrial robots, scholars begin to pay close attention to the robot substitution effect research.

Some scholars believe that the robot replacement is inevitable, which cuts more jobs than create new positions and leads to hundreds of thousands of job losses in the USA.\textsuperscript{[3]} On the contrary, some scholars consider that the robot does not reduce the employment, it improves employment structure, and enhance the value of human capital in Japan and Germany.\textsuperscript{[4]} Also existing researches show that substitution effect is different so the emerging economies should cautiously take advantage of the robot based on their own situation.\textsuperscript{[5]}

Stephen J. DeCanio (2016), based on the C-D production function, the relationship between output and per capita wages, and jobs created and disappeared with the use of robots, built a model of the robot promotion effect on
average incomes and employment opportunities to analyze the robot substitution effect, and summarized the influence on human life in different substitution coefficients.\textsuperscript{6} Dong Bingbing (2015), based on the input function of the robot and the labor force cost to analyze the robot's replacement process, concluded that robot replacement is inevitable.\textsuperscript{7}

\textbf{The Measurement of the Substitution Effect}

Compared with the rich discussion of other essential productive factors’ replacement, the research on the quantitative measurement of robot substitution effect is scarce.

Noh, Sookack and Younghwan, Son (2016), based on the respective economic value of forest and carbon dioxide emissions, analyzed the substitution effect between the total amount of forest resource and bottom dust.\textsuperscript{8} Wu, Li Qiang (2015), based on the two key factors—the energy consumption and the cost—established an analysis model of the alternative effect between electric heating and traditional coal-fired heating, and concluded that the optimum heating mode was mainly the ground source heat pump and auxiliary power boiler.\textsuperscript{9} Bai Xue (2016) analyzed the ratios between the input and the cost under fixed output conditions of different programs, and discussed the substitution effect of electricity on coal in the use of the boiler.\textsuperscript{10} Wu Libo et al. studied the output elasticity and substitution elasticity of capital and labor in the production in China, and discussed the relationship between capital-labor substitution to industrial production and regional economy.\textsuperscript{11} Li Hongsong (2010) chose the amount of capital per capita as the technical feature of capital-labor substitution, analyzed the capital-labor substitution trends in different sectors, and then discussed the capital-labor substitution effect on the enlargement of employment.\textsuperscript{12}

Through the literature analysis above, we find that there are two mainstreams to discuss the substitution effect: the one is analyzing the output elasticity of different factors based on the production function, and the other is employing the marginal technical substitution rate to compare the cost and output variances. The former, in requirements of high quality and big time span data, is suitable for macro level analyses. Since the time is short, and the data content is usually too simple, so the latter seems more sensible at enterprise level. This paper attempts to establish a model to analyze the industrial robot substitution effect with the alternative benefit analysis method based on the input-output ratio and illustrates a case study.

\textbf{Example Analyses}

\textbf{Example Background}

J company was established in September 30th, 1999, with total assets of 5 billion 300 million Yuan, and more than 17,000 employees. The company, listed on the Shanghai stock exchange in 2001, was successful in the implementation of non tradable shares reform in year 2005. The company sold more than 350 thousand vehicles of all types in the year of 2016, and the products cover heavy trucks, large passenger cars, commercial vehicles and passenger cars. The whole vehicle production process are mainly divided into five steps, this paper chooses
the most widely used welding robot, that is take R model’s welding robot as an study example.

The 15 Hyundai welding robots were being used in production since 2003, and have been used for more than 12 years by now. In welding process, welding robot is responsible for the welding of the outside 2,454 welding points, while the workers are mainly responsible for the door and inside of the car 1,418 welding points. According to the spot observation, every welding point is almost the same in processing time, processing complexity, processing methods and other aspects, so this paper only considers the quantity of the solder joints.

Model Building

Variable Selection.

Based on the Life Cycle Cost theory (LCC), the possible industrial robots costs generally include 5 courses, and the labor costs are also divided 5 basic subjects. These variables are shown in Table 1:
Table 1. Variables of the Cost of Using Industrial Robots and Labor.

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable name</th>
<th>Variable content</th>
<th>Data acquisition and processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>Workload of robot</td>
<td>$N_R = N_{SPR} \times N$</td>
<td>$N_{SPR}$ is the workload of robot in the unit product, 2454 solder joints / car as provided by the company.</td>
</tr>
<tr>
<td></td>
<td>Workload of labor</td>
<td>$N_L = N_{SLP} \times N$</td>
<td>$N_{SLP}$ expresses the workload of labor in the unit product, 1418 solder joints / car as provided by the company.</td>
</tr>
<tr>
<td></td>
<td>Administration cost</td>
<td>$C_{adm}$</td>
<td>The basic management and control of robot needs responsible administrators, therefore, the administration cost is in accordance with the actual arrangement of the administrator's costs and safety cost.</td>
</tr>
<tr>
<td></td>
<td>Maintenance cost</td>
<td>$C_{rr}$</td>
<td>Maintenance mainly refers to the routine maintenance and non-routine maintenance. Regular maintenance is the machine management specialist to solve the machine non-hardware failure. However, if industrial robot needs repair, it will need to repair or replace parts. Since it is not conventional maintenance, this maintenance will produce maintenance costs.</td>
</tr>
<tr>
<td></td>
<td>Equipment cost</td>
<td>$C_{ep}$</td>
<td>Costs arising from the purchase or lease of industrial robot equipment. Each Korean Hyundai hx165 welding robot cost 600 thousand in 2003, considering the interest rates of each year, shown in fig 4, this paper can get the equipment cost.</td>
</tr>
<tr>
<td></td>
<td>Produce cost</td>
<td>$C_{pr}$</td>
<td>Cost of using industrial robot to produce. Provided by the company and calculated according to the actual number of occurrence.</td>
</tr>
<tr>
<td></td>
<td>Waste product cost</td>
<td>$C_{wpr}$</td>
<td>The cost of the waste produced in the production of industrial robot and the cost of reprocessing it. According to the results of marketing department, there is almost no vehicle scrap, the rejection rate is close to 0, and the qualified rate is 1.</td>
</tr>
</tbody>
</table>
Table 1. Variables of the Cost of Using Industrial Robots and Labor
(Continued).

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable name</th>
<th>Variable content</th>
<th>Data acquisition and processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration cost</td>
<td>$C_{2t}$</td>
<td>The cost of training, recruiting and other activities of the enterprise to the labor force</td>
<td>In accordance with the &quot;People's Republic of China enterprise accounting principle&quot;, training costs in terms of 1.5% of wages, considering the J company’s state-owned background and the nature of the welder position, this paper assumes that the cost of recruitment and severance is similar to the cost of labor union activities about 2% of wage, summing up to 3.5% of wage.</td>
</tr>
<tr>
<td>Wage cost</td>
<td>$C_{Lw}$</td>
<td>Wages paid to the labor force</td>
<td>Calculated according to the private unit’s average annual wage of workers in the manufacturing industry in the H city where J company is located. The data is obtained from the statistical yearbook of H City.</td>
</tr>
<tr>
<td>Labor cost</td>
<td>Waste product cost</td>
<td>$C_{2w}$</td>
<td>The cost of the waste produced in the production of labor force and the cost of reprocessing it</td>
</tr>
<tr>
<td>Produce cost</td>
<td>$C_{2y}$</td>
<td>Cost of using labor force to produce</td>
<td>Provided by the company, the total annual maintenance cost of welding tools in welding workshop is about 10000 Yuan, and other production cost is calculated according to the actual number of occurrence.</td>
</tr>
<tr>
<td>Welfare cost</td>
<td>$C_{1w}$</td>
<td>The cost of social insurance and other welfare items</td>
<td>In accordance with the &quot;Labor Law of People's Republic of China&quot; and the employee benefit level of J company, housing provident fund is 10% of wage, social insurance costs is 20% of wage, and other welfare fees are 14% of wage. Thus, the cost of labor welfare is 44% of wage.</td>
</tr>
</tbody>
</table>

The Measurements Model of Substitution Effect.

(1) The substitution effect of industrial robot for labor $S_{R-L}$:

$$ S_{R-L} = \frac{C_R}{C_L} $$

(1)

(2) The calculation methods for $C_R$:

$$ C_R = \frac{C_{RM} + C_{RR} + C_{RE} + C_{WR} + C_{PR}}{N_R} $$

(2)
(3) The calculation methods for $C_L$:

$$C_L = \frac{C_{LS} + C_{LM} + C_{LB} + C_{WL} + C_{PL}}{N_L}$$

(3)

(4) Application of the measurements model

Since industrial robots have various applications, we can compare the pros and cons of the use of industrial robots. $S_{R-L}$ is a real number between 0 and infinity. When $S_{R-L} < 1$, the economic efficiency of industrial robots is higher; when it is 1, it is the same; when $S_{R-L} > 1$, it is not as well as the labor force.

Date and Result Analysis.

As mentioned above, the welding robot substitution effect of J company’s R model is $S_{R-L} = \frac{C_R}{C_L}$. The calculation results and substitution effects are respectively shown in Fig.1 and Fig.2:

![Figure 1. Comparison of the Robot Cost and Labor Cost.](image1)

![Figure 2. The Substitution Effect of Industrial Robot for Labor.](image2)

The result shows that the substitution effect of welding robot is less than 1, and the general trend of the substitution effect of welding robot is increased. From 2006 to 2007, and 2012 to 2013, the substitution effect of welding robot has a slight decrease, the volatility of 2006 to 2007 is due to the relatively slow rise in labor wage, and the fluctuation of 2012 to 2013 is attributed to the depreciation of the welding robot equipment, the welding robot production cost as well as maintenance cost increased.
Due to the availability of data, a series of approximate methods are used to deal with the labor cost in this paper, such as the level of labor wage, administration (of labor) costs, etc., and neglected the problem of labor risk in the production. Therefore, the labor cost may be underestimated, so in the actual sense the welding robot substitution effect should be higher than the result of this paper.

**Conclusion & Discussion**

(1) With the possibility of underestimated cost of labor, the economic benefit of the industrial robot is nearly 3 times higher, so in the context of rising wages, manufacturing enterprises may tend to industrial robots. Although in the initial stage the equipment purchase/lease cost, the cost of transformation and other costs are high, in the long run, the economic benefits of the usage of industrial robots increase.

(2) After the introduction of industrial robots, the work changes from direct operation into the management of the robot operation. Great changes have taken place in the organizational structure, management processes and standards, labor mode, knowledge management, employee career development and other aspects of profound. Especially in the case of the coexistence of industrial robot production and labor production, how to deal with these problems will become the key to industrial robots maximum benefits and the enterprise’s competitiveness.

(3) In view of the fact that industrial robot has great alternative benefit to the labor force, the introduction of industrial robots for production will be accompanied by the treatment of original staff, which is likely to harm the social benefits of enterprises. Therefore, enterprises should do a good job in the work of the staff; to ensure minimizing the damage to the social benefits of enterprises as well as enormous economic benefits.

(4) Since this paper is a measuring substitution effect of industrial robots, it didn’t consider the social benefits of using industrial robots. If this factor is taken into account, it may have arrived at a different conclusion.

**Acknowledgement**

This research was financially supported by the National Social Science Foundation, for the key research “Study on the synergistic effect of material capital and knowledge capital on economic development”. (No.13AJY004).

**References**


