

# Does Labor-Saving R&D Hurt Labors?

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## Abstract

In this paper, we consider a right-to-manage model with a monopolist in the final goods market. We investigate how the wage determination of labor union affects the firm's Labor-Saving R&D strategy. We find that if the labor union determines a higher wage, the monopolist may not produce less output or undertake more R&D investments. Besides, we also find that if the firm undertakes Labor-Saving R&D, then the total gains of labor may not decrease.

## Keywords

Labor Union, Labor-Saving R & D

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## 1. Introduction

From the early beginning of the 21th century, the international division of labor has been more popular since the labor wage in developed countries becomes higher and higher. One of the reasons for enhancing the labor wage to grow up is the effort of the labor union. A strong labor union may have a stronger bargaining power to negotiate with firms, but that will also induce firms to move their factories to other countries. However, there are still lots of factories stayed in developed countries, but most of them have applied much industrial automation equipment (IAE) to reduce labor cost in their production process.

The annual report of the International Federation of Robotics (IFR) [1] reveals that “In 2017, the average robot density in the manufacturing industry was 85 robots per 10,000 employees. Europe is the region with the highest robot density with an average value of 106 units. In the Americas, the value is 91 units, and in Asia/Australia it is 75 units”. The average of robot density in Europe and America may imply that the factory, which was located in the country with a high level of average labor wage, may apply more automated machines to reduce the demand for labor. In fact, there are many reasons to support developed countries' high level of labor wage; one of them is because of the power of labor

union being stronger in the developed countries. Therefore, we are interested in how the wage determination of labor union affects the firm's Labor-Saving R&D strategy.

In the past empirical literature, Menezes-Filho and Van Reenen [2] show that there is no consensus among empirical studies on which way unions affect. Besides, there are only a few papers which analyzed the firms' Labor-Saving R&D strategy, even lots of labor union theoretical literature have been well discussed before.<sup>1</sup>

Tauman and Weiss [3] investigate a patent race game for a Labor-Saving innovation and show that a unionized duopolist has stronger incentives to adopt the innovation than its non-unionized counterpart. Dowrick and Spencer [4] show that if the union's elasticity of substitution is small, the union will oppose innovation under there being a single wage-setting union in an industry.

Accordingly, we investigate how the firms' strategy of Labor-Saving R&D affects wage determination by the labor union. We consider a right-to-manage model for the labor union and have the following findings. Firstly, if the labor union determines a higher wage, the monopolist may not produce less output or undertake more R&D investments. Secondly, the labor union determines a higher wage may not induce the monopolist to reduce the demand for labor. Finally, the monopolist undertakes R&D may not force labor union to lower the level of wage and may harm the monopolist's profit.

The rest of this paper is organized as follows. In Section 2, we construct a basic related market model without R&D. In Section 3, we investigate how the monopolist undertaking R&D affects the decision of the labor union. Section 4 is our conclusion.

## 2. Basic Model

Assume that the labor market unionized and the reservation wage of labor is  $z$ , which is assumed to be zero, for simplicity. The utility of the labor union is  $\phi = wL$ , where  $w$  is wage and  $L$  is the number of workers employed. In order to analyze the effects of the labor unions in the simplest way, we assume that each labor union has full bargaining power to determine wage. We consider a right-to-manage model of labor union where the unions determine wages and the firm hire workers according to their requirements.

We assume there only exists a monopolist producing final goods. The monopolist faces an inversed demand as  $P = a - Q$ , which  $a$ ,  $P$  and  $Q$  are market scale, price, and output of monopolist respectively. In this section, we assume that the monopolist producing one product needs to hire one worker. The total worker employed  $L$  is therefore equal to  $Q$ . We assume that production requires only workers, which means that we assume the production cost is zero. As a consequence,<sup>1</sup>Other papers which consider both labor union structure and firms R&D strategy can see Ulph, and Ulph [5] [6] [7], Haucap and Wey [8], Mukherjee *et al.* [9] Manasakis and Petrakis [10], Mukherjee and Pennings [11], Kesavayuth and Zikos [12], Basak and Mukherjee [13], Beladi and Mukherjee [14].

quence, the monopolist's profit is  $\pi = (P - w)Q$ .

We consider the following game. At stage 1, the labor union determines wage. At Stage 2, the monopolist hires workers according to their requirement and determines the output to maximize its profits. We solve the game through backward induction.

Standard calculations give the equilibriums as:  $w^o = a/2$ ,  $P^o = 3/4a$ ,  $Q^o = a/4$ ,  $\phi^o = a^2/8$ ,  $\pi^o = a^2/16$ , the superscript o indicates the non-R&D case.

### 3. R&D Model

In this section, we assume the monopolist undertakes the Labor-Saving R&D for reducing labor demand per unit, such as installing automated production machinery. Assume that the monopolist's amount of investment  $x$  will reduce  $x\%$  of worker demand. The monopolist's labor demand is therefore rewritten as  $(1 - x)Q$ , implying that monopolist profit and the utility of the labor union could be  $\pi = [P - c - w(1 - x)]Q - x^2/2$  and  $\phi = w(1 - x)Q$  respectively.

Accordingly, the game structure is now rewritten as follows. At stage 1, the labor union determines wage. At stage 2, the monopolist hires workers according to their requirement and determines the output and amount of R&D to maximize its profits.

Firstly, we can solve the equilibriums of  $Q$  and  $x$  by maximizing the monopolist profit in stage 2. Standard calculations give the equilibriums as<sup>2</sup>:

$$Q = \frac{a - w}{2 - w^2}, \quad (1)$$

$$x = \frac{w(a - w)}{2 - w^2}, \quad (2)$$

The Equation (1) and (2) show that the impacts of an increase in  $w$  on  $Q$  and  $x$  are<sup>3</sup>

$$\frac{\partial Q}{\partial w} = -\frac{2 - w(2a - w)}{(2 - w^2)^2} \geq 0, \text{ for } a \geq a_1 \quad (3)$$

$$\frac{\partial x}{\partial w} = \frac{a(2 + w^2) - 4w}{(2 - w^2)^2} \geq 0, \text{ for } a \geq a_2 \quad (4)$$

Hence, the following proposition is immediate.

**Proposition 1:** *If the monopolist undertakes the R&D for reducing labor demand per unit, a higher wage may not induce the monopolist to produce less output or undertakes more R&D. In detail, if the market scale is relatively large (small), an increase in  $w$  will induce the monopolist to produce more (less).*

Firstly, an increase in  $w$  will induce the monopolist to produce less, which is

<sup>2</sup>The non-negative output condition is  $a > w$ .

<sup>3</sup>When  $a = (2 + w^2)/2w \equiv a_1$ , we can find  $\partial Q/\partial w = 0$ . Furthermore, if  $a > a_1$ ,  $\partial Q/\partial w > 0$ ; otherwise, if  $a < a_1$ ,  $\partial Q/\partial w < 0$ . When  $a = 4w/(2 + w^2) \equiv a_2$ , we can find  $\partial x/\partial w = 0$ . Furthermore, if  $a > a_2$ ,  $\partial x/\partial w > 0$ ; otherwise, if  $a < a_2$ ,  $\partial x/\partial w < 0$ .

called as the direct output effect. On the other hand, an increase in  $w$  will also increase the incentive for R&D to hire less labor, and thus the monopolist may produce more due to a lower marginal cost. We call this effect as the indirect output effect. Hence, the total effect of an increase in  $w$ , which is the sum of the direct and the indirect output effect, may induce the monopolist to produce more or less. In detail, when the market scale is relatively large ( $a > a_1$ ), the indirect output effect is larger than the direct effect. Because a large market scale will lead to more labor-saving R&D undertaken by the monopoly, the higher labor-saving R&D may result in a larger indirect output effect. Thus, an increase in  $w$  will induce the monopolist to produce more. Contrarily, the monopolist will produce less when the market scale is relatively small ( $a < a_1$ ) due to a smaller indirect output effect.

Secondly, an increase in  $w$  will also increase the incentive for R&D to hire less labor, as we mentioned before. We so called this as the direct R&D effect. Besides, fewer outputs implying the marginal benefit of R&D decreases, and consequently the monopolist will undertake less R&D, which is called as the indirect R&D effect. Therefore, whether an increase in  $w$  will induce the monopolist to undertake more R&D or not depends on the total R&D effect which is the sum of the direct and the indirect R&D effect. In detail, if the market scale is relatively large ( $a > a_1$ ), the direct R&D effect is larger than the indirect effect. Thus, an increase in  $w$  will induce the monopolist to undertake more R&D. Otherwise, the monopolist will undertake less R&D if the market scale is relatively small ( $a < a_1$ ) due to a smaller indirect output effect.

Accordingly, we can further solve the optimal  $w^*$  by maximizing the utility of labor union as:

$$w^* = \begin{cases} a - \sqrt{a^2 - 2}, & \text{for } a > \sqrt{2}, \\ \frac{2 - \sqrt{4 - 2a^2}}{a}, & \text{for } a \leq \sqrt{2}. \end{cases} \quad (5)$$

The superscript \* indicates the equilibrium of R&D case. Next, Standard calculations give the equilibriums as:

$$x^* = \begin{cases} \frac{1}{2}, & \text{for } a > \sqrt{2}, \\ \frac{2 - \sqrt{4 - 2a^2}}{4}, & \text{for } a \leq \sqrt{2}, \end{cases} \quad (6)$$

$$Q^* = \begin{cases} \frac{a + \sqrt{a^2 - 2}}{4}, & \text{for } a > \sqrt{2}, \\ \frac{a}{4}, & \text{for } a \leq \sqrt{2}, \end{cases} \quad (7)$$

$$\pi^* = \begin{cases} \frac{a^2 - 2 + a\sqrt{a^2 - 2}}{8}, & \text{for } a > \sqrt{2}, \\ \frac{a^2 - 2 + \sqrt{a^2 - 2}}{8}, & \text{for } a \leq \sqrt{2}. \end{cases} \quad (8)$$

$$\phi^* = \begin{cases} \frac{1}{4}, & \text{for } a > \sqrt{2}, \\ \frac{a^2}{8}, & \text{for } a \leq \sqrt{2}. \end{cases} \quad (9)$$

Therefore, we can compare the equilibriums of non-R&D and R&D case as follows

$$w^* - w^0 = \begin{cases} \frac{a - 2\sqrt{a^2 - 2}}{2} \geq 0, & \text{for } a \leq 2\sqrt{\frac{2}{3}}, \\ \frac{4 - a^2 - 2\sqrt{4 - 2a^2}}{2a} > 0, & \text{for } a \leq \sqrt{2}, \end{cases} \quad (10)$$

$$Q^* - Q^0 = \begin{cases} \frac{\sqrt{a^2 - 2}}{4} > 0, & \text{for } a > \sqrt{2}, \\ 0, & \text{for } a \leq \sqrt{2}, \end{cases} \quad (11)$$

$$\pi^* - \pi^0 = \begin{cases} \frac{a^2 - 4 + 2a\sqrt{a^2 - 2}}{16} \geq 0, & \text{for } a \geq \frac{2(3^{3/4})}{3}, \\ \frac{a^2 - 4 + 2\sqrt{4 - a^2}}{16} < 0, & \text{for } a \leq \sqrt{2}. \end{cases} \quad (12)$$

$$\phi^* - \phi^0 = \begin{cases} 0, & \text{for } a \leq \sqrt{2}, \\ \frac{2 - a^2}{8} < 0, & \text{for } a > \sqrt{2}, \end{cases} \quad (13)$$

The following proposition summarizes the above results.

**Proposition 2:** *If the monopolist undertakes the Labor-Saving R&D, then we have the following findings. Firstly, the Labor-Saving R&D may not reduce the wage of labor and may not decrease the total gains of labor. In detail, if the market scale is relatively small (large), then the labor union will determine a higher (lower) wage. Secondly, the Labor-Saving R&D may not induce the monopolist to produce more and also may not increase its profits. In detail, if the market scale is relatively large (small), the monopoly will gain (loss) from Labor-Saving R&D.*

The intuition is as follows. Firstly, the monopolist undertaking R&D will lead to lower demand for labor, which brings a negative incentive for the labor union to determine a lower wage. However, the labor union may also have a positive incentive to determine a higher wage since the labor union determining a lower wage leads to a higher output level which enhances the demand for labor. Consequently, the labor union determining a higher or lower wage depends on whether the positive incentive is larger than the negative incentive or not. In detail, if the market scale is relatively small ( $a < 2\sqrt{6}/3$ ), then the labor union will determine a higher wage. On the contrary, if the market scale is relatively large ( $a > 2\sqrt{6}/3$ ), then the labor union will determine a lower wage.

Secondly, Proposition 1 shows that an increase in wage also has two effects on outputs. The direct output effect may lead to a lower output level, and the indi-

rect output effect may induce the monopolist to produce more outputs. In sum, we find that the monopolist undertaking R&D may not result in a lower equilibrium of outputs to the monopolist.

Finally, by combining the above effects, the monopolist's profit of R&D case will larger than non-R&D case if the market scale is large enough ( $a > 2(3^{3/4})/3$ ). Otherwise, if the market scale is relatively small ( $a > 2(3^{3/4})/3$ ), the monopolist undertakes R&D may harm its profit.

#### 4. Conclusion

In this paper, we analyze how the wage determination by labor union affects the firm's R&D behavior. We find that a higher wage which determined by labor union may not induce the monopolist to produce less output or undertakes more R&D. Furthermore, the firm undertaking R&D may not induce it to produce more output and may not enhance its profits. That implies that the labor union could encourage firms to invest in Labor-Saving R&D in some circumstances.

#### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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