

# How Technologies like AI Affect the Profit Rate: Empirical Study for 6 Capitalist Countries

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**Abstract**—Technologies like AI contribute to automate the production of goods and services by substituting for human labor. Capitalists invest in developing technologies in order to obtain more profit and larger profit rate. However, the profit rate has gradually fallen in many countries during the last several decades. Through the empirical study for 6 countries during 1950–2019, this paper shows that the main reason for the falling rate of profit is the technological progress.

**Index Terms**—AI, technological progress, profit rate

## I. INTRODUCTION

Over the last 250 years, capitalism has been developed by automation in production. The Industrial Revolution used steam engines, and then electricity, computers, IT to automate many production processes. Recently, Artificial Intelligence (AI) contributes to automate cognitive processes [1]. Capitalists invest in technologies like AI in order to obtain more profit and larger profit rate. However, during the last several decades, the profit rate has gradually fallen in most capitalist countries [2], which is a contradiction in that the effort to increase the profit rate results in the decrease in it.

Let  $p(t)$  and  $r(t)$  be the profit and the rate of profit in year  $t$ , respectively. Capital producing goods and services consists of *constant capital*  $c(t)$  and *variable capital*  $v(t)$  [3]. Constant capital represents the means of production such as raw materials, machines, factories, softwares, AI algorithms, and variable capital is the wage paid to workers. The profit rate is then determined as

$$r(t) = \frac{p(t)}{c(t) + v(t)} = \frac{p(t)/v(t)}{c(t)/v(t) + 1} = \frac{\alpha(t)}{c(t)/v(t) + 1}, \quad (1)$$

where  $\alpha(t)$  is called the *surplus-value rate* and  $c(t)/v(t)$  is called the *composition of capital* [3]. The surplus-value rate represents the distribution of income between capital and labor, and the composition of capital represents the amount of the means of production which one worker operates with. Therefore, the profit rate is determined by two factors: one is the class struggle between capitalists and workers, and the other is technological progress.

Consider one capitalist to invest 100 dollars and earn 115 dollars. If he invests 60 dollars for a machine and pays 40 dollars as a wage for two workers, then the constant and variable capitals are 60 and 40 dollars, respectively, and the composition of capital is  $60/40 = 1.5$ . Since profit is 15 dollars, the surplus-value rate is  $15/40 = 0.375$ . If the

capitalist replaces the machine with a new AI machine valued at 80 dollars to substitute for one worker, then the constant and variable capitals become 80 and 20 dollars, respectively. Then, the composition of capital rises from 1.5 to 4. Hence, following Eqn. (1), as economy substitutes new technologies like AI for human, the composition of capital increases, and as a result, if the surplus-value rate is constant, the profit rate inevitably falls. However, in reality, the surplus-value rate is not fixed, making it difficult to determine the main reason for the falling rate of profit.

Through the empirical study for 6 capitalist countries (U.S., U.K., France, Germany, Italy, and Japan) where the profit rate has gradually decreased during 1950–2019, this paper shows that the long-run fall in profit rate is mainly caused by the increase in composition of capital. Specifically, while the composition of capital in all countries rises during the period, the surplus-value rate slightly decreases for some countries, but slightly increases for some countries. Then, through the analysis of the growth rates of these variables, I show that the long-run fall in profit rate has been largely affected by the rise in composition of capital, i.e., technological progress.

## II. RESULTS

In this work, the empirical data including profit rate are computed using the data set of the Extended Penn World Table 7.0 (EPWT7) addressed by Marquetti et al. [4]. For 6 countries of U.S., U.K., France, Germany, Italy, and Japan, the variables of profit rate, composition of capital, and surplus-value rate in each year are computed as follows:

profit = NDP(Net Domestic Product) – total wage

total wage = # of employed workers × average real wage

profit rate =  $\frac{\text{profit}}{\text{capital stock} + \text{total wage}}$

composition of capital =  $\frac{\text{capital stock}}{\text{total wage}}$

surplus-value rate =  $\frac{\text{profit}}{\text{total wage}}$ .

NDP is equal to GDP(Gross Domestic Product) less the depreciation of capital stock.

Fig. 1 shows the real profit rates of 6 countries during 1950–2019. It is observed that even though the short-run behaviors of profit rate vary from country to country, the profit rates in all countries have gradually decreased over the period. For

instance, the profit rate in U.S. has slightly fallen from 0.068 in 1950 to 0.061 in 2019. But, the profit rate has largely fallen from 0.17 to 0.07 in U.K., and from 0.08 to 0.037 in Germany. For France, Italy, and Japan, the profit rate rose for the early 20 years, and then has sharply fallen.

Fig. 2 and Fig. 3 show the composition of capital and surplus-value rate of 6 countries during 1950-2019, respectively. It is clear that the composition of capital in all countries has definitely increased during the period. However, the surplus-value rates vary from country to country. In order to analyze the reason for the falling rate of profit, the growth rates of these variables are compared in Tab. I. For example, the growth rate of profit rate in U.S. for 1950–2019 is

$$\rho(r) = \frac{r(2019) - r(1950)}{r(1950)} = -0.11.$$

Considering Eqn. (1),  $\rho(r) = -0.11$ ,  $\rho(\alpha) = 0.045$ , and  $\rho(c/v) = 0.21$  imply that the fall in profit rate in U.S. is definitely caused by the rise in composition of capital. For France, Italy, and Japan with  $\rho(\alpha) > 0$ , the same conclusion holds. For U.K., the surplus-value rate falls, i.e.,  $\rho(\alpha) < 0$ , but the growth rate of composition of capital, 0.93, is much larger than the magnitude of the growth rate of surplus-value rate, which implies that even though the surplus-value rate falls, the main cause of the falling profit rate is the rise in composition of capital. The same holds for Germany.

TABLE I

THE LONG-RUN GROWTH RATES OF PROFIT RATE, SURPLUS-VALUE RATE, AND COMPOSITION OF CAPITAL FOR 1950-2019.

	U.S.	U.K.	France	Germany	Italy	Japan
$\rho(r)$	-0.11	-0.59	-0.3	-0.53	-0.37	-0.33
$\rho(\alpha)$	0.045	-0.3	0.066	-0.15	0.17	0.0053
$\rho(c/v)$	0.21	0.93	0.62	1.04	1.07	0.598

### III. CONCLUSION

This paper empirically shows that the rise in composition of capital is the main reason for the falling rate of profit during 1950–2019 in 6 countries. Since the rise in composition of capital means the gradual growth in constant capital in relation to variable capital, the falling profit rate is largely driven by the development of technologies like AI.

### ACKNOWLEDGMENT

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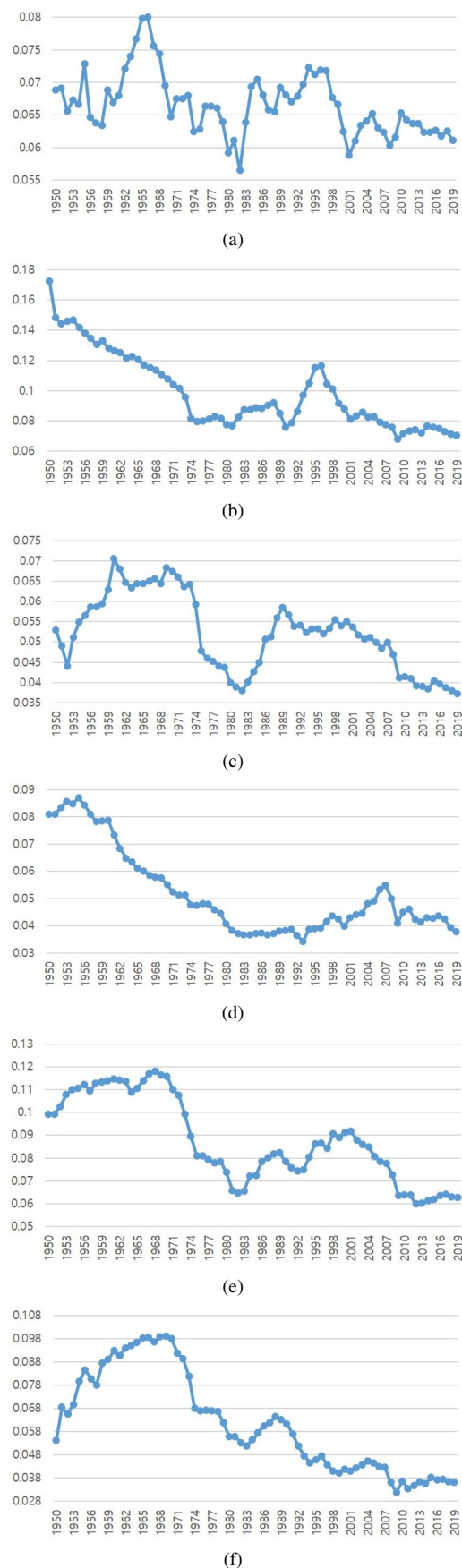
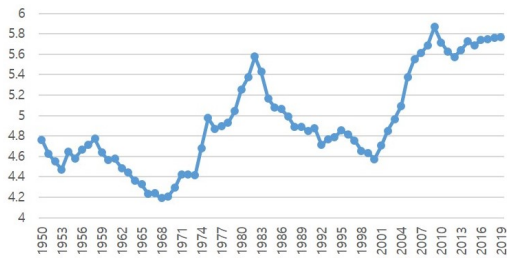
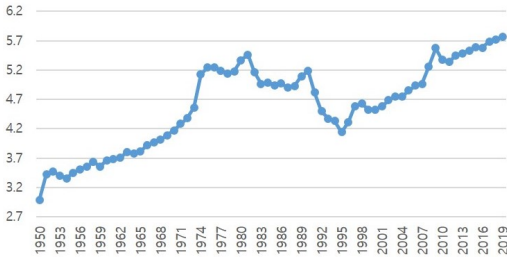


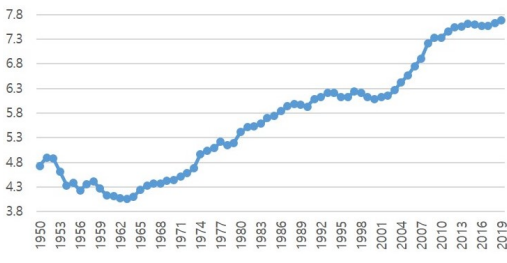
Fig. 1. Profit rate: (a) U.S. (b) U.K. (c) France (d) Germany (e) Italy (f) Japan.



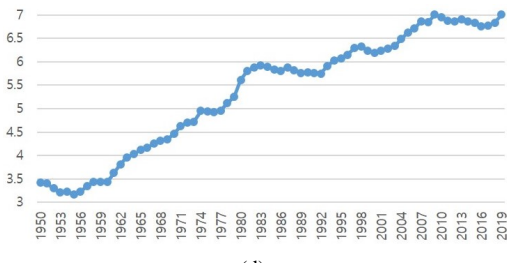
(a)



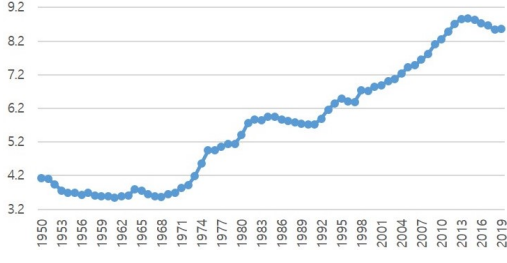
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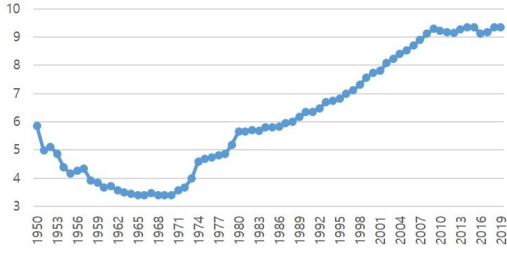
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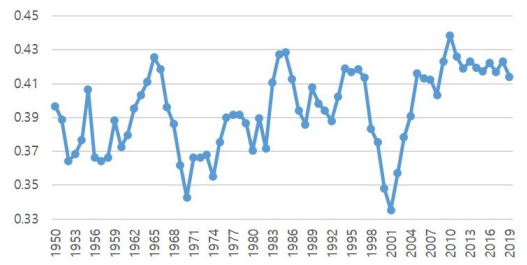
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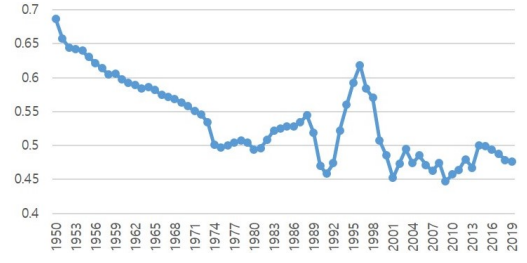
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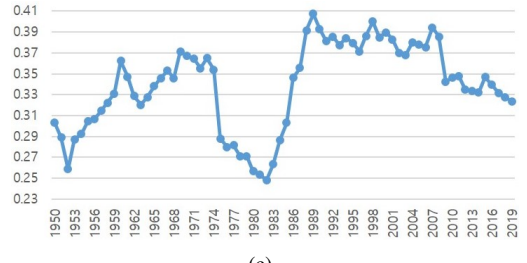
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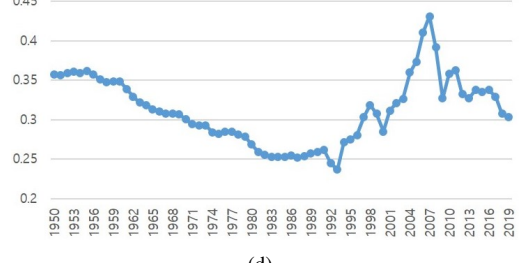
(a)



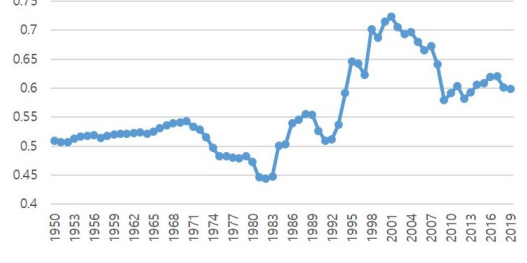
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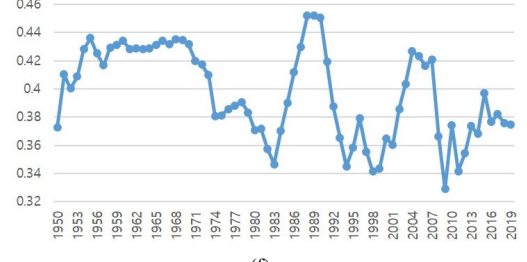
(c)



(d)



(e)



(f)

Fig. 2. Composition of capital: (a) U.S. (b) U.K. (c) France (d) Germany (e) Italy (f) Japan.

Fig. 3. Surplus-value rate: (a) U.S. (b) U.K. (c) France (d) Germany (e) Italy (f) Japan.