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Is the theory of a falling profit rate valid?

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Abstract

Marx's theory of the falling rate of profit makes two main appearances in his work. The first is in Chapter 25 of Capital Volume 1, entitled: The General Law of Capitalist Accumulation. It is further developed in Part III of Volume 3 of Capital, entitled The Law of the Tendency of the Rate of Profit to Fall.

In this paper I will outline the structure of the theory presented in these two volumes of Capital. Following that I will look at some criticisms that have been levelled at it. I will go on to argue that the criticisms are based on a misunderstanding of some of the dynamic causal mechanisms that Marx assumed. Following on from this I shall present a dynamic solution to the equations of accumulation and show under what circumstances these lead to a falling rate of profit. The dynamic model will then be used to analyse the trajectories of some contemporary capitalist economies and to help understand the current structure of the world economy.

1 The theory in Volume 1

Marx presents both of his discussions in the context of capital accumulation. In volume I he is concerned primarily about the interaction of accumulation with the working population. Although this is not so evident in Volume 3 I believe that the same concerns are present there too. According to Marx a key factor in understanding the impact of accumulation is the composition of capital.

The composition of capital is to be understood in a two-fold sense. On the side of value, it is determined by the proportion in which it is divided into constant capital or value of the means of production, and variable capital or value of labour-power, the sum total of wages. On the side of material, as it functions in the process of production, all capital is divided into means of production and living labour-power. This latter composition is determined by the relation

between the mass of the means of production employed, on the one hand, and the mass of labour necessary for their employment on the other. I call the former the value-composition, the latter the technical composition of capital. ([Mar87], page 387)

If the value composition of capital remains the same, an increase in the stock of capital necessarily implies an increase in employment.

Accumulation of capital is, therefore, increase of the proletariat. ([Mar87], page 388)

However, if the growth of the labour supply is slow, the demand for labour may exceed the supply allowing wages to rise. This in turn can tend to reduce the rate of profit. Whilst this condition was the one most favourable to the labouring classes, Marx believed it to be temporary and self limiting.

a rise in the price of labour resulting from accumulation of capital implies the following alternative:

Either the price of labour keeps on rising, because its rise does not interfere with the progress of accumulation. In this there is nothing wonderful, for, says Adam Smith, "after these (profits) are diminished, stock may not only continue to increase, but to increase much faster than before.... A great stock, though with small profits, generally increases faster than a small stock with great profits." (l. c., ii, p. 189.) In this case it is evident that a diminution in the unpaid labour in no way interferes with the extension of the domain of capital. — Or, on the other hand, accumulation slackens in consequence of the rise in the price of labour, because the stimulus of gain is blunted. The rate of accumulation lessens; but with its lessening, the primary cause of that lessening vanishes, i.e., the disproportion between capital and exploitable labour-power. The mechanism of the process of capitalist production removes the very obstacles that it temporarily creates. ([Mar87], page 390)

The system goes through a cycle. Rapid accumulation uses up the supply of labour. This allows wages to rise. This in turn reduces profits and reduces accumulation. So we return to the starting point. Here we have the basic mechanism by which unemployment acts as a break on wages, and full employment as a break on accumulation. The business cycles of the 19th century illustrate this process very clearly. Figures 1 and 2 show how from 1881 to 1883 the rate of accumulation quickened, rising to over 7% of profits being accumulated. This kept unemployment low. But the process reached a crisis in 1883 as competition for labour caused accumulation to slacken. For the next five years accumulation fell and unemployment rose. Once unemployment had reached a peak of 10%, falling wages stimulated a gradual acceleration of accumulation causing the cycle to start again.

But Marx then argues that even if the natural increase in population is inadequate to the needs of capital accumulation, a further mechanism comes into play. At times of labour shortage, firms try to replace workers by machinery. This creates a new reserve army of labour that opens up further opportunities for accumulation. In the process, the value composition of capital changes $\frac{c}{v}$ rises and each additional increment to capital requires fewer workers.

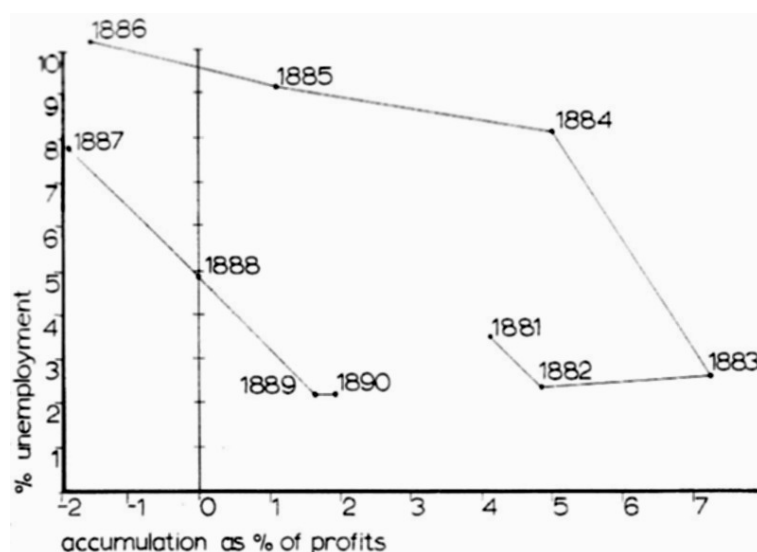


Fig. 1: The basic cycle of accumulation is well shown in 19th century British trade cycles. Relationship between accumulation and unemployment. Reproduced from [Coc77].

So the theory in Volume 1 is of a cyclical process by which capital accumulation adjusts its pace to the supply of labour, and in turn regulates the supply of labour.

If the quantity of unpaid labour supplied by the working-class, and accumulated by the capitalist class, increases so rapidly that its conversion into capital requires an extraordinary addition of paid labour, then wages rise, and, all other circumstances remaining equal, the unpaid labour diminishes in proportion. But, as soon as this diminution touches the point at which the surplus-labour that nourishes capital is no longer supplied in normal quantity, a reaction sets in: a smaller part of revenue is capitalised accumulation lags, and the movement of rise in wages receives a check. The rise of wages therefore is confined within limits that not only leave intact the foundations of the capitalistic system, but also secure its reproduction on a progressive scale. ([Mar87], page 390)

2 The theory in Volume 3

In Volume 3 Marx concerned himself with another implication of the change in the value composition of capital. He had previously been concerned with how this affected the demand for labour power, now he looks at its implication for the rate of profit $p' = \frac{s}{c+v}$. It is clear from this formula that if there is a change in c or in v , let us call them $\Delta c, \Delta v$, then with the mass of surplus value s unchanged, the rate of profit will fall or remain the same if $\Delta c + \Delta v \geq 0$ and otherwise the rate of profit will rise. On the other hand, if s rises with c, v remaining unchanged, then the rate of profit will rise.

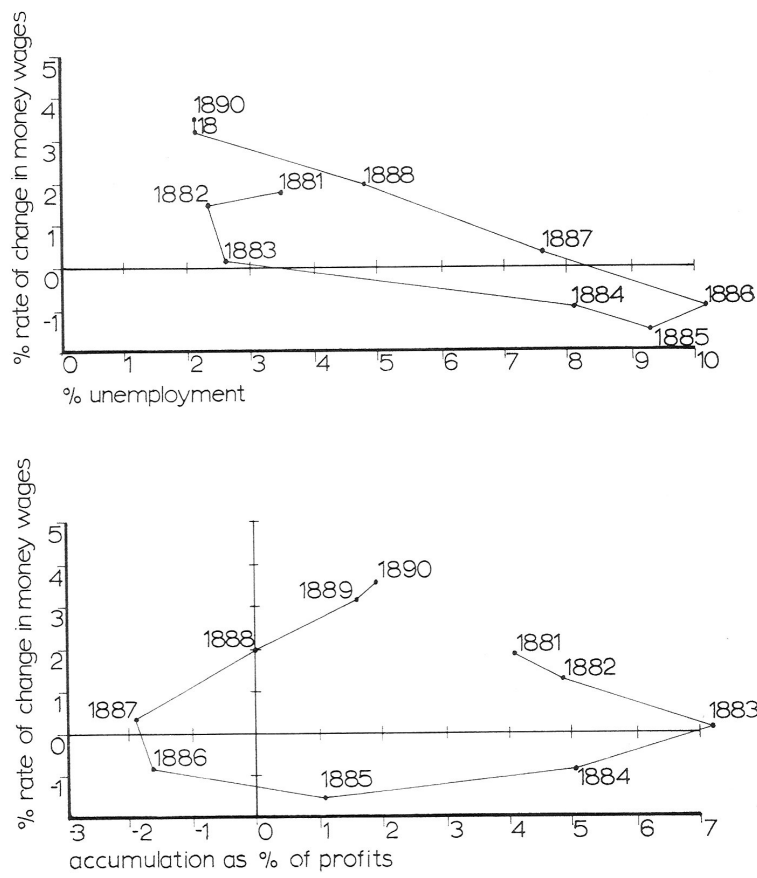


Fig. 2: The relationship between accumulation, unemployment and rate of change of wages.

If the labour theory of value is correct, then the sum daily added value per worker $s + v$ is bounded by the length of the working day. If we assume that the maximum practical working day is say 12 hrs then $s + v \leq 12$. On the other hand there is no equivalent limit to c the value of constant capital equipment used by each worker. Since wages can never fall to zero, it follows that the maximum daily rate of profit \hat{r} would be limited by the relation $\hat{r} < \frac{12}{c}$.

Marx asserted that over time the value of constant capital used per worker tended to rise, and that for any given rate of exploitation this rise tended to reduce the rate of profit. He gives the following example

The rate of surplus-value is 100%:

If $c = 50$, and $v = 100$, then $p' = 100/150 = 66\frac{2}{3}\%$;

$c = 100$, and $v = 100$, then $p' = 100/200 = 50\%$;

$c = 200$, and $v = 100$, then $p' = 100/300 = 33\frac{1}{3}\%$;

$c = 300$, and $v = 100$, then $p' = 100/400 = 25\%$;

$c = 400$, and $v = 100$, then $p' = 100/500 = 20\%$.

This is how the same rate of surplus-value would express itself under the same degree of labour exploitation in a falling rate of profit, because the material growth of the constant capital implies also a growth – albeit not in the same proportion – in its value, and consequently in that of the total capital.

If it is further assumed that this gradual change in the composition of capital is not confined only to individual spheres of production, but that it occurs more or less in all, or at least in the key spheres of production, so that it involves changes in the average organic composition of the total capital of a certain society, then the gradual growth of constant capital in relation to variable capital must necessarily lead to a gradual fall of the general rate of profit, so long as the rate of surplus-value, or the intensity of exploitation of labour by capital, remain the same. ([Mar94]page 148)

He believed the tendency to exist, first because of the mechanism described in the first Volume, but also because he thought that the constantly growing mass of capital that was thrown into accumulation will in the long term outstrip the growth of the proletariat.

There would be absolute over-production of capital as soon as additional capital for purposes of capitalist production = 0. The purpose of capitalist production, however, is self-expansion of capital, i.e., appropriation of surplus-labour, production of surplus-value, of profit. As soon as capital would, therefore, have grown in such a ratio to the labouring population that neither the absolute working-time supplied by this population, nor the relative surplus working-time, could be expanded any further (this last would not be feasible at any rate in the case when the demand for labour were so strong that there were a tendency for wages to rise); at a point, therefore, when the increased capital produced just as much, or even less, surplus-value than it did before its increase, there would be absolute over-production of capital; i.e., the increased capital $C + \Delta C$ would produce no more, or even less, profit than capital C before its expansion by ΔC . In both cases there would be a steep and sudden fall in

Tab. 1: Initial technology table, chosen to give equal value compositions of capital.

<i>Industry</i>	capital goods	labour used	output
luxuries	1	2	3
subsistence goods	1	2	3
capital goods	1	2	3

the general rate of profit, but this time due to a change in the composition of capital not caused by the development of the productive forces, but rather by a rise in the money-value of the variable capital (because of increased wages) and the corresponding reduction in the proportion of surplus-labour to necessary labour. ([Mar94]page 172)

Marx was careful with the way he specified this tendency of the rate of profit to fall. He saw it as a 'law', but one with counteracting influences. In particular, if constant capital goods became cheaper this would tend to offset a fall in profits, and if the rate of exploitation that would also counter a fall in the rate of profit. These might act as partial offsets to a long term tendency for profit rates to decline.

3 Criticisms of the theory

These undefined elements : changes in the rate of exploitation and cheapening of the elements of constant capital, left Marx's theory open to criticism.

The most serious challenge to the theory has come from the Okishio who in a landmark paper [Oki61] showed that any technical invention that is costsaving to the individual capitalist must raise the overall rate of profit in the economy. This paper combined into a single mathematical framework both processes of cheapening constant capital and raising exploitation. It purports to show that any economically rational investment by capitalists will tend to raise the rate of profit. Similar arguments have been made by the influential economist Roemer [Roe86].

The maths used by Okishio is quite complex so rather than present his algebra we will take some worked examples that illustrate his points.

Suppose we have a capitalist setup with the structure in terms of technology shown in Table 1.

We have three industries, the first produces luxury goods, the second subsistence goods, and the last capital goods. In order to produce 3 units of luxuries, two units of labour and one unit of capital goods are required. Similar conditions of production apply in all three industries. We can view the outputs if we like in concrete terms. Thus we might think of the subsistence output in terms of tons of food, the labour inputs as person years, and assume that the capital goods are measured in terms of numbers of machines. But this is just an aid to the imagination. In a real economy each of these industries would produce a large number of different types of machines, different types of food and clothing etc.

We will also assume as a starting point that the rate of surplus value is 100%, so that a worker is paid half a working year of value in wages for each

Tab. 2: Economy in initial state.

whole economy	Mpers.yr			value of	value	cost
	C	v	s	output	per unit	per unit
luxuries	1	1	1	3	1	0.67
subsistence goods	1	1	1	3	1	0.67
capital goods	1	1	1	3	1	0.67
<i>totals</i>	3	3	3	9		
wage in value terms		0.5				
wage in real terms		0.5				
rate of profit		0.5				
value composition of capital		1				

year worked. From these assumptions about technology wages we can obtain Table 2 that describes the whole economy. Since we are talking about the whole economy we can, if we want, imagine that the units are now in millions of person years rather than individual person years.

Since the wage is 0.5, the original 2 (million person years) of labour per industry translated into 1 (million person years) of variable capital per industry. The total surplus value is then equal to 3 (million person years).

The 3 million person years of surplus value, correspond to the value of output produced by the luxuries industry – also 3 million person years. Which in turn tells us, that of the 6 million person years work done in the hypothetical economy, 3 million person years are spent producing luxuries for the upper class. Calculations like this in terms of labour value tell us how the population is distributed. It means that half the population are working directly and indirectly to meet the needs of the upper class: two million working in the luxury goods industry, and 1 million in the capital goods industry.

The value composition of capital in the example is unity, since the total variable capital and the total constant capital are the same. What does a value composition of capital of 1 mean in real terms?

It means, at the current rate of exploitation, for every two workers, the plant and machinery and raw material they use required one years work to make.

Table 2 is set out so that certain constraints required for reproduction are met. These were analysed by Marx when he looked at simple reproduction in Chapter 20 of Capital volume 2. In particular we need to ensure that the total surplus value equals the total output of luxuries, that total wages equal the total output of the subsistence goods, and that the capital goods bought as inputs equal the capital goods sold as outputs.

Suppose now that capitalists reorganise production and find that they can produce 3 units of subsistence goods using only 1 worker and 1 machine instead of 2 workers and one machine. At the then prevailing exchange values this appears a very profitable innovation. The firms in this sector expect to make a saving of 25% in their total costs and expect to sell the output at the same price.

They expect the situation to be as shown in Table 3.

But this situation would not be sustainable. The capitalists making the

Tab. 3: What capitalists producing wage goods hope will happen after they cut their labour costs.

whole economy	C	v	s	value of output	value per unit output
luxuries	1.00	1.00	1.00	3.00	1.00
subsistence goods	1.00	0.50	1.50	3.00	1.00
capital goods	1.00	1.00	1.00	3.00	1.00
totals	3.00	2.50	3.50	9.00	
wage in value terms		0.50			
wage in real terms		0.50			
rate of profit		0.64			
value composition of capital		1.20			

Tab. 4: The economy after stabilising following profit raising technical change.

whole economy	C	v	s	value of output	value per unit output
luxuries	1.00	0.80	1.20	3.00	1.00
subsistence goods	1.00	0.40	0.60	2.00	0.67
capital goods	1.00	0.80	1.20	3.00	1.00
totals	3.00	2.00	3.00	8.00	
wage in value terms		0.40			
wage in real terms		0.60			
rate of profit		0.60			
value composition of capital		1.50			
employment		5.00			

change in productive technique do it on the assumption that prices will not change, and that they will get 3 million units of money for the 3 million units of subsistence goods they still produce. But can they sell all of it at the old price?

They have laid off 1 million workers. If we are talking 19th century capitalism these workers may well have been driven by poverty to emigrate. The advance in the productivity that saved them labour costs has deprived them of a market. There is no way that the workers can buy 3 million worth of consumer goods out of an income of 2.5 million. So their actual sales will be at most 2.5 million and the price of consumption goods must fall. Once we allow consumption goods prices to fall to the level attainable in the shrunken market we get the situation shown in Table 4.

The rate of profit in the whole economy has risen, because the rate of surplus value is now higher at 120% and this has offset the rise in the value composition of capital. But it has not risen as much as the capitalists in the consumer goods industry might have hoped.

So this is what happens if there is an improvement in the productivity of labour with no net accumulation of constant capital (it is 3 million person years before and after the change).

1. The rate of exploitation rises.
2. The number of jobs shrinks.
3. The value composition of capital rises.
4. The real wage rises (from 0.5 to 0.6).
5. The rate of profit across the whole economy is higher.

This is one of the kinds of technical change that Okishio had in mind – one which would increase both the value composition of capital and the rate of profit.

A word on method Drawing up tables like this has a certain arbitrary character to it unless one follows clear rules. How did I obtain Table 4 from Table 3?

It was done using the linear equation solver package within a spreadsheet. The linear programme package was set to maximise total profit under the new technical conditions and subject to the constraints that:

1. Total sales of consumer goods \leq total wages.
2. Total sales of luxuries \leq total surplus value.
3. Total sales of capital goods \leq total capital goods consumed.

The solver was allowed to vary the wage and the relative scales of the different industries.

3.1 A counter example to Okishio

My example was of a technical change which used the same amount of constant capital and less labour to produce the same amount of output. What happens if we introduce a technical change that requires more constant capital and less

Tab. 5: An example of cost saving technical change lowering the rate of profit.

whole economy	C	v	s	sales of output	price per unit output	profit rate
luxuries	0.935	0.95	0.92	2.81	0.94	0.49
subsistence goods	1.065	0.81	0.84	2.71	0.90	0.45
capital goods	1	0.95	1.05	3.00	1.00	0.54
totals	3	2.71	2.81	8.52		
wage in value terms		0.48				
wage in real terms		0.53				
rate of profit		0.49				
value composition		1.11				
employment		5.52				

labour to produce the same amount of output. Suppose that instead of reducing the labour required to produce 3 units of consumer goods by 50%, we reduce it by only 15%, and increase the constant capital required by 10%?

This more modest change will still be cost saving from the standpoint of the capitalists in the consumer goods industry. The effect on the whole economy when we put it into the solver is shown in Table 5.

The overall rate of profit has now fallen, despite the initial change apparently being cost saving.

Okishio's maths was sound, so how have I been able to produce a counter example?

I have been able to do it because Okishio imposed additional very stringent constraints in his models : that the rate of profit must be identical in all industries and a constant wage. In Table 5 the rates of profit are not identical and wages change. If one imposes extra constraints on a mathematical model, one restricts the possible outcomes. The question one has to ask is whether the constraints used in Okishio's model are an accurate reflection of reality?

Okishio himself recognised in a later paper [Oki90] that his argument against the tendency of the rate of profit to fall could be invalidated if a rapid rise in capital stock allowed wages to rise.

I believe that Okishio's constraint of equal rates of profit is also unrealistic for a capitalist economy. What production price theorists like Roemer and Okishio do not answer is by what dynamic mechanism is the rate of profit supposed to equilibrate?

There have been a couple of attempts to address this recently but they arrive at radically different conclusions [SD09, Wri11] claiming respectively to have proven that such convergence can not occur or that it can occur. In the second case, the author argues that the equilibration of profit rates will come about via the interest rate. In Farjoun and Machover's work [FM83] they argued that the chaotic character of capitalist economies must be taken into account when modeling them. This chaotic character meant that it is misleading to assume tight equilibrium conditions like an equal rate of profit in all sectors. Their objection has been well born out by empirical studies [CC03, Zac06] which show that not only are profit rates quite dispersed accross sectors but also, that industries with a high $\frac{c}{v}$ value composition tend to have a lower rate of profit than those with low $\frac{c}{v}$ compositions. These results not only cast doubt

on Okishio's assumptions, but also support Marx's basic theory in that they provide empirical evidence for the determining role of the value composition of capital in profit rates. This determining role is incomprehensible outside the labour theory of value.

4 A dynamic solution

There is, I think, a more fundamental objection to the work of Okishio and Roemer than these rather technical points. It is that they are addressing a different theoretical problem from that of Marx and the classical political economists. Marx was concerned with the overall dynamics of accumulation in the whole economy. He was asking what happens if capital is accumulating at a certain rate, if say 25% of all profits are ploughed back as new capital. This accumulated capital, in his picture, crowds in to different fields of business and competes with existing capital already there. In the end too much capital accumulates undermining the very purpose of capital accumulation itself - the growth of profit.

Okishio shifts the debate to a different question: the optimal choice of technique by individual capitalists. In the example I gave above of cost saving technical change producing a fall in the rate of profit, the costings were done in terms of values not production prices. The essential difference is that I costed constant capital just in terms of what its purchase price. If you use production price theory as Okishio did, then you have to cost constant capital in terms of capital plus expected average profit. This tends to make capital intensive innovations appear less profitable.

If firms reckon, using Okishio's calculus, that there are no profit opportunities for investment in their own line of business at how instead will they attempt to accumulate their profit?

If they simply deposit it with the banks and don't reinvest it, then the lack of investment demand brings on a recession and the rate of profit will fall because of the slackness of trade. Alternatively, as individual firms, they can put their profits into the stock market. This will tend to drive up the price of equities and reduce their yield. This yield on equities is the main indicator that firms have of a general rate of return, so a falling equity yield, brought about by purely financial considerations, will cause firms to mark down their cost of constant capital. Investments that under Okishio's criterion would have appeared unprofitable now seem worthwhile and accumulation can resume.

But this then gives rise to a new question. Just how low does Marx's theory predict that profit rates will be driven?

Can we use Marx's theory to predict what the rate of profit will be in the immediate future?

There is no ready answer to be found in *Capital*, but one can relatively easily extend the theoretical framework laid out by Marx into a dynamic model that does give answers to these questions.

The variables of interest, given Marx's treatment in the sections of *Capital* that I have mentioned are: the division of surplus value between revenue and accumulation, the cheapening of constant capital and the rate of exploitation. I will look at how these affect the endpoint to which the rate of profit will decline¹.

¹ What follows is a condensed version of the analysis in [CCM⁺08].

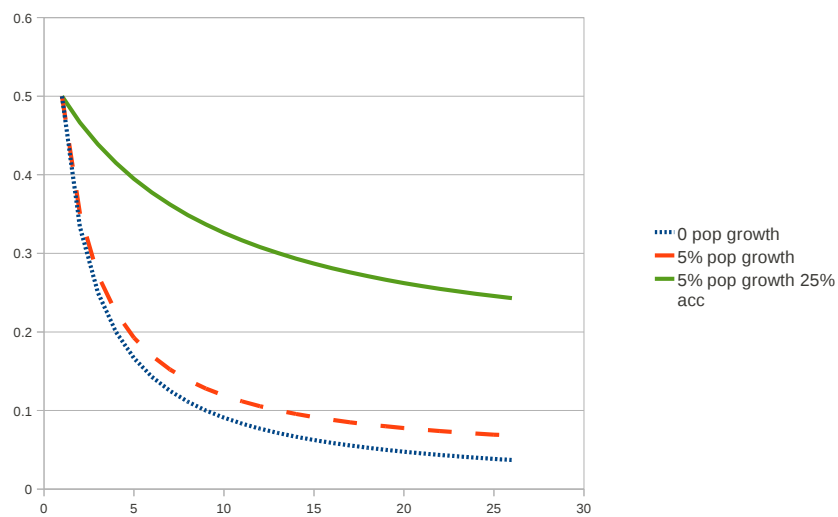


Fig. 3: The way the rate of profit declines with different population growth rates and different accumulation fractions. In all cases the starting position is one where $c = v = s$.

Start with a simple scenario, an economy where there is no population growth and all profits are accumulated. According to Marx's logic, in this economy the rate of profit will tend towards 0 because the capital stock grows without limit whilst the surplus value has a fixed upper bound. This is shown in the bottom line of Figure 3 which gives the result of numerical simulations of the result of capital accumulation in different scenarios.

Next consider the situation where the working population grows by 5% a year, and again all profits are accumulated. In this case the rate of profit will decline until it reaches 5%. Why?

Because at a 5% rate of profit, all reinvested, the capital stock grows at the same rate as the working population, at which point the value composition of capital stabilises. This scenario is shown as the middle line in Figure 3.

Finally consider the scenario where only 25% of profits are reinvested, the rest being unproductively consumed. What is the final rate of profit in this case?

Clear it will be 20%, because at a 20% rate of profit, with a quarter being reinvested, capital stock will again grow at 5% to keep up with the growth of the working population. It follows that the basic equation for defining the equilibrium rate of profit r_e is

$$r_e = g/\alpha \quad (1)$$

where g is the growth rate of the employed workforce and α is the share of profit that is accumulated.

There is one element of Marx's argument that this leaves out - the cheapening of the elements of constant capital. We can assume that this will progress at the same rate as the rise in labour productivity, let us call this t for technical progress.

The effect of a cheapening of constant capital is to devalue the existing capital stock. A 5% annual growth in labour productivity will reduce the value of existing plant and machinery etc, by 5% a year. Its effect on the rate of profit is thus the same as that of population growth. Suppose there is no population growth but a 5% rate of technical progress, and assume that all profits are accumulated. Clearly the rate of profit will stabilise at 5% because at that rate of profit the reinvestment is just sufficient to offset the technical devalorisation of the capital stock. So at that rate the value composition of capital must stabilise.

The final equation for the long term rate of profit, on Marx's assumptions must be:

$$r_e = \frac{g + t}{\alpha} \quad (2)$$

This rate of profit r_e is the level to which the law of the falling rate of profit drives the actual rate of profit. What does it tell us:

1. That the equilibrium profit rates rise with the growth of the workforce. This is important because in developed capitalist countries with a low birthrate the population has tended to stabilise. The theory shows that if the population starts to fall, and if the rate of improvement in technology stagnates, then the rate of profit will tend to become negative.
2. That equilibrium profit rates rise with technical progress. This acts through its effect on cheapening constant capital.

3. That the equilibrium profit rate does not depend on the rate of exploitation. Rises in the rate of exploitation can produce short term rises in the rate of profit, but they do not affect the final level to which it will decline, they can only postpone the decline.
4. That rapid accumulation tends to reduce the long term rate of profit. This is also significant because it shows the antagonistic and in the long term reactionary relation that the capitalist class has with the development of the productive forces. The long term rate of profit is higher if the capitalists consume the surplus unproductively rather than investing it. Their economic interest becomes directly counter to the further development of the productive forces, and they become increasingly concerned with rent seeking activity: securing monopolies via intellectual property rights, trademarks, acquisition of landed property etc.

5 Comparing the theory with reality

A scientific theory is only as good as the predictions that it produces. If the basic model of accumulation put forward by Marx is right, we should be able to use it to predict the evolution of the rate of profit in real capitalist economies.

Equation (2) has three variables on the right hand side: the accumulation share, the rate of increase in labour productivity, and the rate of growth of the working population. Given these three variables for a country one can easily calculate what r_e should be. If the theory is correct then the actual rate of profit will move towards that given by r_e . The short term, but not long term, movement of the actual rate can also be affected by changes in $\frac{s}{v}$, so we should not expect the predictions to be 100% right, but they should be right most of the time, since sudden changes in $\frac{s}{v}$ are not that common. In Figure 4 we show for 4 countries the time series for r_e and the actual rate of profit. Note that r_e almost perfectly predicts what the actual rate will be a few years later.

The equilibrium rate itself changes, primarily due to two causes. In the first period we see a decline in r_e brought about by the exhaustion of labour reserves, which in turn was the effect of declining birth rates and the ending of migration from the land. In Japan, where the natural rate of population growth is low and where immigration is heavily restricted, the profit rate continued an apparently remorseless decline. In the other 3 countries it stabilises at a slightly higher level probably because of the combined effect of inward migration and a fall in the accumulation fraction. One of the paradoxical effects of neo-liberal policies in the USA for example has been to bring about a recovery in the rate of profit by shifting from productive to unproductive use of the surplus product. Naively one would think that unproductive consumption of surplus value would be bad for the rate of profit, dynamic analysis reveals the reverse.

6 Conclusion

The theory of the declining rate of profit that Marx developed was remarkably insightful and fruitful. It captures the key features of accumulation in capitalist economies. It can be cast in a mathematical form that allows one to compute the future evolution of the rate of profit in a capitalist country, and the predictions it gives are remarkably good.

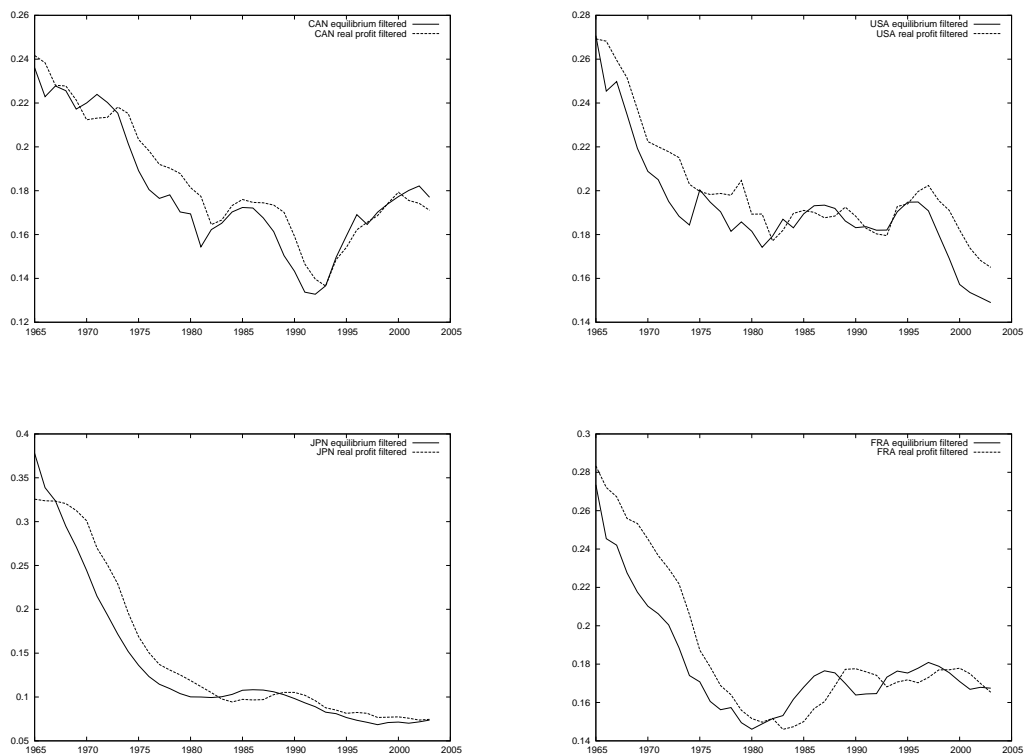


Fig. 4: Evolution of profit rates in Canada, USA, Japan and France. Solid lines are r_e dashed lines the actual rate. Note how the theory predicts the actual rate two or three years in advance. Data taken from the Penn World Tables[Mar09] and processed by Tamerlan Tadjadinov.

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