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Growth, Distribution and Technological Change

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A simple model of a capitalist economy is developed to examine effects of technological change on growth and income distribution. It is shown that the economy – in the long run – can either be demand constrained, labor constrained or capital constrained, and the effects of technological change depend on which of the three cases characterise the economy, and the relationship between technological change and investment behaviour.

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1. Introduction

The purpose of this paper is to examine the role of technological progress in the determination of growth and distribution in capitalist economies. The issue is one that is both important and complicated, and one that has received attention from economists no less than Smith, Ricardo and Marx, among others. This paper will confine its attention to a simple model of a capitalist economy, which introduces technological change in a very simple way, in order to analyse these issues. By so doing, it shall hopefully be able to shed some light on some questions that have been widely discussed in the relevant literature.

The paper proceeds as follows. Section 2 examines the basic assumptions describing the economy modelled. Section 3 considers the behaviour of the economy in the short run, while section 4 examines its long run dynamics and equilibrium without technological change. Section 5 introduces technological change into the model and comments on its role as a determinant of growth. Section 6 concludes.

2. Assumptions of the model

(1) The following assumptions are made in our model.

(2) The economy produces only one good, which can be consumed or invested and thus converted into productive capital.

(3) Production is undertaken by firms, which are similar enough to allow us to use the Marshallian device of the "representative firm", which was used in the analysis of growth by Kaldor (1961).

The firm produces with a fixed coefficients production function exhibiting constant returns to scale of the type

$$X = \min[K/a_1, L/a_0] \quad (1)$$

Where X is the level of output, K the stock of capital employed by firms, L the amount of labor used by firms, a_1 is the (technologically) fixed capital-output ratio and a_0 the fixed labor-output ratio. The input-output coefficients need not be taken to be given technologically, but may be interpreted as the potential ones given technology, efficiency, and social arrangements.

(4) Total income is divided between wage income, which goes to workers, and profit income, which goes to capitalists. A constant fraction of profit income, s, is saved (the rest being consumed), while wages are entirely consumed.

(5) Firms make investment plans, which are independent of the saving decisions made in the

economy. The investment plans can be portrayed by a desired accumulation function. We shall sometimes assume, for simplicity, that desired investment is given in real terms, so that

$$I = I^* \tag{2}$$

But, more generally, especially when examining the long run movement of the economy, we will assume that the desired accumulation function is given by

$$I/K = a + br + c(X/K) \tag{3}$$

Where a, b, and c are positive constants and r the rate of profit. Investment (as a ratio of the stock of capital) is assumed to be a linear (tor simplicity) and positive function of the rate of profit and the degree of capacity utilisation. Higher rates of profit induce faster rates of desired accumulation, this being a central canon of neo-Keynesian growth theory. Higher rates of capacity utilisation imply a greater difference between actual and desired rates of capacity utilisation, and thus induce greater accumulation[1].

(6) Firms are assumed to possess market and not be in a perfectly competitive environment. Fuller examination of their pricing and output behaviour will be considered later on.

(7) The money wage, W, is taken as given[2].

(8) Population, assumed to be the same as the supply of labour, N, is assumed to grow at the exogenously fixed rate n, so that (with overdots denoting time derivatives)

$$\dot{N}/N = n \tag{4}$$

(9) Technological progress is assumed to occur through time. This technological progress can be written in the form

$$\dot{x}/x = t_0 + t_1\, \dot{k}/k \tag{5}$$

Where $t_1 > 0$, $t_1 < 1$ and $x = X/L$, output per worker, and $k = K/L$, capital per worker. We use here a linear form of Kaldor's (1961) technical progress function, which relates the rate of growth x positively with the rate of growth of k, and represents the technological dynamism of the economy.

3. The economy in the short run

In the short we assume that K, N and the input-output ratios are given. We consider in turn the cost conditions facing the firm, its production and pricing policies, the determination of equilibrium with given investment, and the determination of equilibrium for the general case of the desired

[1] This type of investment function was suggested earlier by Steindl (1952). See Dutt (1984) for a fuller description.

[2] Money wage dynamics could be introduced into the analysis to deal with inflation, but would add nothing to what concerns us here.

accumulation function.

Regarding the cost conditions of the firm in the short run, we first define the potential output of the firm, X_p, as

$$X_p = \min[N/a_0\,, K/a_1] \tag{6}$$

which is obviously the maximum output that can be produces by the economy. Figure 1 shows this maximum level, 1(a) for the case in the which the capital constraint is binding and $K/a_1 < N/a_0$ and 1(b) for the case in which the labor constraint is binding, and $N/a_o < K/a_1$ [3]. The economy need not produ.ee at this- potential level, so that $X < X_p$ is possible. Figure 1 also shows the marginal cost curve for the firm when X is less than potential. If the firm produces less than at the potential, it must still hold on to all its capital, but it can conceivably hire less labor, since we assume away long-term labor contracts. Thus marginal costs are given by a_0W, and are shown by the horizontal line in Figure 1.

We next turn to the production and pricing policies of the firm. We assume that the firm determines its supply price, P^s, as being market up on its prime costs, which are here the same as its marginal costs. We assume that the markup rate, z, is given by the degree of monopoly power a la Kalecki (1971), so that

$$P^s = (1+z)a_0W \tag{7}$$

This supply price is also shown in Figure 1. Given any level of production X, the level of production to aggregate demand we call the demand price P^d. We then assume that the firm increases output at a rate depending on the difference between P^d and P^s, whenever such as an expansion is possible, which can be formalised by the equation

$$\frac{\partial X}{\partial t} = G[P^d - P^s], \text{for } X < X_p, G > 0 \tag{8}$$

This implies that if equilibrium output is reached for $X < X_p$, so that $\partial x/\partial t = 0$, by (8), $P = P^d = P^s = (1+z)a_0W$. If equilibrium output is reached at $X = X_p$, the firm cannot raise output due to capital or labor constraints, and $P = P^d > P^s$. This type of formalisation synthesises the work of Kalecki and Kaldor (as well as others) with a simple theory of pricing and output decision making by firms in a Marshallian tradition[4].

We now analyse the determination of output and price of the economy in the short run for a given level of investment. It is obvious from the foregoing that there are three possible cases to consider, one of which has $X < X_p$ and two of which have $X = X_p$, one in which capital is the binding constraint, and one in which labor is. Before we consider these cases, however, let us examine how

[3] The case in which $N/a_o = K/a_1$ is not considered separately.

[4] There is no need to assume that P must actually rise to its equilibrium level. If the firm is sensitive enough, even a tendency for $P_d > P_s$ will result in (if possible) the output response, so that there may be imperceptible price changes.

P^d is determined. Recall that P is the price, which makes

$$X = C + I \tag{9}$$

for a given X. Our assumptions regarding consumption and investment imply

$$X = \frac{W}{P} a_o X + (1 - s) \left[X - \frac{W}{p} a_0 \right] + I^*$$

which implies in turn that

$$P^d = \frac{sWa_0 X}{sX - I^*} \tag{10}$$

which shows that there is an inverse relationship between P^d and X for the given I^*, its slope given by $-\frac{sWa_o I^*}{(sX - I^*)^2}$[5]. It is shown as the curve DD in Figure 2.

Consider now the first case with $X < X_p$. In this case, as we have seen,

$$P = (1 + z)Wa_o \tag{11}$$

Since this P is equal to both P^s and P^d the equilibrium value of output can be found by substituting equation (11) into equation (10). This gives

$$X = \frac{(1 + z)I^*}{zs} \tag{12}$$

This case is shown in Figure 2(a), and will be called the demand constrained case. The DD curve must intersect the P^s line with $X < X_p$ (or if with equality, at the level P^s). This requires, clearly, that the parameters of our model must be such that

$$\frac{(1 + z)I^*}{zs} < X_p \tag{13}$$

If this condition is not satisfied, the DD curve will intersect the vertical X_p line at a level higher than P^s, and we will be in one of the two other cases, with $X = X_p$. In words the demand is too high to allow an equilibrium with $X < X_p$.

In one case, $X_p = K/a_1$, which implies that

$$X = \frac{K}{a_1} \tag{14}$$

The equilibrium price is obtained by substituting (4) in equation (10), which gives

$$P = \frac{(sWa_o K/a_1)}{(s K/a_1 - I^*)} \tag{15}$$

This case is illustrated in Figure 2(b). While this case has capital as the binding constraint and labor is surplus, the other case with excess capital and labor the binding constraint is shown in Figure 2(c). Equilibrium P and X in this case are given by

[5] If I were an increasing function of X, then it is possible for th is curve to have a positive slope.

$$X = \frac{N}{a_0} \tag{16}$$

and

$$P = \frac{sWN}{s\frac{N}{a_0} - I^*} \tag{17}$$

It is instructive to examine an alternative geometric depiction of these short run equilibria. Figure 3 we measure r on the horizontal axis, and I/K and S/K on the vertical axis measuring up and X/K on the vertical measuring down. From our saving assumption, we can see that (with S being real savings)

$$\frac{S}{K} = sr \tag{18}$$

while our fixed investment (and fixed capital stock in the short run) assumption implies

$$\frac{I}{K} = \frac{I^*}{K}$$

which is fixed. These provide us with the S/K and I/K curves of the upper quadrants, which must intersect to satisfy equation (9). For the case of $P = P^s$ we have, using equation (11) and the definitional identity

$$PX = Wa_0X + rPK \tag{19}$$

the equation

$$r = \frac{z}{1+z} \cdot \frac{X}{K} \tag{20}$$

For given z this gives the relationship between r and X/K in the lower quadrant, which is valid only for equilibrium $X < X_p$. if X/K is constrained in some way (with the shortage of capital or labor), then this curve becomes horizontal, and z is no longer constant; r can rise, but X/K cannot. In Figure 3(a) we show the demand constrained case, in which equilibrium X/K is less than $1/a_1$ and $N/a_o\,K$. In Figure 3(b) the I/K and S/K curves intersect to determine r, but X/K is equal to $1/a_1$, implying that the economy is capital constrained. In Figure 3(c), on the other hand, $X/K = N/a_oK$, implying that the economy is labor constrained. These figures do not explicitly determine the equilibrium price level, but for given W and K, with everything else determined, it can be solved from equation (19).

Our analysis so far has assumed that desired investment is fixed in real terms. The same results would be obtained if we assumed investment to be given by equation (3) instead, and this is done easily with the geometric device we have just used. For the demand constrained case, we can substitute equation (20) into equation (3) to obtain

$$\frac{I}{K} = a + \left[b + \frac{c(1+z)}{z}\right] r \tag{21}$$

which replaces the horizontal I/K curve of Figure 3 by the upward rising curve of Figure 4(a), the demand constrained case. When X/K becomes fixed, either by capital or labor constraints, (3) becomes

$$\frac{I}{K} = a + c\left(\frac{X}{K}\right)^{*} + br \tag{22}$$

where $(X/K)^{*}$ is the fixed value of X/K, and the slope of the I/K curve is only b, flatter than in the demand constrained case. The capital and labor constrained cases are shown in Figures 4(b) and 4(c). We only require, for stability, that the slope of the investment curve is less than the slope of the saving curve, a sufficient condition for which is that

$$s > b + \frac{c(1+z)}{z} \tag{23}$$

Otherwise, with the investment response being greater than the saving response, the short run equilibrium would be unstable[6].

4. Long run dynamics and equilibrium

We now examine the long run dynamics of the model. We shal1 continue assuming given technology by taking the input-output ratios to be fixed, an assumption to be relaxed in the next section. This is done to enable us to focus on dynamics due to changes in capital stock and the supply of labor given by equations (3) and (4). We will consider in turn the demand constrained and output-at-potential cases.

The demand constrained case is easiest to handle. In this case we have seen the rate of profit is determined by the intersection of the S/K and I/K curves of Figure 3 (a), and X/K is also determined in the Figure. Changes in K and N do not change any one of the three curves determining these variables, so that over the long run these valu.es are also the equilibrium values. Assuming away depreciation, the rate of growth of capital stock, g, is seen (from equations (21) and (22)) to be equal to

$$g = a + \frac{b + c(1+z)}{z} \cdot \frac{a}{s - b - \frac{c(1+z)}{z}} \tag{24}$$

The economy will remain in this type of long run equilibrium indefinitely if none of the parameters of the model change (as we will assume to be the case), and if $g < n$[7]. If $g > n$, eventually the economy will hit the labor constraint, and the nature of the short and long run equilibria would

[6] This type of instability could always push the economy to X_p. We assume short run stability, which follows almost macroeconomic approaches, including those of Keynes and Kalecki.
[7] This model is fully worked out in Dutt (1984), See also Rowthorn (1982) for a similar model.

have to change to take this into account.

We now consider the capital and labor constrained cases[8]. In the capital constrained case, $X/K = 1/a_1$, so that substitution into equation (3) implies

$$\frac{I}{K} = a + \frac{c}{a_1} + br \tag{25}$$

which is the full capacity utilisation case. With the economy labor constrained, $X/K = N/a_0 K$ so that

$$I/K = a + br + c(N/a_o K) \tag{26}$$

which is the excess capacity case. In the full capacity utilisation case we equate I/K from (25) to S/K from (21) to solve for

$$r = \frac{a + c/a_1}{s - b}$$

Since $g = sr$

$$g = s\frac{a + c/a_1}{s - b} \tag{27}$$

In the labor constrained, excess capacity case we equate I/K from (26) to S/K from (21) to get

$$r = \frac{a + c\, N/a_0\, K}{s - b}$$

which implies that

$$g = s\frac{a + c\, N/a_0\, K}{s - b} \tag{28}$$

The growth rate of capital stock, g, has been calculated for each of the two cases. In the case of full capacity utilisation, equation (27) shows that it is independent of the value of N/K, and determined completely by the values of the fixed parameters. For the case of excess capacity, however, equation (28) shows that it rises with N/K. Figure 5 shows these relationships, with g^N showing g for the labor constrained case and g^K showing g for the capital constrained case. By the g curve we will denote the segment of the g^N curve for the excess capacity region in which $N/K < a_0/a_1$, and the segment of the g^K curve for $N/K > a_0/a_1$, the two being equal at $N/K = a_0/a_1$. The figure also shows the rate of growth of N, n.

Two cases must be distinguished, depending on whether a_0/a_1 is 1ess than or greater than N/K at which the n and g curves intersect[9]. Figure 5(a) shows the first case. If the initial short run equilibrium is one of excess capacity, we will start from a position of $N/K < a_0\, /a_1$, while if it is one of full capacity, we will start from a position with $N/K > a_o/s_1$. In either case, the economy

[8] The analysis follows Dutt (in preparation).

[9] The two curves intersect at $\frac{N}{K} = \frac{a_0}{c}\left[n\frac{1-b}{s} - a\right]$. The intermediate case in which the two are equal is easy to deal with. So is the case in which the n curve is always below the g curve (even at $N/K = 0$).

will move to the right (hitting full capacity if it started off with excess capacity) and grow along K the g^K line with increasing N/K and unemployment, but with full capacity utilisation. Figure 5(b) shows the second case, in which we can start with excess capacity with $g < n$ (below E) or with $g > n$ (between E and a_0/a_1), or with full capacity (above a_0/a_1). In either case we end up at E, in a position of long run equilibrium in which the economy operates with excess capacity, but has fully employed labor.

We thus have three different long run outcomes, constrained, respectively, by demand, capital and labor. Which of the long outcomes of the economy will end up with depends on the values of the parameters of the model[10]. We conclude our discussion with a simple comparison of the three possibilities, showing how they can be treated as being alternative ways of closing an underdetermined model[11]. In the economy we have been considering, since output can either be consumed or invested, we have

$$1 = Ca_0 + g(K/X) \tag{29}$$

where C is the real consumption per worker. Also, from equation (19) we have

$$1 = (W/P)a_0 + r(K/X) \tag{30}$$

The savings assumption implies that

$$g = sr \tag{31}$$

Finally, our investment function implied

$$g = a + br + c(X/K) \tag{32}$$

We thus have four equations to solve for five unknowns; C, g, W/P, r and X/K. We clearly need one more equation. In long run equilibrium, given our assumptions, we have to satisfy

$$W/P \leq 1/a_0\,(1+z)$$
$$K/X \geq a_1$$
$$g \leq n$$

[10] Due to parametric shifts, the economy could, of course, be shifted from one regime to another.
[11] See Marglin (1984) and Dutt (1986A).

We have shown that depending on the values of the parameters, the economy will be driven to satisfy one of these as an equality to provide the fifth equation to dose our model. The demand constrained long run equilibrium uses equation (11) to make the first an equality, the capital constrained equilibrium makes the second, while the labor constrained equilibrium uses the third.

5. The role of technological progress

In this section we introduce technological progress into our model and examine the role it plays in each of the three types of long run equilibria we have analysed, and make some general comments on the role of technological change in growth and distributions based on our results. In the demand constrained case, recall from (24) that the rate of growth of capital stock depends on the parameters of the investment function (a, b and c), s and z, and is in dependent of the input output ratios. Also recall that the equilibrium value of r depends only on these parameters, and is hence independent of the technological parameters, and by equation (20), for given r and z, the rate of growth of K is equal to the rate of growth of X. Finally, since the level of employment, L is given by

$$L = a_0 X$$

we have

$$\dot{L}/L = \dot{a}_0/a_0 + \dot{X}/X \tag{33}$$

The technological progress function (5) can be written as

$$\dot{X}/X - \dot{L}/L = t_0 + t_1[g - \dot{L}/L] \tag{34}$$

Our result that the rate of growth of K equals the rate of growth of X in long run equilibrium implies $g = \dot{X}/X$ so that (34) can be rewritten as

$$\dot{X}/X - \dot{L}/L = t_0 + t_1[\dot{X}/X - \dot{L}/L]$$

Substitution from (33) and the rearrangement of terms implies

$$-\dot{a}_0/a_0 = t_0/(1 - t_1) \tag{35}$$

Upward shifts in the parameters of the technological progress function will increase $-\dot{a}_0/a_0$. Thus in the demand constrained model the technological progress function determines the rate of decline of a_0 (or the rate of growth of labor productivity), Whether or not a_1 changes is irrelevant for the model[12]. Technological change cannot affect the rate of growth of output, which depends only on the parameters of the saving and investment functions and the markup rate. From equation (33) it follows that more rapid technological progress would, with our assumptions, reduce the rate of employment growth and thus increase unemployment in the economy[13]. The only way in which this would not happen is if changes in the rate of technological progress resulted in changes in the parameters of the saving or investment functions, or the markup rate, possibilities that we will turn to later.

In the capital constrained case we have $X/K = 1/a_1$, which implies

$$-\dot{a}_1/a_1 = \dot{X}/X - \dot{K}/K \tag{36}$$

Since it is still true that $L = a_0X$ we also have equation (33). The technological progress function can be written as

$$\dot{X}/X - \dot{L}/L = t_0 + t_1[(\dot{K}/K - \dot{X}/X) + (\dot{X}/X - \dot{L}/L)]$$

which implies, from equations (33) and (36), that

$$-\dot{a}_o/a_0 = t_0 + t_1[\dot{a}_1/a_1 - \dot{a}_0/a_0]$$

which can be rewritten as

$$-\dot{a}_0/a_0 = t_0/(1-t_1) - [t_1/(1-t_1)](-\dot{a}_1/a_1) \tag{37}$$

Given the parameters of the technological progress function we obtain a linear, downward-

[12] There is one negative influence of technological progress which has been hidden in the form of our investment function (3). If the rate of investment is to depend on an index of capacity utilisation in the presence of technological change, it is perhaps more sensible to rewrite it as

$$I/K = a + br + c'a_1(X/K)$$

where $c = c'a_1$ has been substituted in (3). The reason for using this form is that the ratio of actual to potential output (which ought to be a measure of capacity utilisation) is $a_1 X/K$, not X/K. In this case, if technological change implies that al falls through time, the utilisation of capacity falls through time and hence the growth rate of the economy declines, This should be an indication that technological progress only reduces a_0 and not a_1, as will be assumed explicitly later on. This possible negative effect of technological progress on investment will thus be ignored.

[13] Since the real wage, however, increases, the distribution of income will be unchanged (as long as z is -fixed).

sloping relationship between $-\dot{a}_0/a_0$ and $-\dot{a}_1/a_1$, which is the same as the innovation possibility frontier used in neoclassical growth theory[14]. The technological progress function cannot tell us where on this frontier the economy will be, that is, what will be the nature of the bias of technological progress. Kaldor's (1957) "stylised facts", however, would suggest that the capital-output ratio is constant over the long run, so that $\dot{a}_1/a_1 = 0$, implying that technological progress is Harrod-neutral, again given by equation (35). This type of technological progress also results in a steady state growth equilibrium which is easy to analyse[15].

Equation (27) shows that with a_1 constant, the rate of technological progress does not affect the rate of growth of capital stock, g. Also, with $X = K/a_1$, output grows at the rate g, independently of the rate of technological progress. Equation (33) thus implies that a higher rate of technological progress will merely reduce the rate of growth of employment, worsening the problem of unemployment. The rate of profit would not change (this follows from equation (31)) and the real wage (from (30)) would rise over time (and at a faster rate if technological change were more rapid). Since $(W/P)a_1$ does not change, the distribution of income would not change. All this need not be true if technological change involves reductions in a_1, or affects the parameters of the investment function.

Finally, consider the labor constrained case. In this case, we have $X = N/a_0$, so that

$$\dot{X}/X = n - \dot{a}_0/a_0 \tag{38}$$

In this case the rate of growth of output depends on the rate of growth of labor supply and the rate of fall of the 1abor-output ratio (the rate of growth of labor productivity). Assuming again that technological progress is Harrod neutral, so that a higher rate of technological progress only increases the fall in $\dot{a}_0/a_0$, a faster rate of technological progress, from equation (38) would increase the rate of growth of the economy. Employment would grow at the rate of growth of labor supply. In long run equilibrium, the rate of profit would not change, implying a rising real wage over time. A faster rate of technological change would increase the rate of profit (this follows from (31), since the rate of growth would be higher), raise the rate of growth of the real wage in long equilibrium (since $(W/P)a_0$ must be constant at long run equilibrium, this follows from (30), and also raise the degree of capacity utilisation (this follows from equations (31) and (32)). But since in long run equilibrium

$$r(K/X) = [a/(s-b)](K/X) + c/(s-b)$$

[14] See, for example, Hacche (1979).
[15] As is also the case for Harrod's model and for the neo-classical growth model.

(again from equations (31) and (32)), a higher X/K implies a lower $r(K/X)$, implying a higher $(W/P)a_0$ in long run equilibrium, so that the labour share in income goes up.

We now make some general comments based on our results. First, our model shows (in the absence of possible effects on other parameters) that in general, greater technological dynamism need not increase the rate of growth of the economy (or improve the distribution of income). This seems to be the only possibility in growth neoclassical models. Kaldor (1957, 1959, 1960, 1961), no neoclassical, also argued that greater technological dynamism would necessarily increase the rate of growth of the economy. Our results contradict the neoclassical claim which should be no surprise, given the different assumptions made here, but also Kaldor's. This is somewhat surprising, since our model is similar in spirit to this. The difference in results lies because Kaldor simply *assumed* – illegitimately in our opinion – that in the long run the economy would grow with fully employed labor, while our model shows that while this is one possibility, it is not the only one[16]. In the other possible cases, greater technological dynamism would reduce the rate of labour absorption, and leave unchanged the distribution of income and growth rates.

Second, it is possible that a change in the technological dynamism of the economy could change some of the other parameters of the model, and thereby have other effects on the rate of growth of the economy and its income distribution.

One possibility, central to the writings of Schumpeter (1934), is that a higher rate of technological progress could affect the rate of investment. Kalecki (1971) argues that one of the effects of technological progress is that new machines are more productive than old ones, so that the real costs of operating old machines rise as a result of the introduction of new machines. The profits from the old machines fall, getting transferred to the new ones. All this implies that a faster rate of technological progress would increase the rate of investment[17]. Similar ideas can be extracted from Marx's views on accumulation and competition. Marx (1976) saw technological change as resulting from competition, and leading to competition between capitalists. Any capitalist that did not accumulate and innovate would not be able to survive in this competitive struggle. Consequently, if greater possibilities of innovation were opened up, the pace of accumulation could be expected to accelerate. Not all economists – even those within the Marxist tradition – however, have accepted these ideas. Steindl (1952), in his analysis of accumulation under monopolistic conditions, argued that "technological innovations accompany the process of investment like a shadow, they do not act on it as a propelling force". Baran (1957) argued strongly in favour of Steindl's view in his first edition, but changed his position somewhat later on Baran and Sweezy (1966) took a middle ground, distinguishing between two types of technological changes. Regarding "normal" innovations they

[16] See Dutt and Maurette (1986) for a more complete discussion of Kaldor's result and its legitimacy.
[17] See also Kalecki (1941). Kalecki's ideas are also spelled out. in one of his last papers, Kalecki (1968).

argued that monopoly capital tended to place restrictions on the implementation of the new methods and new products to protect existing capital values, and this did not increase investment. But "epoch-making innovations" such as the steam engine, the railroad and the automobile tended to "shake up the Entire pattern of the economy and hence create vast investment outlets in addition to the capital which they directly absorb"[18].

Assuming, for the sake of argument, that a higher rate of innovation does increase the parameters of the investment function, say a, equations (24) and (27) show that the rate of growth of the economy would be increased in both the demand constrained and the capital constrained cases. In either case the effect on the rate of labor absorption is found from equation (33): it could be positive if a was very responsive to the rate of technological change to raise g more than the decline in a_1/a_0. In the demand constrained case a faster rate of technological change would still not change the distribution of income, which depends on z; in the capital constrained case a higher rate of growth would be possible only with a higher rate of profit and hence a lower wage share.

Another possibility is that a higher rate of technological change could increase z in the economy. Kalecki (1941) argued that a higher rate of technological progress could raise the degree of monopoly power by increasing the scale of investments required, and this would directly increase z. If faster technological progress reduces the rate of labor absorption along standard Marxian lines and thus increases unemployment over time (adding to the reserve army)[19], the position of workers in class struggle would be worsened, Kalecki argued that the markup could rise with the weakening in the power of unions, for example[20]. In this case, it is possible that an economy which was not demand constrained could become demand constrained. Further, for the demand constrained case a rise in z implies a worsening in the distribution of income. This redistribution of income from capitalists to workers, given our savings assumptions, implies (other things constant) a reduction in aggregate demand, lower capacity utilisation, and a reduction in the rate of growth of the economy. If a higher rate of technological change also increased investment spending, the effect on the growth rate would depend on the strength of the two opposed forces, but the effect on income distribution would be negative. All this suggests that a higher rate of technological change could spur investment, but yet be immiserizing in the sense of reducing the rate of growth of the economy.

[18] The effects of these types of innovations could be felt through upward shifts in consumption functions. In our models, s would fall, and the results would be similar to those affecting the parameters of the investment function, for the demand constrained and capital constrained cases.

[19] The previous paragraph implies that this could happen even when investment responds positively to the rate of technological change.

[20] See Dutt (1986, in preparation for a formal model in which the markup is endogenously determined and this proposition is demonstrated.

6. Conclusion

In this paper we have developed a simple model of a capitalist economy and examined the effects on growth and income distribution of greater technological dynamism.

We have found that the effects of such increased dynamism would depend crucially on (1) whether the economy happens to be demand constrained, capital constrained or labor constrained in the long run, and (2) the relationship between technological change and some parameters of the model, such as the investment parameters and the markup. Only in the labor constrained case does greater technological dynamism have the favourable effects that. have become a part of conventional wisdom, but there is no reason why the economy of our model, given the configuration of parameter values, should end up thus constrained. In the other cases, the effects depend on the other relationships mentioned, and not enough is known about them to pass a definite judgement, but our analysis shows that greater technological dynamism could possibly be immiserizing, and suggests what issues should be further explored for ascertaining the likelihood of such an outcome.

The conclusions, of course, are derived on the basis of a very simple macroeconomic growth model which analyses technological change in a simpleminded manner. For example, the economy portrayed in the model exhibits fixed coefficients of production. Modifications to allow for flexible coefficients would blur the differences between the demand constrained and capital constrained cases, but keep them apart from the full employment of labour case, so that our main results regarding technological dynamism would not be altered[21]. Technological change in the economy, though introduced with Kaldor's technological progress function, is in effect exogenous in our model. A proper understanding of the interaction between growth and distribution on the one hand and technological change on the other, cannot be thus developed on the basis of the model, although hopefully, it sheds some light on the effects of technological change on growth and distribution.

[21] Dutt (in preparation) considers these modifications.

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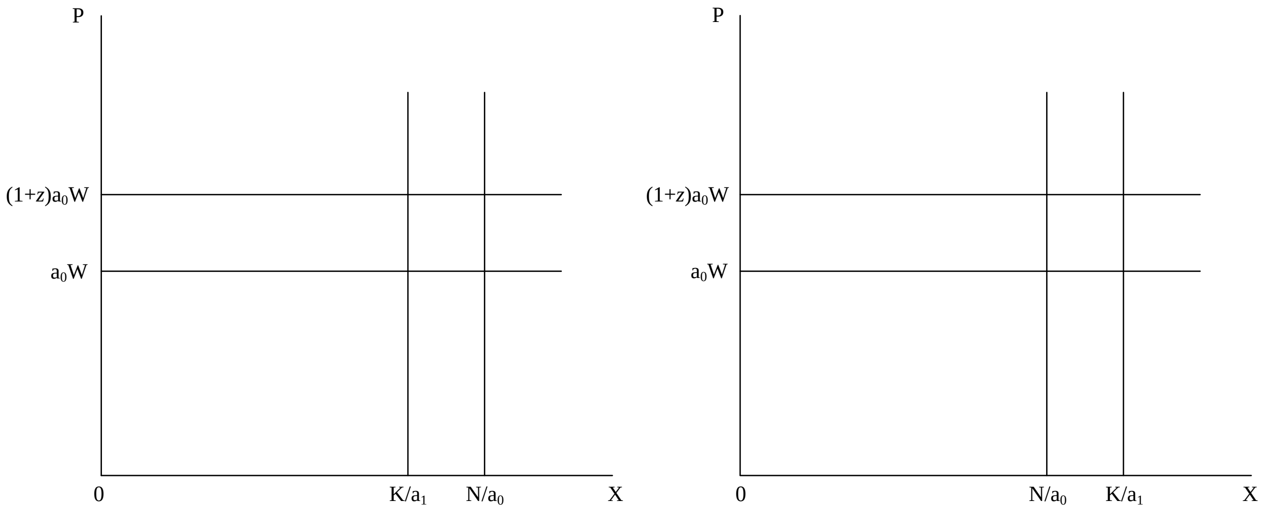
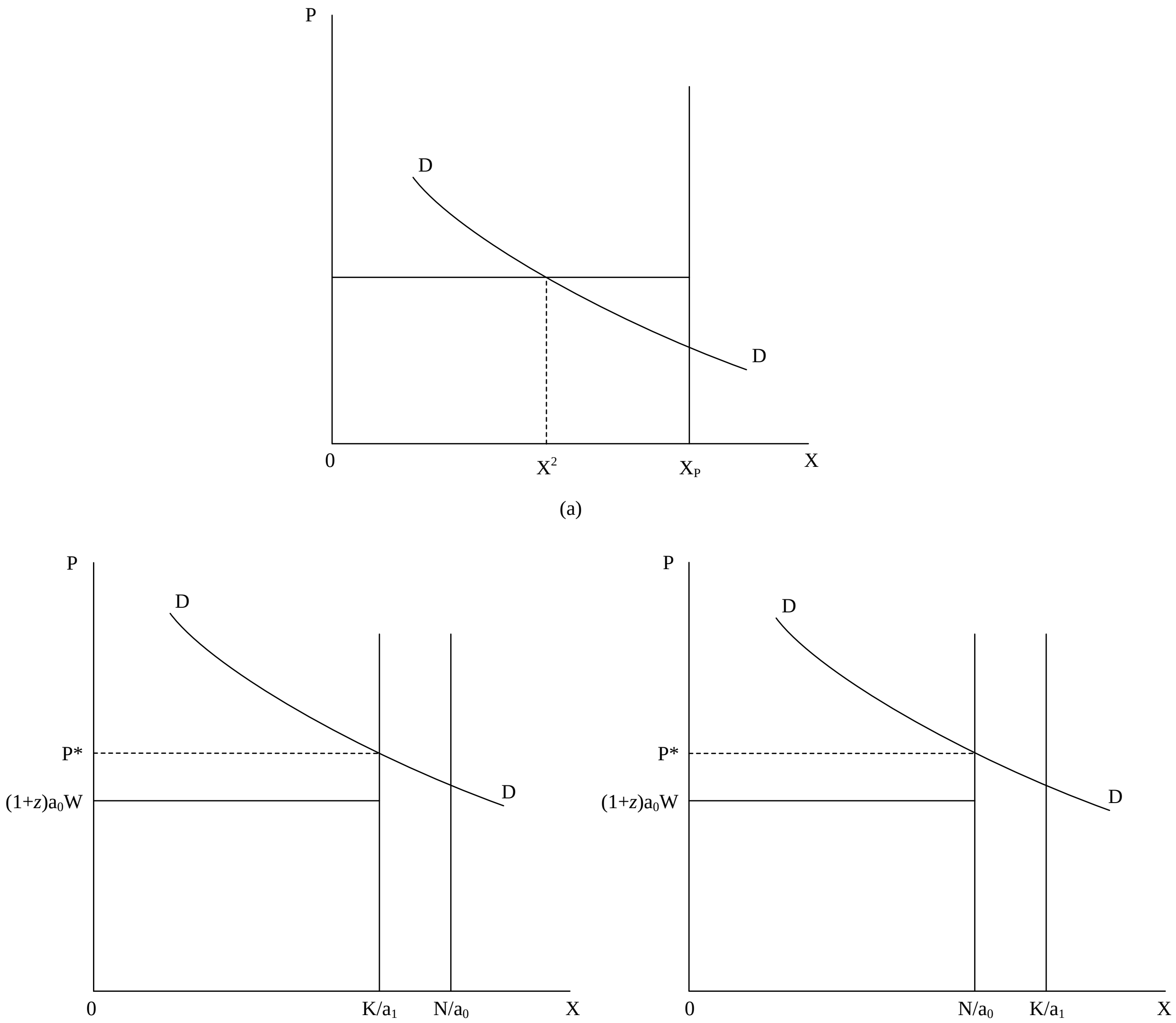


(a) (b)

Figure 1



(b) (c)

Figure 2

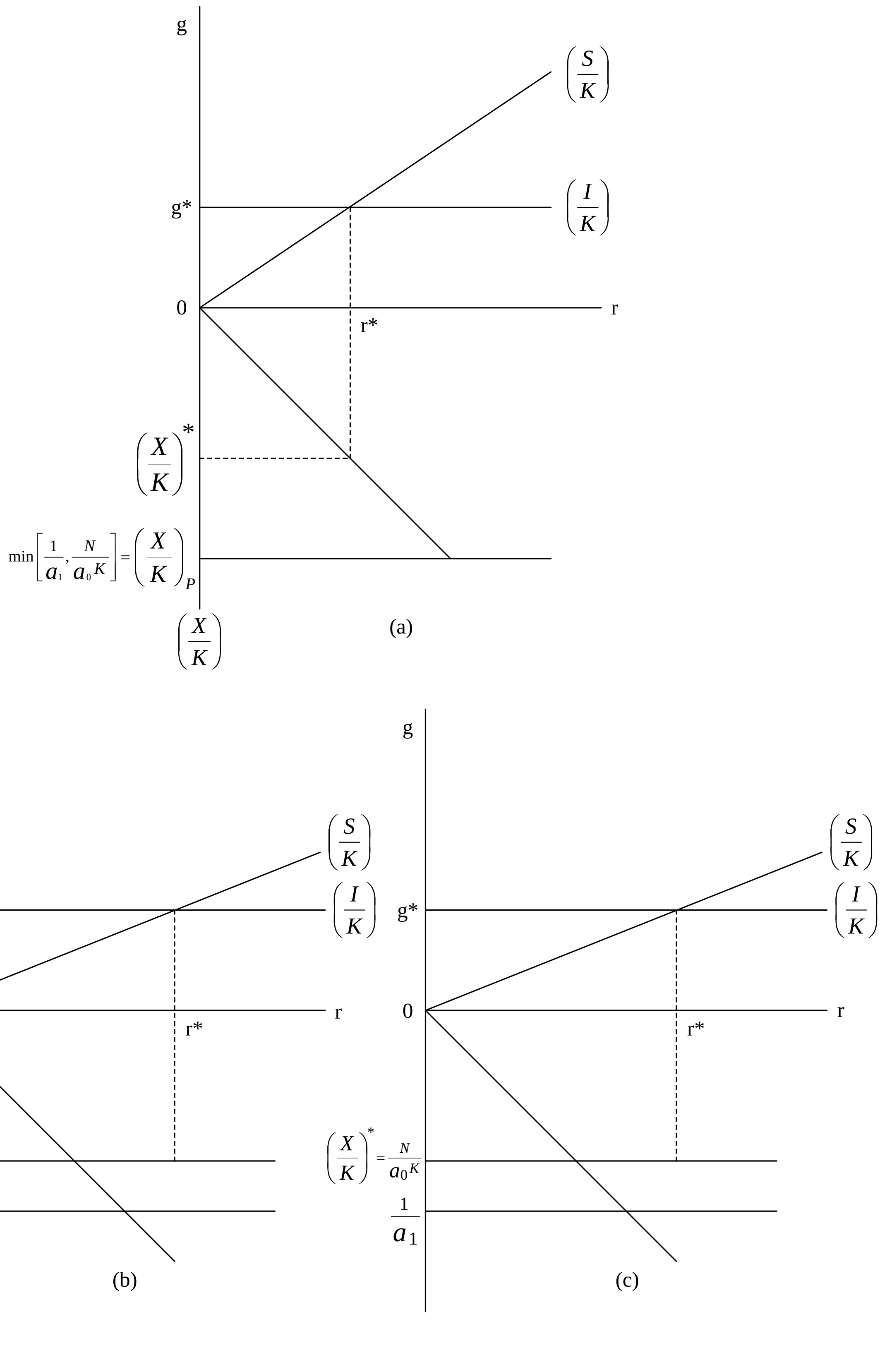


Figure 3

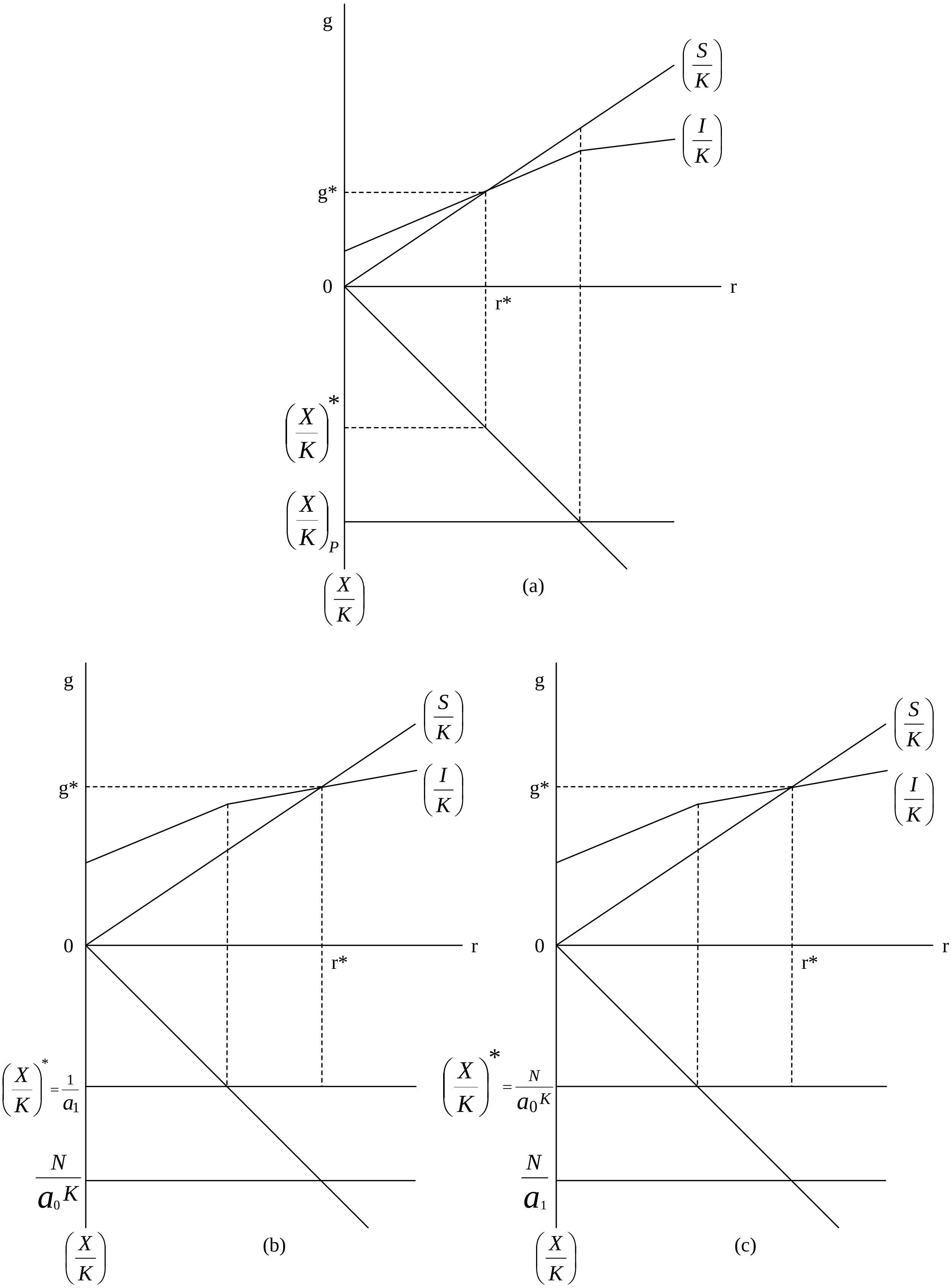
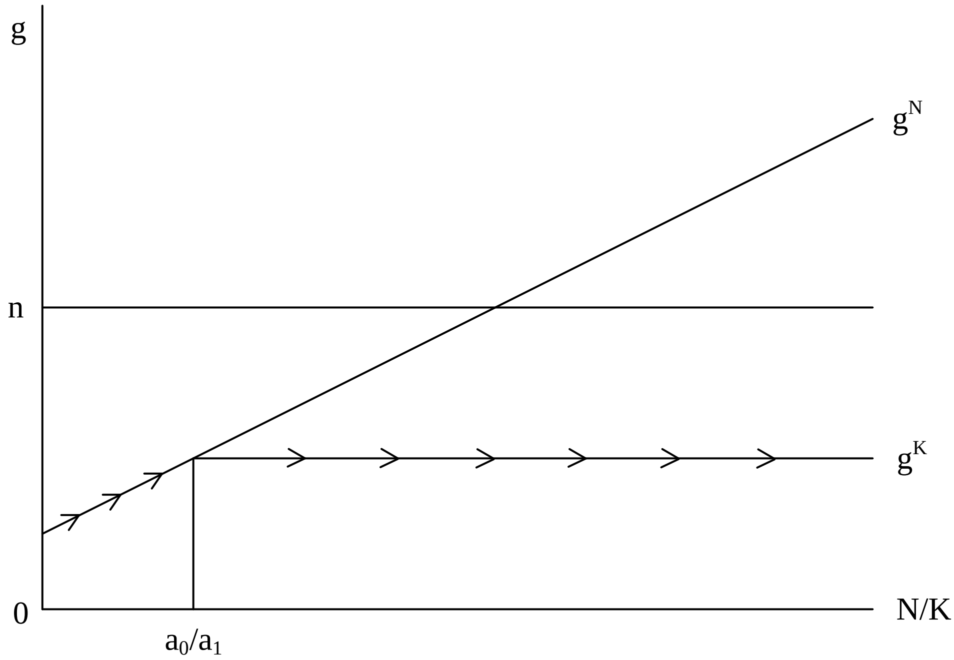
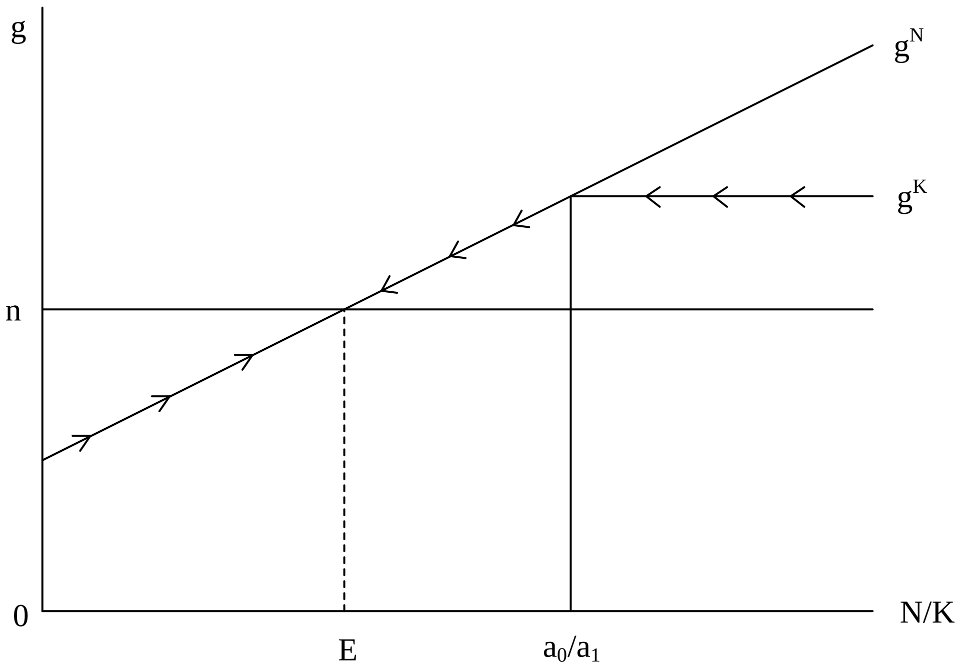

g
(S/K)
(I/K)
g*
0
r
r*
(X/K)*
(X/K)_P
(X/K)
(a)
g
(S/K)
(I/K)
g*
0
r
r*
(X/K)* = 1/a_1
N/(a_0 K)
(X/K)
(b)
g
(S/K)
(I/K)
g*
0
r
r*
(X/K)* = N/(a_0 K)
N/a_1
(X/K)
(c)

Figure 4



(a)



(b)

Figure 5