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Technical Change, Effective Demand and Employment

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Ricardo and Marx saw technological change as a possible cause of long-period unemployment. Neoclassical and Schumpeterian economists regard technological unemployment as a transitory phenomenon. This paper argues that the capital critique (i) demolishes the neoclassical claim that market mechanisms will restore full employment whenever workers are displaced by technical change, and (ii) rehabilitates the old Ricardian argument that automatic compensation factors are generally absent. The neo-Schumpeterian notion of autonomous investment is also rejected, in favour of the view that, in the long period, all investment is induced. By extending Keynes's theory of effective demand to the long period through a model based on the supermultiplier, this paper suggests that the ultimate engines of growth are located in the autonomous components of effective demand—exports, government spending and autonomous consumption. Technical change plays a role in the accumulation process through its effects on consumption patterns and the material input requirements. However, the impact of technical change is now seen to depend upon circumstances such as income distribution, the availability of bank liquidity and exchange rate policy.

> … it seems to me that we should not make use of the concept of autonomous investment at all. (Duesenberry, 1956, p. 141)

1. Introduction

Over the past 20 years, the rate of job creation in most European countries has been anaemic, and unemployment has reached levels unknown in the preceding post-war period. Could technological change be the cause of these high unem-

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ployment levels? This familiar hypothesis has recently been revived by popular authors (Rifkin, 1995), and is echoed, with more sophisticated arguments, by mainstream economists to justify the dismantling of post-Second World War labour and social institutions, allegedly to cope with structural change. The mainstream position seems to derive support from the case of the US, where the association of a more ‘flexible’ labour market with rapid technical change is claimed to be behind strong employment performance over the same 20-year period.

The purpose of this paper is to present a critical examination of the relationship between technical change and aggregate employment. According to traditional neoclassical theory, technical change cannot cause persistent unemployment and will, in most cases, increase all incomes, provided factor markets are competitive. However, the work of Piero Sraffa and the results of the capital theory controversy have given renewed strength to the old Ricardian view that innovations can be harmful to employment (see Ricardo, 1821, ch. XXXI). The neo-Schumpeterian approach suggests a ‘compensation mechanism’ to technological unemployment, based on the positive association between technical change and effective demand, owing to the positive effects of innovations on autonomous investment. This view is discussed and criticised below using a simple supermultiplier model in which effective demand is the determinant of economic growth. Our general conclusion is that there is no reason to believe that there will be sufficient automatic compensation effects of the neo-Schumpeterian type. Only the existence of exogenous or policy factors that stimulate effective demand—such as a burst of exports or expansionary macroeconomic policies—can ensure that rapid technical change will be consistent with full employment.

2. Technical Change and Unemployment in Neoclassical Theory and in Ricardo

2.1. The Marginalist View

According to the traditional marginalist approach, if left free to operate (i.e. if prices are flexible and there are no obstacles to competition), market economies always tend to the full employment of labour, even when technical change reduces the labour inputs required to produce a given output. This tendency towards full employment is brought about by the substitutability of factors of production, which in turn relies on two mechanisms.

Direct substitution operates through changes in the proportion in which the factors of production are used in the production process of each industry.

Indirect substitution works through adjustments in the composition of agents’ optimal consumption baskets in response to relative price changes. This ensures that, even if there is no possibility of factor substitution in production (as when the production coefficients are fixed), there will be a decreasing demand curve for ‘factors’ and the economy will tend to full employment.

In this analytical framework, innovation has, in one respect, the same effect as an increase in the quantity of factors of production, say labour and capital:[1] since these always tend to be fully employed, productivity-increasing technical innovations will necessarily increase the level of production and income 'as soon as the liberated resources can be effectively transferred to new uses' (Hicks, 1932, p. 121).

According to the seminal analysis of Hicks, an innovation is likely to raise the full-employment marginal productivity of both labour and capital. An innovation is said to be 'labour saving' if the full employment marginal productivity of labour increases proportionally less than that of the other factor, indicating that the innovation has made labour relatively less scarce. Only in the case of 'very labour saving' innovations will the full employment marginal productivity of labour and the equilibrium real wage fall (Hicks, 1932, pp. 121–122).[2] In this case, if the downward adjustment of the real wage is not immediate, the innovation may initially create some unemployment.[3] Note, however, that Hicks regarded 'very labour saving' innovations as an extreme case that is very unlikely to occur so pervasively as to outweigh the positive effects on the equilibrium real wages of other types of innovations.

Contemporary mainstream analyses generally maintain that not only temporary, but also rather persistent, unemployment may result from innovations. This is attributed, drawing inspiration from search theory and 'new-Keynesian' contributions, to various market imperfections and price rigidities, often caused by institutional factors, such as the existence of unions, unemployment benefits, and costly firing procedures, which prevent the adjustments of real wages and the mobility of the labour force between industries that is required for the full operation of the two factor substitution mechanisms.[4] Because of these imperfections and rigidities, technical change may affect the natural unemployment rate and the Non-Accelerating Inflation Rate of Unemployment, or NAIRU. The first is mainly associated with frictional (mismatch) and voluntary search unemployment; the second generally refers to equilibrium unemployment that includes, besides frictional and search unemployment, involuntary unemployment resulting from market imperfections and information asymmetries that keep equilibrium wages above full employment wages.

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[1] In another respect the outcome is quite different. An innovation may well increase the equilibrium marginal product, hence the returns, of all factors of production, while the increase in the available quantity of one factor (the others remaining unchanged) will certainly diminish its own equilibrium marginal product.

[2] To understand the nature of 'very labour saving' techniques, one can refer to the usual labour demand and supply diagram. A very labour saving innovation will cause an upward shift of the intercept of the labour demand schedule on the vertical axis; at the same time, the schedule's slope will change so that it intersects the supply schedule below the previous equilibrium real wage.

[3] If the technical innovation occurs in a single industry and the elasticity of demand for the product of this industry is not high enough to allow the same employment level in that industry, part of the labour force will have to move to other industries and this may create some frictional unemployment.

[4] This is, for example, the diagnosis provided by the OECD's *Jobs Study*: 'After having considered the available evidence and the various theories which have been advanced to explain today's unemployment, the basic conclusion was reached that it is *an inability of OECD economies and societies to adapt rapidly and innovatively to a world of rapid structural change that is the principal cause of high and persistent unemployment*' (OECD, 1994, p. vii; italics added).

The continuous structural changes, including technical innovations, which characterise economic systems, are considered to be at the root of the two major components of the natural unemployment rate.

(i) *Mismatch between labour supply and demand*. Structural changes tend to cause differences to open up between the characteristics (skills, education etc) of the labour supply and those required by employers.
(ii) *Voluntary search unemployment*. This type of unemployment, all other things being equal, would be increased by an *intensification* of the shocks—hence by an intensification of technical change—because this would increase the wage dispersion around any given mean, which (according to the model) in turn increases the reservation wage and the optimal duration of the search on the part of the unemployed.[5]

In addition, according to the NAIRU literature, equilibrium may be associated with involuntary unemployment due to:

(iii) *Market imperfections and obstacles to free competition*. Technical change may also raise the NAIRU that results from these factors. In particular, 'Insider–Outsider' models appear to provide a basis for the analysis of the employment consequences of innovations. These models emphasise the market power of employed workers (insiders) caused by hiring and firing costs. The insiders' objective is to obtain the maximum wage compatible with preserving their employment. If an initial shock, which may be caused by a technical innovation, diminishes employment in some firms, the remaining insiders in these firms will attempt to fix the wage at the higher marginal product compatible with the lower employment level. Once employment has diminished in this way, the mechanism of wage determination in these models prevents competitive pressure towards wage adjustment from the unemployed outsiders (Lindbeck & Snower, 1986, 1988).[6]

Hence, contemporary mainstream theory still posits an underlying tendency towards the maximum employment compatible with existing 'imperfections', but innovation and structural change can increase the level of equilibrium unemployment. The employment losses due to technical change can be reduced by increasing labour market flexibility, by establishing incentives for workers to adjust rapidly to a changing environment, and by creating an institutional framework that is favourable to labour mobility.

[5] In this respect, the conclusions from search models are at odds with the data, which show that higher unemployment in OECD countries is associated with periods of less intense structural change (see Stirati *et al*., 1999).
[6] Employment will fall as a consequence of a 'very labour saving innovation', but also when the innovation is *not* very labour saving and there are, as assumed in some insider–outsider models, asymmetries in the response to shocks. These mean that there is only a rise in the wage at a constant employment level in firms where the innovation shifts the labour demand schedule to the right, whereas there is no change in wages while employment falls in firms where the innovation has a negative impact (for example because they have not innovated and have lost market share).

2.2. Technological Unemployment in Ricardo

At the beginning of the 19th century, David Ricardo initially believed that the 'application of machinery to any branch of production' is 'a general good, accompanied only with that portion of inconvenience which in most cases attends the removal of capital and labour from one employment to another' (Ricardo, 1821, p. 386). But he subsequently came to a different conclusion, namely that 'the discovery and use of machinery' can be 'injurious to the labouring class' (Ricardo, 1821, p. 390). According to Ricardo, the introduction of machinery would reduce the labour requirement in the innovating industry, and hence also production and employment in the wage goods industry.[7] Observe that in Ricardo we do not find the idea that wage flexibility can lead to 'factor substitution' and hence to full employment.[8]

The interest and the force of the 'Ricardian case' have been renewed by Sraffa's recovery of the classical approach and his clarification of its distinctive analytical structure. It is the absence of substitution mechanisms that explains the possibility of persistent unemployment in the Ricardian framework (Montani, 1985). Failure to perceive this crucial difference has often led to misinterpretations of the 'Ricardo effect' as a transitory or short-run phenomenon occurring in the transition towards a new full employment equilibrium and its association with special assumptions about the nature of technical progress (Wicksell, 1924, Schumpeter, 1954).

Sraffa not only suggested that the neoclassical substitution mechanisms were absent in the classical approach, but he also demonstrated that they have logical flaws. This inspired the controversy on the neoclassical notion of 'capital'

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[7] See also Stirati *et al.* (1999, pp. 221–222). Ricardo's reasoning could be illustrated in the following way. Consider the relations:

$$(\mathbf{I}-\mathbf{A})\mathbf{X}=\mathbf{Y},$$

where **A** is the matrix of production inputs per unit of output including, as in the classical tradition, the wage goods entering the worker's subsistence, **X** is the vector of the social product, and **Y** is the *given* vector of output net of the circulating capital used in production. The labour requirement, hence the employment level L associated with a given **Y**, is given by:

$$L=\mathbf{l}\ \mathbf{X}=\mathbf{l}\ (\mathbf{I}-\mathbf{A})^{-1}\mathrm{Y}$$

where **l** is the vector of labour requirements per unit of output. According to Ricardo, the introduction of machinery would reduce terms in **l** and **A**. Ricardo assumed that the machinery would not be subject to wear and tear. Removing this simplifying assumption would mean also considering a matrix of amortisation quotas of existing fixed capitals, some of which might be increased by the innovation. There would, however, be no *a priori* reason to expect that this would compensate for the fall in direct labour requirements and circulating capital. In principle, it is possible to conceive innovations that would allow an increase in the rate of profit for given values of the real wage and, at the same time, increase labour requirements for a given vector of net output. In terms of the wage–profit curve these would be innovations that shift towards the origin the intercept on the real wage axis, and outwards the intercept on the profit rate axis. Again, however, there is no reason to expect that these types of innovation would systematically occur in such a way as to compensate for the fall in employment caused by the innovations that reduce the labour requirements per unit of output.

[8] Ricardo, who accepted Say's Law, conceded that the negative effect of the innovation on employment *might* be *gradually* and *partially* offset if the capitalists invested their higher real incomes, thus enlarging productive capacity and employment.

in the 1960s and 1970s, which is concerned precisely with the logical foundation of the decreasing relation between the demand for a 'factor' and its remuneration.

The first substitution mechanism, direct substitution in production, predicts that when, for example, the wage rate falls, methods of production using more labour relative to other inputs will become more profitable and the demand for labour will rise. Yet it has been shown that when there are a multiplicity of techniques and more than one type of capital good, the possibility of re-switching techniques undermines the neoclassical prediction (Sraffa, 1960, pp. 81–84; Garegnani, 1970).

Traditional conclusions concerning the outcome of the second mechanism, indirect substitution through changes in consumption, are also undermined. According to marginalist theory, a fall in the relative price of any 'factor' will lead to a fall of the relative price of, and an increase in the demand for, the goods in whose production the factor is used relatively more intensely. However, as the real wage varies from zero to maximum, the price of any commodity *A* produced with a given technique may alternately fall and rise relative to the price of another commodity *B*, produced with a different given technique, so that no *a priori* expectations as to the direction of the change, based on the 'factor intensity' in the production of the two commodities, are justified (Sraffa, 1960, pp. 37–38).[9]

Thus, modern non-conventional theory confirms Ricardo's view that there are no *necessary* compensation effects to technological unemployment. Does this mean that technological unemployment is an irreversible result in the non-conventional view? To answer this question we must turn to the effective demand side. Compensation effects on effective demand have no role in neoclassical theory (since there the substitution mechanisms always lead the system towards the level and composition of output that ensures the maximum possible utilisation of existing resources). On the other hand, the Ricardian approach does not *necessarily* mean acceptance of Say's Law, and once this is rejected, effective demand-related compensation effects and policy prescriptions become possible in principle.

3. Technical Change, Investment and Effective Demand

The association between innovation and gross investment has traditionally been considered one of Schumpeter's main lessons and it is taken for granted by most economists. Noticeably, mainstream economists have seen this view as consistent with neoclassical theory. By contrast, some modern heterodox followers of

[9] Moreover, even leaving aside the weak theoretical foundations of these substitution mechanisms, it cannot be claimed that the conventional supposition of an inverse relation between the real wage and employment has overwhelming empirical evidence on its side (see Zenezini, 1993). Work by Anyadike-Danes & Godley (1989) shows that the relation between real wages and employment found in econometric models may be spurious, while research on real wages over the cycle does not support the inverse relation (Michie, 1988). Recent empirical research showing that the introduction or increase of minimum wage rates has no negative effect on employment (Card & Krueger, 1996) also signals the lack of empirical support for the inverse relation.

Schumpeter have advanced the idea of complementarity between Schumpeter's explanation of investment and Keynes's theory of effective demand.

3.1. Technical Progress and Investment: neoclassical and Schumpeterian views

According to marginalist principles, technical change normally shifts the marginal productivity of capital schedule to the right. In flow terms, the gross investment function, derived from the capital demand schedule, also shifts to the right. In general, the long-period real interest (profit) rate will rise. How much it rises depends on the behaviour of the full employment saving supply schedule, the slope and position of which hinge on the elasticity of full employment saving with respect to the interest rate and to income, respectively. The positive effect of technical progress on gross investment must not be interpreted as a relaxation of the marginalist view that sees full employment saving as the determinant of aggregate investment. In this approach, the technical conditions of production, along with the physical quantities of the other production factors being employed, determine the demand for investment (capital); hence technical change may increase the *demand* for investment.[10] But the *actual level* of investment (capital) depends on the position and slope of the supply of full employment savings.

Schumpeter did not challenge this view.[11] His focus was on the effects of innovation on the *composition* of investment, not on the determination of its *level* and *rate* of growth; that was left to traditional theory. He argued that: 'the carrying into effect of an innovation involves, not primarily an increase in the existing factors of production, but the shifting of existing factors from old to new uses' (Schumpeter, 1939, p. 111; cf. also Schumpeter, 1934, pp. 67–68). The role of the credit system in a non-planned economy is precisely that of permitting this shifting of resources from the old to the new firms (Schumpeter 1939, pp. 111–112; 1934, p. 69). The independence of the *level* of investment from full employment saving is therefore not a feature of Schumpeter's analysis. His view of the association between technical change and investment is complementary to the marginalist position rather than an alternative to it.[12] Indeed, Schumpeter's contribution, although relegated to the wings, has never been rejected by

[10] However as Wicksell and Hicks have noted (see Section 2.1 above), if technical change is 'very capital-saving' the marginal product of capital may actually decrease and with it the demand for gross investment.

[11] Nor do the recent neoclassical Endogenous Growth Theories. For a critical discussion of these see Cesaratto (1999a, 1999b).

[12] The nature of a *qualification* of the traditional theory of growth is apparent from the footnote that Schumpeter (1939, p. 111) adds to the above statement: 'Even with respect to those quantities of factors which currently accrue, say, in an increasing population, and can be used for the new purposes without having previously served any old ones, it is more correct to say that they are shifted from the uses they would have served had the new purposes not been decided on, than simply to say that they go to the new uses directly. The point is of some importance, because in the traditional model it was increase in factors, rather than the shifting of factors, that was made the chief vehicle of economic progress.'

mainstream economists, and the process of 'creative destruction' can be identified with the process of structural change discussed in Section 2.1 above.

3.2. A Marriage between Schumpeter and Keynes?

Other economists working in the Schumpeterian tradition (e.g. Freeman *et al.*, 1982) and in the 'long waves' tradition (e.g. Freeman, 1983; Kleinknecht, 1992) have seen the possibility of a marriage between Keynes and Schumpeter, via the idea that the *level* of investment (not only its composition) is determined by innovations.[13] In this perspective, the technological unemployment generated by innovations on the production side can be compensated on the demand side:

> Whereas in neo-classical theory the emphasis is on factor price flexibility and in Keynesian theory on aggregate demand, with Schumpeter it is on *autonomous investment*, embodying new technical innovation that is the basis of economic development and new employment. (Freeman, 1995, p. 52; italics added)

We shall now consider the extent to which we can expect technical change to have positive compensation effects on the various components of effective demand.

3.3. The Long-period Theory of Effective Demand

In *The General Theory*, Keynes (1936) showed that when an economy is operating below the full utilisation of its existing capital stock, an increase in investment does not require a prior reduction in consumption. The higher level of income generated by greater utilisation of capacity generates savings equal to investment. The neoclassical synthesis limited this result to short-period situations of low business and financial confidence. On the opposite side, some non-orthodox economists have tried to extend Keynes's analysis to the long period. The argument is that, in the long run (when productive capacity may vary considerably), even more than in the short period, investment is independent of, and determines saving through, changes in output. Thus, aggregate output is determined by effective demand, defined as aggregate expenditures forthcoming at normal prices of production (see Garegnani, 1962; Garegnani & Palumbo, 1998).

Given the technology, the level of employment will then also depend on the level of effective demand. Innovations will usually reduce the total labour requirements per unit of aggregate output and thus reduce the employment

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[13] More than in Schumpeter, seminal work in this direction can be found in Kalecki and Dennis Robertson. Kalecki regarded technical change as a factor that could break capitalism's tendency to stagnate (e.g. Kalecki, 1971, pp. 150–151), although he was rather sceptical about the long-run demand effects of innovations (Kalecki, 1971, p. 151). Robertson (1915) linked the instability of investment to waves of technical change. This explanation of investment led Robertson (1926), who was then working closely with Keynes, to look at investment as independent of saving and to anticipate some elements of *The General Theory*.

Table 1. Components of effective demand

	Capacity creating	*Non-capacity creating*
Autonomous		Government spending, Exports, Autonomous consumption, Business expenditure
Induced	Gross Investment	Induced consumption

associated with any level of output. However, high growth rates of output could, in principle, compensate decreasing labour requirements.[14]

Does innovation compensate technological unemployment by positively affecting the level and rate of growth of effective demand? To discuss this question, we shall sketch a simple model of accumulation and examine the persistent effects of innovation on the level and rate of growth of effective demand in the process of accumulation.

3.4. The Components of Effective Demand[15]

We classify the components of effective demand according to two criteria:

(a) whether or not they depend on the actual or expected level of real income generated by firms' decisions to produce;
(b) whether or not they have gross capacity generating effects.

On this basis, we propose the classification given in Table 1.

Let us comment on this classification. *Induced consumption expenditure* is that part of the wage bill spent by workers on consumption goods. This expenditure is induced since it is actually generated and paid by firms' decisions to produce, which create contractual or 'earned' income, i.e. wages and salaries. From the point of view of the income generating process and the multiplier mechanism, all other expenditures are autonomous. In particular, all investment expenditures are necessarily autonomous or independent variables. However, this need not be the case when we extend the analysis to the process of accumulation and take full account of the feedback between the capacity and demand generating effects of investment. In this context it is better to consider all gross investment to be induced, since these capacity-creating expenditures basically depend on expectations about the evolution of normal levels of effective demand over the life of the equipment and are therefore subject to an accelerator or capital stock adjustment mechanism.

As a result, in our taxonomy, the autonomous expenditure comprises all

[14] Consider the well-known identity equation $e = y - p$, where e is the growth rate of employment, y of output and p of productivity (all measured in logarithms). Partial compensation occurs as long as y is positive; employment loss due to technical change is fully compensated ($e \geq 0$) if $y \geq p$.
[15] The taxonomy adopted here is borrowed from Serrano (1995, 1996).

sources of potential discretionary or autonomous injection of purchasing power in the economy that, at the same time, do not create capacity. They include:

(a) *Total government spending*, the level of which is decided autonomously by Government.
(b) *Total exports*, the level of which, *ceteris paribus*, depends on foreign demand (i.e. exports are financed by exogenous purchasing power).
(c) *Autonomous consumption*, financed by credit to consumers and accumulated wealth (Steindl, 1982). Most expenditure of households on owner-occupied housing, usually classified as 'residential investment', should be included here.
(d) *Autonomous business expenditure*, including R&D and managerial expenses, that likewise do not lead to gross capacity creation. Here we include the important and relatively unexplored component of autonomous business expenditure that consists of the 'superfluous' business expenditure in, say, company cars, executive jets etc, which is clearly a form of unproductive consumption, although it is usually treated as a production cost for tax reasons (or to hide the appropriation of surplus from the stockholders). This type of discretionary expenditure is not financed by the wage bill and should therefore be classified as an autonomous component of aggregate demand (Cowling, 1981).

4. Technical Change and Effective Demand: a supermultiplier analysis

4.1. The Output and Capacity Supermultipliers

In order to classify and assess the various possible effects of technical change on effective demand, we have found it useful to use a model of accumulation based on the *supermultiplier* (Kaldor, 1971; Serrano, 1995, 1996; Bortis, 1997) in which the growth of output and of the productive capacity of the economy follows the growth of the various autonomous components of aggregate demand via combined multiplier and accelerator effects. In the model, the investment function should not be taken to imply that actual output is equal to capacity output. According to the principle of effective demand, income in any period is determined, independently of the level of capacity, by the level of effective demand. As noted below, the way we regard the formation of growth expectations shows that firms do not try to adjust the capital stock fully in a single period. The investment function is such that amortisation and expansion depend on current effective demand (hence, the degree of utilisation of capacity) and long-term expectations.

We use standard notation. Y is the current level of effective demand and output. C_a, G, B and X are, respectively, autonomous consumption, government expenditure, autonomous business expenditure and exports, the autonomous components of effective demand. Induced (gross) investment is I_i. d is the replacement coefficient, g_e is the expected average rate of growth of normal effective demand over the life of the investment that is currently being installed, and v is the capital-output coefficient. M stands for imports, and m and t for the marginal propensities to import and to tax, respectively. The five equations that follow are a simple extension of the standard Keynesian model for the determination of Gross Domestic Product. The main difference is in Equation (3), where the gross level of induced investment is a function of g_e, d and v.[16]

$$Y = C + I_i + B + G + X - M \tag{1}$$

$$C = C_a + c(1-t)Y \tag{2}$$

$$I_i = v(d + g_e)Y \tag{3}$$

$$M = mY \tag{4}$$

Let us group together all the autonomous components of final demand that do not create capacity and denote them as Z:

$$Z = C_a + B + G + X \tag{5}$$

We can also group together the determinants of the aggregate marginal propensity to save (s) as:

$$s = m + (1-c(1-t)) \tag{6}$$

We solve these equations to obtain the level of long-period effective demand and output:

$$Y = \frac{Z}{s - v\,(d + g_e)} \tag{7}$$

We shall call the reciprocal of the denominator of Equation (7) (after Hicks, 1950) the *output supermultiplier*.[17] This equation shows the level of effective demand as a function of the autonomous components of aggregate demand, with investment assumed not to be autonomous but induced by the expected trend of effective demand.

The level of output given by our output supermultiplier does not necessarily entail the normal utilisation of existing productive capacity. This, however, does not mean that a continuous tendency of capacity to adjust itself to the trend of effective demand is not at work. An adjustment of this kind will be occurring over time as the capacity effects of the propensity to invest at a given g_e materialise and as the expected rate of growth g_e itself is gradually revised in the light of actually realised growth performance.[18] Indeed, in the process of accumulation (defined as the process in which long-period positions such as Equation (7) undergo changes), the actual degree of capacity utilisation tends to

[16] For the sake of simplicity we follow the practice, usual in Keynesian models, of ignoring circulating capital. By contrast, the model in Serrano (1995, 1996) assumed production was carried out with circulating capital only, ignoring fixed capital.

[17] As must be the case in a demand-driven model, we assume that the denominator of Equation (7) is positive and therefore that the aggregate marginal propensity to spend in induced investment and consumption is less than one. This implies that the given g_e is not too high or, more precisely, that it is less than $s/v - d$ (see Serrano, 1995).

[18] As long as g_e is constant and thus the investment share is constant, productive capacity will grow at the same rate as actual effective demand. Discrepancies between g_e and the actual rate of growth of demand and output will appear as a difference between the *level* of productive capacity and the *level* of effective demand and output.

move towards its normal or planned level, as the distance between actual and expected growth rates of effective demand narrows and the size and growth rate of capacity output adjust to the trend of effective demand. As a result, the economy's productive capacity slowly gravitates towards a fully adjusted path in which capacity follows the trend of effective demand and the degree of capacity utilisation is equal to the planned utilisation rate. It is easy to see that, in this process, productive capacity will tend to grow at the rate at which autonomous expenditures are growing, since (given the parameters s, v and d, and assuming that investment is induced) it will not be possible to sustain growth without the expansion of autonomous expenditures.

If we assume that g_e is made endogenous in the process of accumulation and is gradually revised by means of a flexible accelerator process (Chenery, 1952), both the expected and actual rates of growth of the economy will tend to converge to the rate of growth of autonomous expenditures, as long as the response of g_e to the actually observed growth rate g is slow.[19] This means that the productive capacity of the economy (Y^*) will have a moving centre of gravity expressed by a supermultiplier equation in which the growth rate that appears in the propensity to invest is given by the growth rate of autonomous expenditures (g_z). This secular *capacity supermultiplier* or 'fully adjusted' supermultiplier can be written:

$$Y^* = \frac{Z}{s - v\,(d + g_z)} \tag{8}$$

This equation describes the centre of gravitation of the accumulation process, the pace of which is set by the growth of the autonomous components of effective demand.[20] Changes that affect one or more of the elements of Equation (8) can have a persistent effect on the trend of the economy's productive capacity. Let us use this result to look at the effects of technical change on the long-period rate of accumulation through the lenses of the two supermultipliers in Equations (7) and (8).

4.2. The Effects of Technical Change on Long-period Effective Demand

Autonomous or unjustified investment? As seen above, there is a well-established view that technical change directly affects effective demand through its effect on the level of autonomous investment. Indeed, since Kalecki's earlier trade cycle

[19] We are assuming that the current value of g_e is revised over time according to an equation such as $g_{et} = g_{et-1} + x(g_{et-j} - g_{t-j})$ where t is the period in which those expectations are formed, x is the reaction coefficient and j is the time lag. If we set x and j equal to 1 we have the rigid accelerator used by Hicks (1950) which for most parameter values lead to empirically implausible instability (and the need for non-linearities to produce plausible results). We are thus assuming a 'flexible' Chenery accelerator with low values of x and/or longer lags to ensure the dynamic stability of the multiplier–accelerator process.

[20] Again in order for the level and growth of capacity output to be seen as demand-led, the marginal propensity to spend must be less than one. This requires the actual rate of growth of autonomous expenditures z to be sufficiently small (strictly lower than $s/v - d$).

models and Hicks' own supermultiplier, it is common practice to include both an induced and an autonomous component of investment in the same model and to explain the autonomous components by reference to technical change (e.g. Gandolfo, 1996, ch. 6).

Although this practice is still quite common, it was long ago criticised by Kaldor (1951) and Duesenberry (1956), for it ignores the capacity effects of these autonomous investments. The main point of their criticism is that when the innovators who are making the autonomous investments steal market share from non-innovators, it is hard to see why non-innovators do not react to their now-reduced market shares and capacity utilisation rates by contracting their own induced investment expenditures. Indeed, in models in which autonomous and induced (gross) investments are simply added, the implicit assumption is that non-innovators keep trying to provide productive capacity for the whole market, even when their market share clearly and systematically does not justify it. Thus, it seems reasonable to think that the accelerator or capital stock adjustment process will tend to compensate for the expansionary effects of innovators' autonomous decisions to invest, by reducing induced investment. Since there is also the problem that most gross investment includes technical innovation to some degree and since investors (whether 'innovators' or not) are unlikely to be indifferent to the capacity effects of their investment expenditures, it seems better not to use the concept of autonomous investment at all.

This does not mean that a wave of innovative investment may not affect the level of effective demand of the economy or that all induced investment must be seen as 'justified' by the actual level or growth of demand. 'Unjustified' investment—or 'misdirected investment' as Keynes (1936, p. 321) defined it—occurs all the time, whether because of technical change or 'animal spirits' or more generally because of the very nature of competition in a capitalist economy. However, the best way to analyse these expenditures in a long-period context is to represent a wave of innovative investment (which may later turn out to be 'unjustified' in the aggregate) as an exogenous increase in the aggregate estimate of g_e, the expected trend of the growth rate of demand, while still considering all gross investment to be induced so that we do not forget that capital stock is always adjusting. We can therefore complete the quotation at the beginning of this paper: 'it seems to me that we should not make use of the concept of autonomous investment at all. We should regard exogenous events, such as innovations, as factors which influence the response of investment to the level of income and the size and character of the stock of capital' (Duesenberry, 1956, p. 141). If we do this, we see that in the *output supermultiplier*, Equation (7), a wave of innovative investment generates an increase in g_e, since it increases the aggregate marginal propensity to spend.

This does not imply that a single increase in g_e leads to a permanently higher rate of growth, since, without an increase in the rate of growth of proper autonomous expenditures (Z), the economy will grow faster than the rate of growth of autonomous expenditure only in the period immediately after the increase in g_e. Later, the economy will have a higher supermultiplier but its growth rate will fall back to the rate of growth at which autonomous expenditures grow (g_z). Therefore, a single rise in g_e will have a persistent level effect (because it implies a bigger supermultiplier) but not a permanent growth rate effect (since the rate of growth of autonomous expenditures has not changed (see Equation (7) above).

When we extend the analysis to the secular process of accumulation and use the *capacity supermultiplier*, we see that even this initial 'autonomous' increase in g_e gradually tends to be undone as g_e is gradually revised in the light of the actual growth rates as the effects of the excess capacity are felt. Thus, the capacity supermultiplier shows that the capacity effects of any 'unjustified' g_e are not lasting and thus the initial wave of investment will not tend to have a persistent effect on the trend level of capacity output. The capital stock adjustment process is continuously revising any given g_e and making it tend towards g_z, the growth rate of autonomous expenditures that do not create capacity. It is therefore very unlikely that, in the process of accumulation, a wave of innovative investment could have a persistent effect on the growth rate of output and capacity by its direct effect on investment. In particular, it is very hard to see how a persistently higher trend growth rate of effective demand can be sustained through that direct route via 'autonomous' investment decisions.

Another way in which intensification of technological competition may directly increase effective demand is if it leads to increases in autonomous business expenditure in research and development. Note, however, that R&D is not innovation but expenditure in search of innovations; thus, increases in R&D may be the direct effect of increased competition but they are not the direct effect of technical change *per se* (being one of its causes). In most industrialised countries, firms spend significant amounts on private R&D which, according to our classification, is an autonomous component of effective demand. An increase in the rate of growth of R&D expenditure will increase the levels and rate of growth of autonomous expenditures (Z and g_z) and thus have a growth rate effect on the long-period output supermultiplier (Equation (7)) and both a growth rate and level effect on the capacity supermultiplier (Equation (8)).

Effects of technical change on the capital–output and depreciation coefficients. Technical change will have persistent effects on gross induced investment through its effects on the capital–output and replacement coefficients. Changes in these coefficients will affect the marginal propensity to invest via both the output and the capacity supermultipliers. By thus changing the values of the supermultipliers, changes in the replacement coefficient or capital–output ratio will cause level effects on long-period output and the trend of productive capacity.

Faster technical change may cause an increase in the replacement coefficient d. This may be due to the faster economic obsolescence of plants following product and process innovations. The competitive process can lead to early replacement of capital goods in sectors subject to technical change and a higher level of gross investment. This would be a *level* effect on the marginal propensity to invest. However, even if technical change is so persistent as to determine systematic accelerated economic obsolescence of capital goods, other circumstances mentioned in the literature may delay or reduce the effects on gross investment.

It has been pointed out that expected shortening of the economic life of capital goods can lead to *capital-saving innovations* (Caminati, 1986), in which case higher gross investment due to early replacement is compensated by the lower value of the new capital goods. Although in this case d increases, the capital–output ratio v decreases and the net effect on the marginal propensity to invest is ambiguous. It has also been argued that expectation of further technical change may induce postponement of replacement (Caminati, 1986; Rosenberg, 1982). Of course, this decision depends on the balance between losses the firm may incur by the delayed introduction of new machinery (smaller market shares; being held back in learning how best to apply the new techniques) on the one hand; and the expected losses due to its short anticipated economic life on the other. Thus, faster technical change does not necessarily increase d and thus has no definite effect of increasing induced gross investment.

Turning now to the capital–output ratio v, we know it will change according to the overall bias of technical change. Thus, if innovations are, on average, capital-saving (in Harrod's sense), v will be lower and technical progress will imply *lower* levels of gross investment and a decrease in the aggregate marginal propensity to spend. Of course, if technical change is Harrod-neutral, v will remain unaffected. On the other hand, if technical change has a capital-using bias, v will increase together with gross investment and the marginal propensity to invest.

Note, however, that in the latter case, while technical change clearly has a positive effect on gross investment, we cannot be sure it will have an expansionary effect on aggregate demand as a whole. As we know from the classical analysis of switching of techniques, a capital-using system (i.e. one with a lower maximum rate of profits) will be cost minimising only if it saves enough labour to prevent the normal rate of profits from falling. This means that such techniques will only be adopted if wages lag behind the increase in output per worker and this associated change in the distribution of income is bound to have a depressive effect on the economy's marginal propensity to consume.

We conclude that when technical change is capital-using and thus the marginal propensity to invest increases, we cannot be sure whether the economy's aggregate marginal propensity to spend and the supermultiplier will increase or decrease (v will increase but so will s) because of the negative effect of the associated change in distribution on the marginal propensity to consume.

Technical change and consumption patterns. Innovations are traditionally classified as product or process innovations, according to whether they create new products or change production processes. This is not an entirely satisfactory classification since a new machine, for instance, is both a new product and a process innovation. Moreover, as far as consumer goods and services are concerned, process innovations are often what create or at least enable many product innovations to occur. As observed by Garegnani (1962, p. 98) the substantial fall of prices that follows large process innovations can have the same effects as major product innovations, insofar as it enables mass consumption of previously inaccessible products and services.

In general, the process aspect of innovations has an impact on the economy's marginal propensity to consume through the innovations' effect on the rate of profits and the share of wages. If the long-period impact of innovations is to leave the normal rate of profits and the share of wages unchanged then there will be no impact on the marginal propensity to consume. On the other hand, if technical change leads to a higher normal rate of profits and a lower wage share, then the marginal propensity to consume will decrease (s will increase) and with it the long-period levels of output and productive capacity via the supermultipliers of Equations (7) and (8).

To the extent that innovations generate new or differentiated products, they may actually increase or at least prevent the decrease in the aggregate marginal propensity to consume. In a closed economy, the most direct route by which the product aspect of innovations has a decidedly positive impact on the growth of aggregate demand is through the effects of continuous introduction of new products on the growth of autonomous consumption. In fact, the continuous introduction of new and differentiated products may help to explain the stylised fact of the rough long-run constancy of the average propensity to consume in advanced capitalist economies. The average propensity to consume depends both on autonomous consumption and the marginal propensity to consume. Even if the latter is constant (or decreasing), it is easily compensated by the continuous growth (or acceleration) of autonomous consumption so that the average remains unchanged.

Product innovations, by continuously creating new needs and making consumer durables quickly obsolete may foster autonomous consumption. This is more likely if, on the one hand, income distribution and consumer credit are favourable to mass consumption of workers; and, on the other, the wealthy use their financial property to obtain access to new products. The economy's credit and financial system should create enough liquidity for the realisation of accumulated wealth and the new purchasing power necessary for the expansion of autonomous consumption. A stream of product innovations may thus increase the rate of growth of autonomous consumption, and consequently of autonomous demand g_z, and have the effect of increasing the rate of growth of long-period output and the longer-run trend of productive capacity.

Exports and the propensity to import. Let us finally consider the magnitudes associated with the foreign trade performance of an economy. Theory and historical experience suggest that technological advantages are a main determinant of the growth of exports. The single most important expansionist effect of technical change for a particular economy is the increase in the growth of exports that it can bring. A faster growth of exports leads to a higher growth rate of autonomous demand z and thus to faster growth of long-period output and capacity through the supermultipliers.

Other factors, in particular exchange rate policy, can of course affect the virtuous circle between export performance and productivity growth (Kaldor, 1971). Technological advantages also reduce import penetration, which has a level effect by increasing the economy's domestic marginal propensity to spend (reductions in m lower s). Note, however, that these open economy effects cannot operate for all countries simultaneously. It is not possible for the world economy to grow through increasing its share of world exports and reducing its import share. The expansion of world trade inevitably depends on the expansion of domestic effective demand in many countries simultaneously.

4.3. Effective Demand as a Compensation Mechanism

In the preceding paragraphs we have provided an orderly classification of the possible effects of innovations on effective demand, using the supermultiplier model summarised by Equations (7) and (8). What can we conclude about the neo-Schumpeterian thesis of compensation effects of effective demand on technological unemployment?

As we have seen, many aspects of technological change positively affect the long-period level of effective demand. However, the supermultiplier analysis clarifies that even when the effects of innovation on effective demand are positive, they are often only level effects incapable of sustaining a higher growth rate of effective demand. It is also clear that the expansionary macroeconomic effects of technical change often depend crucially on the macroeconomic policy regime; that is, on fiscal, credit, exchange rate and income distribution policies. Thus, there is nothing 'automatic' about those macroeconomic effects, since under different policies they may not happen.

The neo-Schumpeterian compensation thesis requires that, in the long run, a higher growth of output per worker should lead automatically (and not as policy choice) to a compensating increase in the growth rate of effective demand (a *growth* not just a *level* effect). As we have seen, not only is it unclear that faster technical change will automatically increase the trend growth rate (in the closed economy) but even if it does there is no mechanism to ensure that this increase in the growth rate will be sufficient to match the growth of output per worker.

4.4. Expansionary Macroeconomic Policies and Demand Induced Technical Change

The thesis that there must be some strong automatic compensating forces is usually supported by reference to the fact that some historical episodes of very fast technical change have been accompanied by relatively fast growth of aggregate output and employment. In some countries and periods, this is often explained by export-led growth as countries with fast technical progress quickly increase their shares in the world market (Medeiros & Serrano, 1999). On the other hand, for the world economy as a whole, periods such as the 'golden age' of fast growth from the end of the Second World War to the early 1970s, in which there was fast growth in output per worker and at the same time a high rate of job creation, can be explained by the highly expansionary international macroeconomic regime in which demand management policies in the US (particularly in the area of government spending) and the special position of the dollar as the international currency, stimulated export-led growth in many developed countries (Pivetti, 1992; Stirati *et al.*, 1999; Medeiros & Serrano, 1999).

The high rate of growth of output per worker can, in turn, be partially explained by a set of factors that fall under the headings of increasing returns, learning by doing effects, etc, that show that there is a strong endogenous element in the growth of output per worker. Economic growth induces a greater division of labour, facilitates the penetration of new products, and fosters innovative activities by accelerating the recovery of their costs before innovations are imitated (Cesaratto, 1996). What historical experience seems to be showing is that fast aggregate demand growth allows more inventions to turn into innovations and that makes output per worker grow faster.

5. Conclusions

This paper takes what could be called an effective demand approach to the study of the long-run impact of technical change on employment. Using a supermultiplier model of long-period effective demand, we examined the various channels whereby aggregate demand may be positively affected by innovations. A first result is the criticism of the notion of autonomous, innovation-led investment. In the long period, all gross investment should be considered demand-led, although technological competition might explain the existence, in each period, of some 'unjustified investment', something that may raise the level of gross investment but not its growth rate. Secondly, the impact of innovation on consumption patterns cannot be considered without taking account of income distribution, the character of technical change, the availability of consumer credit, and the reverse causation from income growth to technical change. Thirdly, even allowing that circumstances are favourable to a positive impact of innovations on aggregate demand, this is not enough to ensure that the growth of effective demand will be high enough to compensate labour productivity growth. The main conclusion is that technical change is not a sufficient explanation of long-run economic growth, let alone a sufficient force to keep the economy on a full employment path. Technical change can therefore be a cause of persistent unemployment quite independently of the existence of the various market imperfections and rigidities stressed by neoclassical theorists.

Only the growth of the autonomous components of effective demand shown in the supermultiplier, induced by exogenous factors as in the case of export growth or by expansionary macroeconomic policies, can guarantee that technical change is consistent with full employment. Therefore, we do not think it is appropriate to attribute the current high levels of unemployment in Europe to technical and structural change. The recent high unemployment rates appear to be the result of slow output growth, in turn the outcome of slow growth of long-period effective demand, which is the result of the progressive abandonment of expansionary macroeconomic policies in most developed countries since the mid-1970s (for a fuller discussion, see Stirati *et al*., 1999).

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