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Product and Process Innovations in Economic Growth*

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With 4 Figures

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1. Introduction

Economic growth and development have been strongly influenced and shaped by new products. It is sufficient to think of the deep impact on society and the economy which has been brought about by the automobile and by television.

It can well be said that the introduction of new consumers' products is a necessary condition for economic progress in a market economy. If there were only the same unchanged products available, people would tend to reduce their purchases more and more as they gradually reach satiation. Thus, if there exists an Engel-curve (with an income elasticity of smaller than one, and perhaps even falling over time) for the aggregate of existing products, the consumption ratio of an economy is bound to fall continuously in the absence of new products. With technical progress on the production side, this means that the secularly rising per capita income level is not accompanied by a similarly rising demand. The market system must ultimately brake down because of underconsumption.

Economic theory, and more precisely growth theory, have almost exclusively been concerned with technical progress on the production side, i. e. with process innovations. The literature us full of discussions about the cause, rate and bias of process innovations. Product innovations are rarely mentioned at all, except by writers such as Schumpeter, Kalecki or Joan Robinson. Among the model builders there is the notable (but seemingly unnoticed) exception of Pasinetti[1].

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[1] L. Pasinetti: A Multi-Sectoral Model of Economic Growth, in: Le Rôle de l'Analyse Econométrique dans la Formulation de Plans de Développement. Pontificiae Academiae Scientiarum Scripta Varia *28,* Città del Vaticano, 1965.

The importance of new products for growth theory has also been pointed out by M. Neumann: Kapitalbildung, Wettbewerb und ökonomisches Wachs-

The neglect of product innovations in economic theory may be due to the fact that it is subsumed under process innovations. Though the interpretation of most writers stands against it, there is some truth in it. New products can be directly used for consumtion as well as for production purposes. To the extent in which new goods are used in production, the production function is indeed shifted, satisfying the definition of technical progress. There can be little doubt, however, that the specific impact of new products on the *demand side* is neglected in such an interpretation.

The role of new products in economic growth can only be captured in a satisfactory way if it is explicitely introduced as a seperate factor influencing the demand side. This will be attempted in the simplest way possible in the framework of a neoclassical growth model.

2. The Model

Following the definition of an Engel-curve, it is assumed that the per capita demand for *existing goods* (and services) E/L is tied to per capita income Y/L with a constant elasticity ε

$$\frac{E}{L} = \left(\frac{Y}{L}\right)^{\varepsilon}, \tag{1 a}$$

or

$$\frac{\dot{E}}{E} = \varepsilon\left[\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}\right] + \frac{\dot{L}}{L}, \tag{1 b}$$

where (in general) $\dot{X} \equiv dX/dt$. If the consumers reach a satiation point for existing products, $\varepsilon < 1$, and the demand for existing goods grows less rapidly than output. Only if $\varepsilon = 1$, demand for existing products keeps pace with per capita output.

For equilibrium growth — or a Golden Age — it is *required* that the consumption ratio c (or its complement, the savings ratio s) is constant over time. This means that the demand for *existing and new products* C must rise at the same rate as national income

$$\frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} \rightarrow c \equiv (1 - s) = \frac{C}{Y} = \text{const.} \tag{2}$$

In order for an economy to grow in a Golden Age it is thus necessary that new products at all time fill the gap in demand between $C(t)$ and $E(t)$. The model thus comprises two sectors: the sector in which existing

tum, Berlin—Heidelberg—New York 1968. See also: K. Borchardt: Die Veränderlichkeit der Konsumgüterstruktur in einer wachsenden Wirtschaft, in: W. Krelle (Hrsg.): Theorien des einzel- und gesamtwirtschaftlichen Wachstums. Schriften des Vereins für Socialpolitik, N. F. Bd. 34, Berlin 1965. These two authors do not develop any formal model on product innovations, however.

goods, and the sector in which new goods, are produced. Product innovations $T_G(t)$ must therefore grow at the rate τ_G:

$$\tau_G \equiv \frac{\dot{T}_G}{T_G} = \frac{\dot{C}}{C} - \frac{\dot{E}}{E}. \tag{3 a}$$

This means that

$$E(t) \cdot T_G(t) = C(t). \tag{3 b}$$

Technical progress on the product side thus must take a specific form in order to allow equilibrium growth. Product innovations must result in such a shift of consumers' preference functions that the total demand for existing and new products is "augmented" by the factor $T_G(t)$. Other kinds of product innovations prohibit the attainment of a Golden Age because they change the savings ratio over time.

The correspondence with the production side is obvious. There equally, technical progress must take a specific "factor-augmenting" form [called Harrod-Neutrality $T_p(t)$] in order to allow growth at a steady rate. Other forms of process innovations change the capital-output ratio.

The production function is given by

$$Y(t) = F[K(t), T_p(t) \cdot L(t)]; \quad F' > 0, \ F'' < 0, \tag{4}$$

where $K(t)$ is the capital stock and $L(t)$ the labour force. The growth rates of labour and of process innovations are assumed constant

$$\dot{L}(t)/L(t) = \lambda; \quad \lambda \geqslant 0, \tag{5}$$

$$\dot{T}_p(t)/T_p(t) = \tau_p; \quad \tau_p \geqslant 0. \tag{6}$$

Taking into account the savings/investment relation

$$\dot{K}(t) = s\,Y(t); \quad s = \text{const.}, \tag{7}$$

the Golden Age growth rate is given by

$$\frac{\dot{Y}}{Y} = \tau_p + \lambda. \tag{8}$$

From (1 b) and (3 a) it follows that

$$\frac{\dot{C}}{C} = \tau_G + \varepsilon\left[\frac{\dot{Y}}{Y} - \lambda\right] + \lambda, \tag{9}$$

which according to (2) must be equal to the overall growth rate

$$\tau_G + \varepsilon\left[\frac{\dot{Y}}{Y} - \lambda\right] + \lambda = \frac{\dot{Y}}{Y}$$

and remembering (8) this becomes

$$\frac{\dot{Y}}{Y} = \tau_p + \lambda = \frac{\tau_G}{1-\varepsilon} + \lambda,$$

$$\tau_G = (1-\varepsilon)\,\tau_p = \Phi\,(\tau_p). \qquad (10)$$

This equation shows that the growth process depends on an interaction of the speed of technical progress in products (τ_G) and in processes (τ_p). If technical change on the process side is given (e. g. τ_p), then equilibrium growth is only possible if technical change on the product side happens at a completely determined rate $\hat{\tau}_G$ as given by (10):

$$\hat{\tau}_G = (1-\varepsilon)\,\hat{\tau}_p = \Phi\,(\hat{\tau}_p).$$

Conversely, process innovations must occur at a specific rate $\Phi^{-1}\,(\tau_G)$ if product innovations happen at the speed τ_G. This required relationship between the two forms of technical progress is shown in Fig. 1 (with $\varepsilon < 1$).

3. The Equilibrium Expansion

The possibilities of technical progress open to an economy can be formalized in the concept of an innovation possibility frontier. This frontier has been introduced by Kennedy, von Weizsäcker and Samuelson[2] to show the choice open to a society between labour aug-

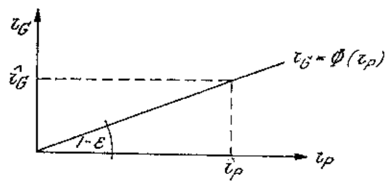

Fig. 1

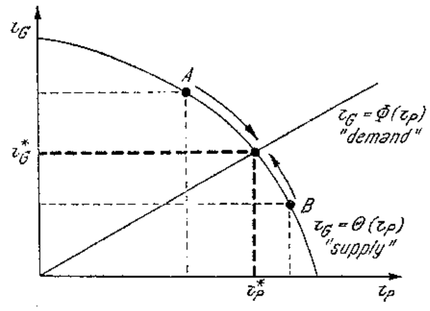

Fig. 2

menting and capital augmenting technical change. It is even more fruitful for the description of the choice between product and process innovations:

$$\tau_G = \Theta\,(\tau_p); \quad \Theta' < 0, \; \Theta'' < 0. \qquad (11)$$

[2] See P. Samuelson: A Theory of Induced Innovation Along Kennedy-Weizsäcker Lines, The Review of Economics and Statistics *XLVII* (1965), p. 343–356.

The enterpreneurs are faced with this innovation possibility frontier; they must decide wether they should use the available technological possibilities for the creation of new goods or for more efficient production techniques.

The interaction of the "demand" side $\tau_G = \Phi(\tau_p)$ and the "supply" side $\tau_G = \Theta(\tau_p)$ of the two forms of technical progress is pictured in Fig. 2.

The intersection of (10) and (11) determines an equilibrium, at which the two kinds of innovation proceed at the rates τ_G^* and τ_p^*. Thus, in addition to the require *proportion* of the creation of product and process innovations, the *speed* of both forms of technical progress is now fully determined. It can be seen hat there is only *one* equilibrium growth rate of the economy: $\lambda + \tau_p^*$, and one per capita income growth rate: τ_p^*.

A comparison of the dynamic equilibrium situations gives the following (cet. par.) results:

(a) The smaller the elasticity of demand for existing goods, the smaller is the natural growth rate of the economy. The society must deviate its technical ingenuity from the production aspects to the creation of new products in order to keep up demand, which entails less rapid growth.

It is interesting to note, that in the present neoclassical growth model the demand side co-determines the steady state rate of growth of the economy. The natural growth rate is no longer completely exogeneous as in the usual neoclassical growth model of the Solow-Meade type. The natural growth rate is determined through an interaction with the rest of the economy.

(b) The natural growth rate of the economy and of new products is the larger, the more technical possibilities there are, i. e. the further outwards the innovation possibility frontier is situated.

(c) If the innovation of new goods becomes easier to untertake (i. e. if the frontier for new products *only* shifts outwards) per capita growth increases together with the more rapid introduction of new goods. The model thus predicts that in equilibrium a rise of product innovations and of output growth go together. This corresponds to the view of Schumpeter, Kalecki and Joan Robinson who stress the chances for more rapid growth which arise with the introduction of new goods[3].

If, on the other hand, there is an outward shift of process innovation possibilities only, the growth rate of per capita output grows less than proportionately, because at the same time the innovation of new goods must be stepped up. There is only a full effect on output growth, if $\varepsilon = 1$.

[3] J. Schumpeter: Die Theorie der wirtschaftlichen Entwicklung, Leipzig 1912. — M. Kalecki: The Theory of Economic Dynamics, London 1954, p. 158. — J. Robinson: The Accumulation of Capital, London 1956, p. 260 et seq.

(d) It is conceivable that the innovation possibility frontier itself depends on factor prices. If product innovations require a different capital/labour ratio to implement than process innovations, a change in factor prices leads to a *twist* of the whole frontier. If e. g. product innovations are more labour-intensive than process innovations, and the wage/rental ratio increases, there will be a twist of the curve in favour of process innovations. In most circumstances, this means that the growth rate of both per capita income and of new goods increases (Fig. 3 a).

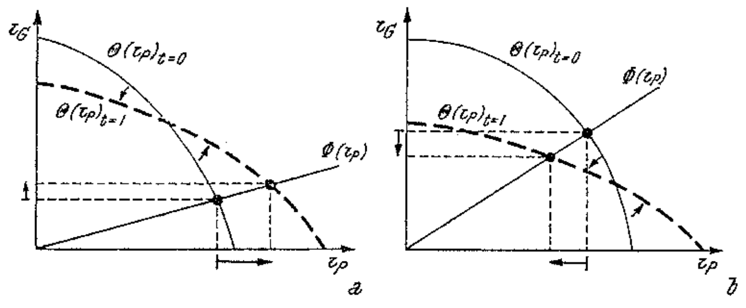

Fig. 3

With a low income elasticity of demand for old products and a very marked twist in favour of process innovations a case may arise, in which both growth rates are reduced (Fig. 3 b).

4. Advertising and Technical Change

So far in this paper, "new goods" were considered to be objectively measurable innovations in the consumer goods sector. In a modern economy with predominantly large managerial firms and oligopolistic competition, advertising may take the place of the introduction of new products[4]. The managers must decide whether it is more profitable to introduce genuine technical improvements in production processes or whether they should rather try to influence consumers through advertising. With minor reinterpretations, the model developed holds equally for this case. The income elasticity ε now gives the demand for consumers' goods *in the absence of advertising*. In equilibrium, advertising A (t) must increase the demand for goods such as to make up the gap between the growth rates of output and demand (without advertising). This continuous increase in demand is achieved through the influence of advertising on the preference function of consumers, which is reflected in the market by shifts of demand. When the gap between supply and demand is closed by the introduction of new products, the preferences of consumers *may*

[4] I owe this point to a suggestion by Prof. Streissler.

stay unchanged[5]. When the gap is closed by advertising, however, consumer preferences (or welfare) are no longer exogeneously given and constant over time, but they become an endogeneous part of the model: they influence other parts of the economy and they are themselves changing over time to adjust to the technical conditions in the economy.

Eq. (3 a) becomes

$$\tau_A \equiv \frac{\dot{A}}{A} = \frac{\dot{C}}{C} - \frac{\dot{E}}{E}. \tag{12}$$

Instead of (10) there is now a "required" relationship between the growth of advertising and of process innovations

$$\tau_A = (1 - \varepsilon)\, \tau_p = \Psi(\tau_p). \tag{13}$$

The trade-off between advertising and process innovations is given by a curve similar to (11)

$$\tau_A = \Omega(\tau_p); \quad \Omega' < 0, \; \Omega'' < 0. \tag{14}$$

The intersection between (13) and (14) determines the growth rate of advertising and process innovations going with an equilibrium expansion.

The smaller the growth of consumers' demand without advertising (i. e. the smaller ε), the larger must be the advertising effort compared to the introduction of new techniques, and the smaller will hence be the steady state rate of per capita output growth. The society must devote a large part of its brainpower to keep up demand, and therefore can employ less effort to increase supply.

The welfare implications of the introduction of new consumer goods and of advertising may be quite different. The consumers may well be unaware of it because they are made believe by "the hidden persuaders" that they buy new goods though in fact they are fundamentally unaltered.

In reality, both advertising and the introduction of genuinely new goods are simultaneously used by enterpreneurs in their sales policy. It does not present any major difficulty to incorporate this mixed case into the present framework. However, the analysis proceeds now further with the pure case of product and process innovations.

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[5] This is true if consumers' preferences are not defined in the (ordinary) coordinate system of goods, but rather in the Lancaster-coordinate system of "characteristics". In that case new products are represented by a more efficient combination of characteristics; the consumers need not change their preference in terms of characteristics in order to buy new goods. For this approach see K. Lancaster: Change and Innovation in the Technology of Consumption, The American Economic Review, Papers and Proceedings *LVI* (1966), p. 14—23.

5. Disequilibrium and Stability

Is there a tendency for the economy to reach equilibrium at the point (τ_G^*, τ_p^*) in Fig. 2, and to remain there?

Consider a situation in which there are relatively too many product innovations undertaken, e. g. point A in Fig. 2, where $\tau_G > \tau_G^*$ and $\tau_p < \tau_p^*$. The consumers are confronted with an upsurge of new products which they want to purchase. They will continually increase the share of their income devoted to consumption. As is well known in growth theory, the growth rate of the economy falls as long as the savings ratio falls. Though the savings ratio does not influence the equilibrium rate of expansion, it is positively correlated with the *level* of income. With a falling s, the economy takes a path as indicated in Fig. 4. Depending on the size of the natural growth rate ($\tau_p + \lambda$) the output of the economy may rise or fall in absolute terms, but the disequilibrium growth rate is lower than the natural one.

The downward movement of the savings ratio and the growth rate certainly come to an end when the lowest possible savings ratio (say s_3 in Fig. 4) is reached; after that the economy grows again at the natural rate. The constancy of the savings ratio means, however, that a part of

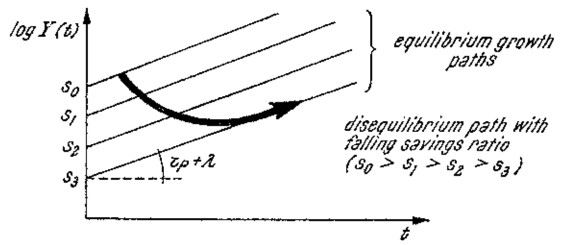

Fig. 4

the excessively growing new products is not sold. Unlike in the orthodox neo-classical model, no full equilibrium is reached. The enterpreneurs experience a continuous lack of demand for their new products put on the market. They will realize that the market is overstuffed with new products and that there are better profit oppurtunities in the application of new technology to processes. The proportion of product innovations will change in favour of process innovations, the savings ratio will rise again to the "normal" level, and equilibrium will be re-established.

The forces tending back to the equilibrium will not only arise when the lowest possible savings ratio is actually reached, but make themselves felt already during the initial disequilibrium phases. The rise of the consumption ratio will certainly decrease over time because the households become more and more used to new products and can therefore no longer be so easily induced to buy new products and to change their savings behaviour. A slowdown of the rate of change of the savings ratio has a negative effect on the market for new products. The enterpreneurs feel thus gradually, but always more strongly, a pressure to change the mix of product to process innovations back to the equilibrium configuration.

Due to the index number problem involved with the appearence of new products it is difficult to speak of the "general price level" going with this fall and recovery of output growth. It is, however, clear, that the excessive rate of introduction of new products depresses the price level of new goods (compared to before)[6].

If, on the other hand, product innovations are too sluggish compared to process innovations (e. g. point B in Fig. 4, where $\tau_G < \tau_G^*$, $\tau_p > \tau_p^*$), consumers react by increasing their savings ratio which leads to a disequilibrium phase of increased growth. The lack of growth of new products leads to a general shortage of new goods and tends to increase the price level for new goods (compared to before)[7]. Enterpreneurs adapt by using the technical possibilities of the society for the creation of new products for which there are such good profit opportunities. Equilibrium will be re-established; it is stable.

6. Conclusions

The following main conclusions can be drawn from the analysis:

(a) The ordinary neo-classical equilibrium growth model considering only process innovations is inconsistent, if it is accepted that there exists satiation for existing goods. In such a model there is a continuous lack of demand so that the neo-classical "equilibrium" cannot persist.

(b) A growing market economy can stay in equilibrium only if there is a balance between technical change used to create new products and applied to processes.

(c) The natural growth rate of the economy is no longer exogeneous as in the orthodox neo-classical model, but depends on the interaction with the rest of the economy.

(d) There are two structural changes going with *equilibrium* growth, namely (i) a constant rise of the proportion of income to employment and (ii) a secular fall in the share of old products in favour of new products in total output.

(e) Phases of inflation and price stability are (partly) due to imbalances in the introduction of product and process innovations.

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[6] If the rigid relationship $E/L = (Y/L)^\varepsilon$ is relaxed, the consumers would probably buy less old goods when there is an excess supply of new goods, partly because of changing relative prices. The general price level (measured by a Laspeyres index of an unchanged goods basket) would fall.

[7] If the rigid relationship between old and new products is relaxed, the general price level rises.

(f) Allowing for advertising, the preference function of consumers becomes an endogeneous part of a growing economy; it changes continuously to adjust to evolving technical conditions in the society, and at the same time it influences other parts of the economy.

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