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A "technology-gap approach to cumulative growth": toward an integrated model. Empirical evidence for Spain, 1960-1997.

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Abstract

The purpose of the present paper is to explore the possibility to compound in a unique formalization two different but complementary theories of technical change and macroeconomic growth, that is the Kaldorian idea of cumulative causation and the technology-gap approach to economic growth.

In section 1 the main linkages between macroeconomic aggregates are considered. In a first step, the French school of “regulation” is presented, as an interesting framework to compound the main relationships between institutions, technology and the economy (section 1a). Given such a general framework, the main long-run macroeconomic relationships between growth in average productivity and growth in demand are considered in section 1b, in which the Regulationist-Kaldorian idea of cumulative growth is put forward. However, as observed in section 1c, such a framework is unable to explain the process of catching up through the diffusion of innovation created in more technologically advanced countries (regions), so that its complementarity and integrability with a technology-gap view of economic growth is explored in sections 2 and 3.

More precisely, in section 2 the structural form of this model of "technology-gap approach to cumulative growth" is presented; and in section 3 the characteristics of the sub-reduced forms for the dynamic of productivity and demand and the main analytical properties of the model are discussed.

The main findings of these sections can be sum up in the following way: an higher rate of diffusion or creation of innovative activity in a country determines a higher and stable rate of productivity increase only if it is "sustained" by the technological characteristics of the system, by the prevailing type of investment of firms and by the distribution of the productivity increases between profit earners and wage perceivers. In other words, what matters for growth is not just innovation, accumulation or distribution, but their structural compatibility over time. Many different growth regimes are theoretically possible, but only some of them lead to a cumulative-technology-gap led growth.

As a first experiment, the model has been empirically tested for the case of Spain in the period 1960-1997. The results of the estimations show that there

has been a structural break with the transformation from a Kaldorian cumulative growth regime led by internal consumption, in the first period (1960-1975), to a technology-gap growth regime, in the second period (1982-1990). Hence, as a general conclusion for the case of Spain, the Kaldorian cumulative causation process and the technology-gap growth appear to be alternative rather than complementary explanations of economic growth.

It is then necessary in future works to extend the empirical test of the model to a set of advanced countries, in order to investigate whether this conclusion is common to other countries, or rather it is peculiar to the evolution of the Spanish growth regime.

1. Institutions, innovation and economic growth

Following the evolutionary perspective, a macroeconomic theory of technical change and economic growth should coherently includes three different but complementary aspects:

a. A general framework with the linkages between institutions, technology and the economy.
b. A macroeconomic theory to account for the dynamic of the most important variables, with special regard to the interactions between growth in productivity and growth in demand.
c. A description of the way in which the creation and the diffusion of the innovative activity fuel economic growth.

Then, the hypothesis that will be put forward in the following sections is that only a good match between national institutions (a), productivity-demand interactions (b) and creation and diffusion of innovative activity (c) can ensure a sustained period of economic growth and lead to convergence in GDP per capita.
Therefore, in order to present such hypothesis in further details, each of these three aspects will be briefly and separately considered in the following three sections (1a-1c). Then, in section 2 and 3, the possibility to combine the three aspects in a unique formalization will be discussed; in section 4 the results of the empirical test for the case of Spain (1960-1997) will be presented; and in section 5 the main ideas and results of the paper will be sum up.

1a. Relationships between institutions, technology and the economy: the French school of “regulation”

An interesting and rather general framework for the relationships between institutions, technology and the economy is offered by the French school of "regulation", developed by Robert Boyer and his colleagues at CEPREMAP (Paris). This approach does not accept either economic or technological determinism, the aim being to study economic and technological issues within the range of social and institutional relationships. In addition, the approach tries to put forward a real dynamic framework which can reconcile the study of economics and technology with attention to historical evolution.

In this context, the economic system is seen as something "regulated" by economic, technological, social and institutional issues which allow the system to work. A good match between these relationships leads to the growth of the system, whilst a mismatch can entail the crisis of the system and eventually the modification of the "modes de règulation". These comprise the "accumulation regime", the "monetary relationships", the "wage-labour nexus", the "type of competition", the "international regimes" and the forms of "state interventions" (Boyer, 1988; Boyer and Petit, 1988 and 1989). These institutional forms can have different and alternative features and when combined together they offer a framework for technical progress and economic growth. If a good match between institutional forms and technological opportunities occurs, a "mode" of regulation is estabilished which can ensure the economic growth for a given historical period.

This framework might turn out to be very useful for an evolutionary theory of economic growth, as it tries to bridge the gap between the evolutionary perspective of innovation studies and institutional and historical aspects. Thus, a general view combining together these two streams of the literature is needed, in order to provide the successive analysis with a wide background.

1b. Macroeconomic theory of growth and interactions between productivity and demand: the Kaldorian cumulative growth model revisited

Given such a general framework, it is now important to see in further details which are the main long-run macroeconomic relationships taken into account. Following the tradition of the “regulation school”, an interesting description of economic growth coherent with the general institutional framework just presented, is the Kaldorian cumulative growth model (Kaldor (1967; 1981)).

The structure of this model is based on the two elements which are essential to the class of growth models deriving from Kaldor: a causal link of a Keynesian kind between growth in demand and growth in production, and a process of interaction between growth of demand and growth of productivity.

The latter is developed through two distint causal sequences. On the one hand, we presuppose the existence of Kaldor-Verdoorn returns to scale with which the presence of a causal connection, leading from a growth in demand to a growth in productivity, is made explicit, mainly through the capital formation process ("productivity regime"). On the other hand, the same productivity growth determines growth in demand, both via the positive influence has on exports by raising the price competitiveness of national products on foreign markets, and by means of its effects on the internal components of demand induced by the growth of real incomes and the change in their distribution between various income categories, mainly the profit earners and the wage perceivers ("demand regime").

With regard to the causal relationship from growth in demand to growth in productivity ("productivity regime"), its sources can be different: static increasing returns to scale; the deepening of the division of labour due to the expansion of the market; technical advances embodied into specific equipment and machine tools; learning by doing and, by extension, learning by using. Recent works by Fingleton and McCombie (1998), Pini (1996; 1997) and Vivarelli (1995) show that the Verdoorn law can still significantly explain a part of the average productivity increases, both at a national and regional level in many OECD countries.

On the other hand, the causal relationship from growth in productivity to growth in demand ("demand regime") is based on two different mechanisms, an external causation and an internal causation mechanism.

The external causation mechanism is based on the medium- and long-term dynamics of the foreign component of the aggregate demand, exports. These are influenced by external exogenous factors, such as the evolution of foreign markets and the price and non price competitiveness of foreign goods, and by internal factors, such as the dynamics of the exchange rate and productivity gains. The latter affects the terms of trade and thus the competitiveness of national products on foreign markets, besides the results of the innovation process, which influence the non price competitiveness of national products.

The core of the internal causation mechanism lies in the way the various components of aggregate demand, mainly private consumption and private investments, are stimulated by the growth in real incomes and by the changes in their social distribution which follow from productivity increases. The benefits of technical progress are distributed between the various social classes of the economic system affecting the growth paths of aggregate demand and its distinct components, investment and consumption. Investments depend on the dynamics of both, the aggregate demand (the Keynesian accelerator principle) and the profits (according to a classical accumulation mechanism). Consumption, on the other hand, depends mainly on the overall income of the workers and therefore on the dynamics of real wages and of employment, without, however, excluding an influence of the consumption decisions of the profit earners.

In this Kaldorian approach to cumulative growth, technological change takes on an essential role in the determination of the dynamics of production, demand and productivity. The intensity, bias and results of the innovation process, together with the dynamic returns to scale, not only trace the growth path of labour productivity, but also set off important mechanisms which are both external (stimulating the export dynamics) and internal (affecting real incomes, their distribution and therefore the internal components of aggregate demand, private consumption and private investments). However, what the model is unable to explain is the process of catching up through the international diffusion of innovation, a potential and powerful source of growth and convergence, that is briefly analysed in the following section.

1c. The creation and diffusion of innovative activity: a "technology-gap approach" to economic growth

While the cumulative growth model is suitable to explain the dynamic process of interaction between the growth of productivity and the growth of demand, its main limit is that the only source of growth for a country or a region is its internal innovation activity, that is the very beginning of the cumulative causation circle. On the other hand, what the model is unable to explain is the process of catching up through the diffusion of innovation from other more technologically advanced countries. On the contrary, a rich tradition (known as “technology-gap” approach to economic growth) has shown that the domestic capability to absorb knowledge spillovers from abroad is a key factor in order to explain growth rate differentials over time and space.

According to the “technology gap theory” (Fagerberg 1987, 1988 and 1994; Fagerberg, Guerrieri and Verspagen 1999; Verspagen 1993), it is argued that succesful adoption of new technology is “a costly activity, that requires investment in indigeneous capabilities, capital equipment, infrastructure, etc. Without a sufficient level of such investments, a country is unlikely to benefit from backwardness, and risk of falling behind relative to the technology leaders, rather than ‘catching up’” (Verspagen, 1991).

Thus, following this perspective, economic growth may be seen as the outcome of three sets of factors:

- innovation activities in the country/region;
- the potential for exploiting technologies developed elsewhere (diffusion);
- complementary and structural factors affecting to what extent this potential is realized.

As regards to the third factor, the complementary and structural variables usually taken into account by the empirical works along this tradition include physical infrastructure, population density, industrial structure and long-term unemployment. Among these, the first two are found to have a positive impact on technology diffusion, since both a more developed infrastructure and a higher population density increase the profitability or reduce the cost of introducing new technology. Regarding the other two, they measure respectively how the industrial structure and long-term unemployment, as an indicator of institutional failure, affect the catching up process and thus the economic performance.

It may be interesting to present a very simple model that represents this process of catching-up. The version presented here is a linearization of the model originally proposed by Verspagen (1993, chapter 5).

Suppose that there are two countries, North (N) and South (S). Their growth of productivity are given by the following equations:

$$AP_n = a_n INNO_n$$
$$AP_s = a_s INNO_s + bGAP + cSTRUCT^1,$$

where it is rather intuitive that the only source of growth for the technology leader (N) is its internal creation of innovation ($INNO_n$); while for the technology follower (S) an alternative engine of growth is also the potential for diffusion (GAP), whose actual exploitation depends on some structural and institutional factors (STRUCT), that define the social capability of S.

The difference between the rate of growth in the two countries defines the dynamic of the technology-gap, that is:

$$GAP' = Ap_n - Ap_s = a_n INNO_n - a_s INNO_s - bGAP - cSTRUCT,$$

whose stationarity condition is given by the following expression:

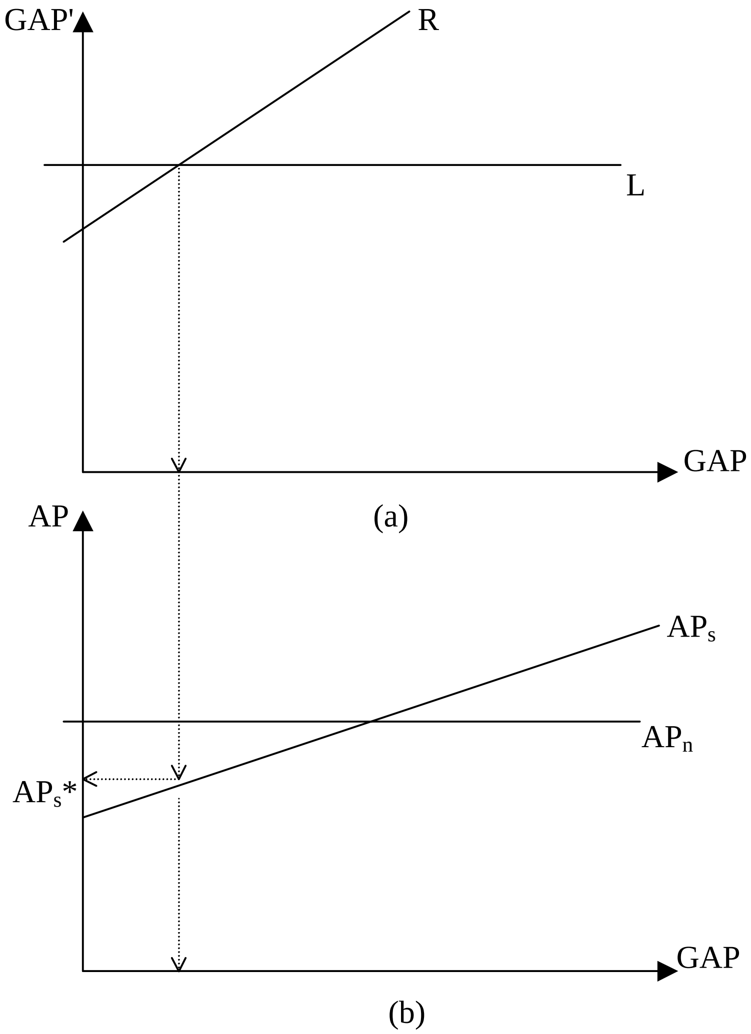
$$GAP' = 0 \Rightarrow a_n INNO_n - a_s INNO_s = bGAP + cSTRUCT$$

As it is evident from fig.1a, the expression on the left hand side (L) is a horizontal line, while the expression on the right hand side (R) is a line with positive slope b and y-intercept cSTRUCT. The intersection of the two lines defines the stationary level of the technology-gap, GAP*, to which it corresponds in fig.1b a rate of increase of the productivity in S (Ap_s*). The relationship between this dynamic equilibrium and the one found in a Kaldorian framework will be investigated in next sections.

[1] As explained in section 1c, in the technology-gap empirical works the complementary and structural factors that are found to significantly affect the diffusion of innovation include physical infrastructures, population density, industrial structure and long-term unemployment. Then, the variable STRUCT presented in the equation for AP_s here is thought to be a sum up of these variables, ad hoc built for our present purposes. However, in an empirical estimation of the model such STRUCT variable should be disaggregated back in the various components indicated by the technology-gap approach.

Summing up, the technology-gap theory of economic growth is a fundamental approach to explain why growth rates differ between countries and regions in a modern global economy. Its relationships and complementarities with the Regulationist-Kaldorian view of economic growth presented in section 1a-1b, will be discussed in the next sections.

Fig. 1: a linear representation of the dynamic of the technology-gap (a) and the dynamic of average productivity (b) in the technology-gap approach to economic growth.



2. A "technology-gap approach to cumulative growth": structural form of an integrated model

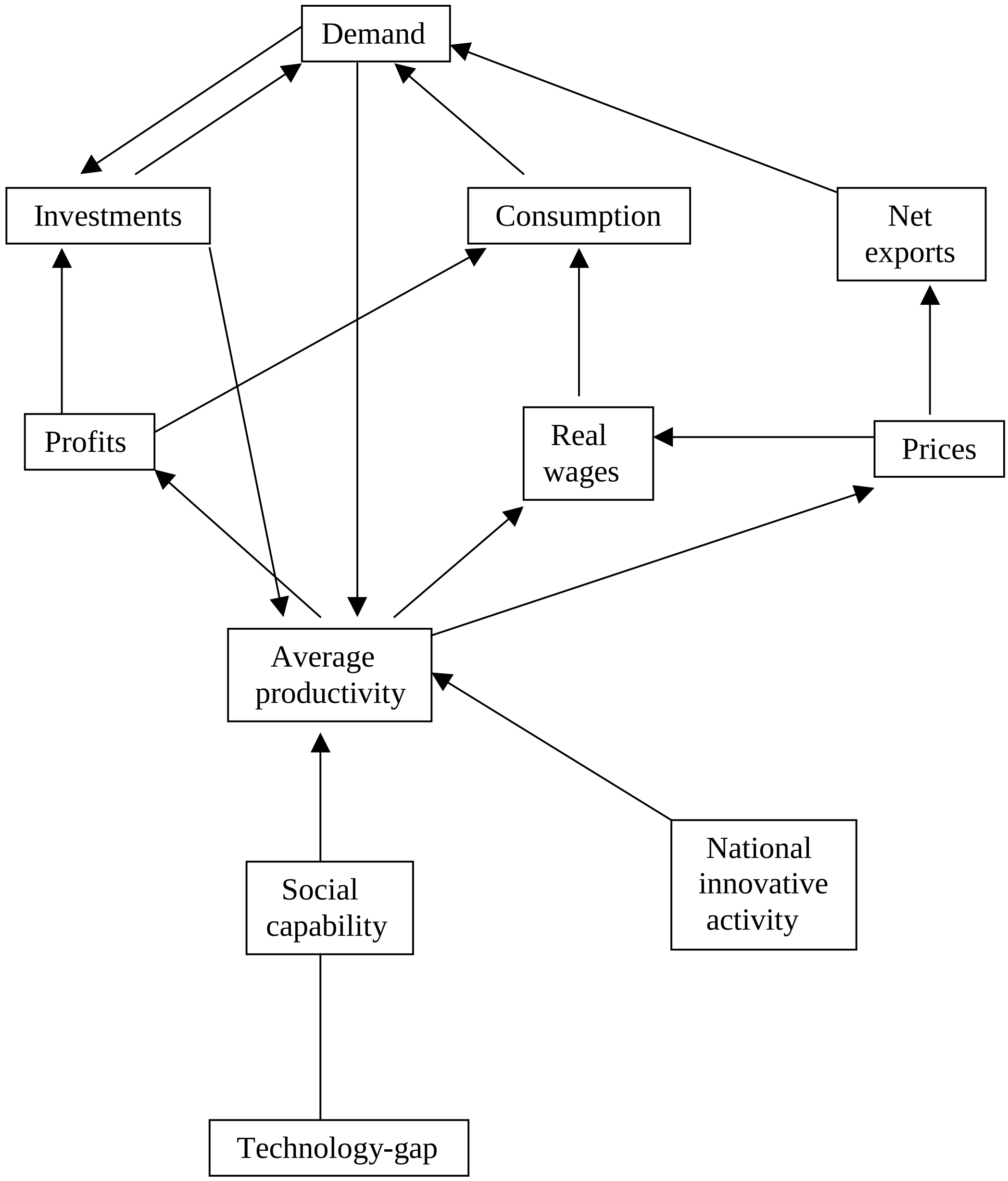
While the Kaldorian cumulative growth model is unable to catch the international diffusion of innovation, on the other hand the technology-gap approach to economic growth do not consider the cumulative causation mechanism that can be generated by the interactions between the growth in productivity and the growth in demand. However, the two processes appear indeed strictly interrelated and complementary, so that it may be interesting to consider them jointly.

As we have just seen in section 1c, a country lagging behind the technological frontier can benefit from the process of catching up through the diffusion of innovation elsewhere created, if it has some basic structural characteristic to exploit this potential. This catching up process leads to the introduction of new technologies and thus to increases in the average productivity.

But once an initial increase in productivity is realized, the way in which it is distributed between the various income perceivers can stimulate the different components of aggregate demand. In fact, as we have seen in section 1b, an increase in productivity can either raise the price competitiveness (thus stimulating exports), or it can be redistributed to both, wage perceivers and profit earners (thus stimulating private consumption and investments). In turn, the overall growth in demand can itself spur further increases in the average productivity through the existence of Kaldor-Verdoorn returns to scale, thus possibly activating a cumulative causation process of economic growth.

On the whole, as it is clear from the scheme in fig. 2, the engines of growth are both, the innovative activity of a country internally developed, and the catching up process through the imitation of more advanced technologies developed elsewhere. However, the specific hypothesis put forward here is that whether or not this mechanism leads to a quick catching up and convergence process, it also depends on the way in which the increases in productivity can interact with the

Fig. 2: a "technology-gap approach to cumulative growth": main aggregate relationships.



increases in demand, thus possibly leading to a cumulative causation mechanism. On the other hand, such an ideal convergence pattern may not be realized either if a country (region) lacks the structural capability to exploit the potential for diffusion developed elsewhere (as pointed out by the technology-gap literature), or otherwise if its internal interactions between institutions, distribution and aggregate demand components leads to a vicious rather than a virtuous pattern of economic growth (as pointed out in the Regulationist-Kaldorian literature).

From a pure theoretical point of view, the temptative combination of a technology-gap theory with a Regulationist-Kaldorian view of cumulative growth appears to be reasonable. However, the extent to which such theoretical framework is able to explain uneven growth between advanced countries is not easy to state on 'a priori' ground. Therefore, it is interesting is to try to formalize such ideas into a structural model of macroeconomic growth, and then to empirically test the suitability of this model to explain long-run economic performances and convergence/divergence processes between countries. In section 4 of the present work, in particular, the model will be used to test its suitability to explain growth in the case of Spain for the period 1960-1997. However, the idea is to extend in future works this kind of investigation to a set of advanced countries for the same period.

In order to explain how such an idea of technology-gap approach to cumulative growth may be represented by a macroeconomic model in structural form, a simple 8 equations model is presented here. It derives from a combination of recent works on Regulationist-Kaldorian lines by Pini (1996; 1997) and Vivarelli (1995), with the equation for the growth in average productivity of the technology-follower country (Ap_s) given in section 1c.

I will first present and explain each single equation of the model, and then outline its general features. Notice that all the variables are thought to be "rates of change", as the focus of the analysis are the dynamic relationships between variables over time.

Equation 1: average productivity

$$AP = a_0 + a_1GI + a_2X + a_3INNO + a_4GAP + a_5STRUCT$$

The equation for the determinants of the average productivity increases (AP[2]) is the very core of the model. The first three explanatory variables are typical of a Regulationist-Kaldorian view of technical change, according to which increases in productivity can be obtained either through technical progress embodied in gross investment in capital equipment (GI); or through increases in aggregate demand (X) that can generate dynamic economies of scale (Kaldor-Verdoorn effect).

On the other hand, a large part of productivity changes may be explicated by the technology-gap hypothesis, according to which the average productivity depends on the innovation activities internally developed (INNO); on the potential for exploiting technologies developed elsewhere (measured by the variable GAP, as a proxy for the "technology-gap"); and on some complementary and structural factors affecting to what extent this potential is realized (STRUCT).

Equation 2: aggregate demand

$$X = b_0 + b_1C + b_2GI + b_3EXP$$

According to a Keynesian "demand-led" production, the overall increase over time in demand (X) depends on the sum of the dynamic pattern of its component, that is private consumption (C), gross investments (GI) and net exports (EXP).

Equation 3: private consumption

$$C = c_0 + c_1(RW*N) + c_2PROF$$

The private consumption (C) depends on the total purchasing power of the wage perceivers (obtained multiplying the real wage RW by the number N of

[2] The index "s", used to specify that we are considering the average productivity of the technology-follower country S, will be omitted.

wage perceivers), and on that part of profit of firms (PROF) that is redistributed and consumed by the profit earners.

Equation 4: gross investment

$$GI = d_0 + d_1PROF + d_2X$$

Gross investments mainly depend, on the one hand, on that part of the extra-profit (PROF) obtained by firms that are not redistributed but reinvested (according to a classical view); and, on the other hand, they may depend on aggregate demand (X) (according to a typical Keynesian view).

Equation 5: net exports

$$EXP = e_0 + e_1AP + e_2EER + e_3INNO + e_4OPEN$$

Equation 5 defines net export rates of change as depending on the real rate of exchange (EER) and on a measure of the degree of openness of the economy (OPEN), on the one hand; and on the pattern of the average productivity itself (AP) and of the innovative activity internally developed (INNO), that are strictly linked to non-price competitiveness, on the other.

Equation 6: profit of firms

$$PROF = f_0 + f_1AP + f_2INNO$$

The extra-profits of firms are mainly dued to the obtained gains in productivity (AP); and may also be related to the innovative activity created by the firms themselves (INNO).

Equation 7: real wages

$$RW = g_0 + g_1AP + g_2U$$

The increase or decrease of real wages (RW) is supposed to depend first on the distribution to workers of the gains in productivity (AP), and second on the overall rate of unemployment (U), according to the Phillips-curve relationship. Thus, the coefficients g_1 and g_2 measure the wage formation mechanism, that can be more or less competitive according to different labour market institutions and historical conditions.

Equation 8: prices

$$P = h_0 + h_1AP + h_2INNO$$

Equation 8 defines a price index (P) as determined by the dynamics of the average productivity (AP), whose increases can be partly translated in decreases in prices; and by the dynamics of the innovative activity (INNO), that can determine further decreases in prices through the introduction of new products and processes in the markets.

Then, the entire structural form of the model is the following:

$$AP = a_0 + a_1GI + a_2X + a_3INNO + a_4GAP + a_5STRUCT$$
$$X = b_0 + b_1C + b_2GI + b_3EXP$$
$$C = c_0 + c_1(RW*N) + c_2PROF$$
$$GI = d_0 + d_1PROF + d_2X$$
$$EXP = e_0 + e_1AP + e_2EER + e_3INNO + e_4OPEN$$
$$PROF = f_0 + f_1AP + f_2INNO$$
$$RW = g_0 + g_1AP + g_2U$$
$$P = h_0 + h_1AP + h_2INNO$$

On the whole, the specified model is an attempt to compound technological trends and market forces in a unique formalization. In the model are endogenized both the catching up process through the diffusion of innovation elsewhere developed, typical of a technology-gap approach, and the dynamic interrelationships between demand and productivity that may lead to a Kaldorian cumulative growth. More precisely, equation 1 attempts to compound the technology-gap hypothesis with a Kaldorian "productivity regime"; equations 6-

8 define the distribution of the increases in productivity between the different classes of income perceivers; and equations 3-5 define the consequences of such a distribution on the various components of demand, that in turn are expected to stimulate further increases in productivity, thus leading to cumulative growth.

Before using the model for an empirical test of economic growth, its analytical properties will be studied in the following section.

3. Sub-reduced forms and analytical properties of the model

Obtaining the sub-reduced forms of the model and studying its analytical properties, such as the existence and the stability/instability of the equilibrium, are important steps to be done in order to analyse some basic features of the model. In doing so, an effort will be done to point out the effects of the inclusion of the technology-gap variables in the Regulationist-Kaldorian scheme[3] from an analytical point of view.

First of all, it is interesting to obtain the sub-reduced forms of the model for the productivity and the demand respectively.

From equations 1, 4, 6 and 8 it is easy to obtain the productivity regime (PR), that is the relationships that goes from increases in demand to increases in average productivity:

$$\text{PR:} \quad AP = \alpha + \beta X,$$

where:

$\alpha = (a_0 + a_1 d_0 + a_1 d_2 f_0 + a_3 INNO + a_4 GAP + a_5 STRUCT) / (1 - a_1 d_2 f_1)$,

and:

$\beta = (a_1 d_1 + a_2) / (1 - a_1 d_2 f_1)$.

[3] For a review of the main analytical properties of the models originally proposed by Boyer on Kaldorian lines, see Boyer (1988) and Boyer and Petit (1988 and 1989).

The other important relationship to define the growth regime is the demand regime (DR), that is the linkage between growth in productivity and growth in demand. It is obtained by equations 2, 3, 4, 5, 6, 7 and 8:

$$\text{DR:} \quad X = \gamma + \delta AP,$$

where:

$\gamma = (b_0 + b_1c_0 + b_2d_0 + b_3e_0 + b_1c_1Ng_0 + b_1c_1Ng_2U + b_1c_2f_0 + b_2d_2f_0 + b_3e_3OPEN + b_3e_2EER) / (1-b_2d_1)$,

and:

$\delta = [b_1c_1Ng_1 + f_1(b_1c_2 + b_2d_2) + b_3e_1] / (1-b_2d_1)$.

Considering first the productivity regime, its y-intercept depends on the coefficients that represent the technological characteristics of the system (a_0, a_1), the ones that embody the idea of technology-gap (a_3, a_4 and a_5) and the ones that define the type of investment (d_0, d_2, f_0, f_1); while its slope depends only on the coefficients representing the technological characteristics of the system and the type of investments (a_1, a_2; d_1, d_2, f_1).

Turning to the demand regime, both its y-intercept and slope depend on the coefficients that define the type of investments and the characteristics of the distribution of the average productivity increases (b_0, b_1, b_2, b_3; c_0, c_1, c_2; d_0, d_1, d_2; e_0, e_2, e_3; f_0; g_0, g_2).

Then, a first interesting result must be outlined: *the inclusion of technology-gap variables in the Regulationist-Kaldorian model affects the position of the productivity regime line through its y-intercept; but it does not affect neither the slopes of the PR and DR, nor the y-intercept of the latter*. On the importance of this result to interpret the upward shift of the PR equation observed for the Spanish case in the last 15-20 years, I will go back again in next section.

Consequently, as the PR line shifts upward after including the technology-gap variables, the dynamic equilibrium for AP and X changes. In fact, considering jointly the equation for the PR and the one for the DR, it is easy to obtain the analytical solution of the model, that is:

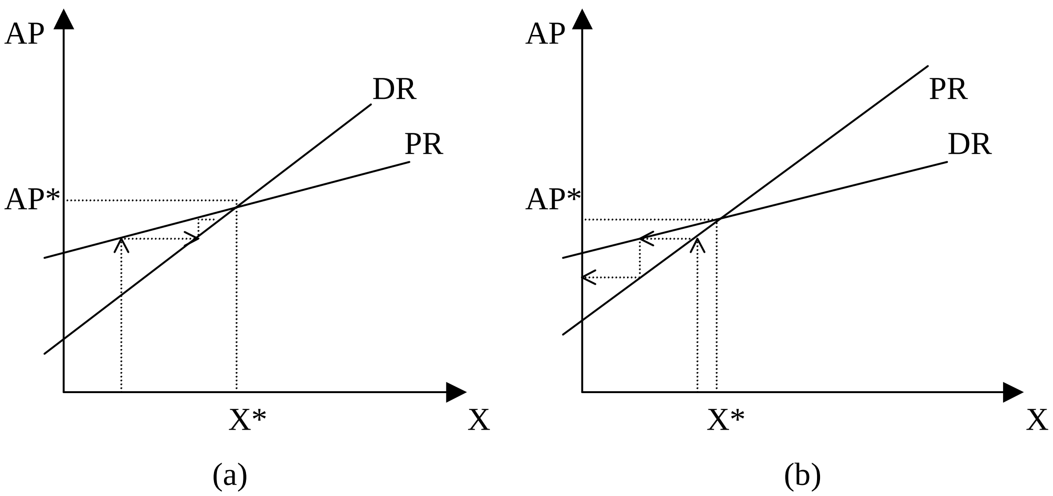
$AP^* = (\alpha + \beta\gamma) / (1-\beta\delta)$,

$X^* = (\gamma + \delta\alpha) / (1-\beta\delta)$.

This equilibrium can be stable or unstable. In order to have a stable cumulative growth, the stability condition must be satisfied, that is:

$$|\beta|<|1/\delta| \Rightarrow \beta\delta<1.$$

Fig. 3: dynamic equilibrium determined by the productivity regime (PR) and the demand regime (DR): stable (a) and unstable (b) cases.

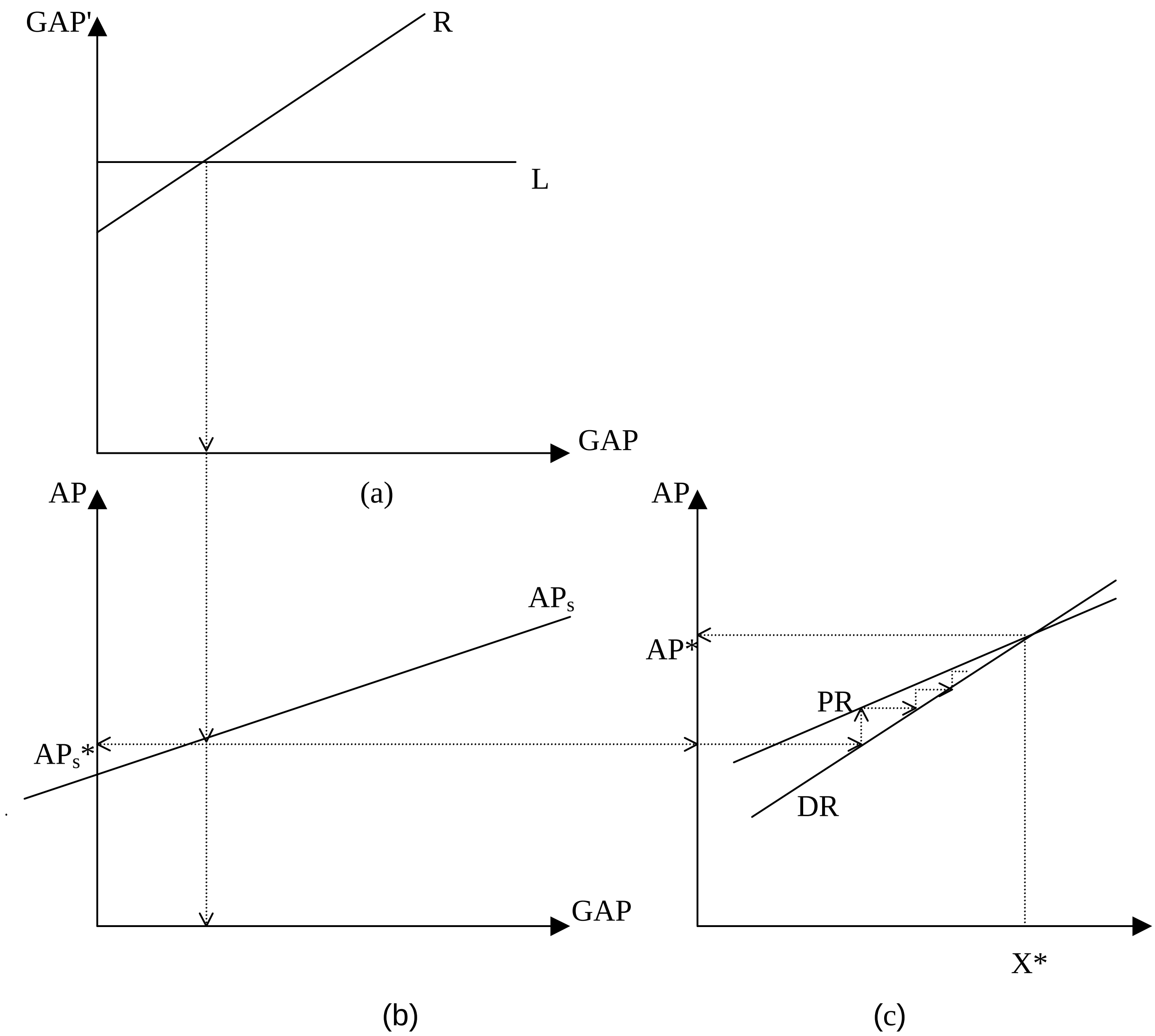


As it is clear from fig.3, this condition requires that the slope of the DR line must be higher in absolute value than the one of the PR line.

As the stability condition only depends on the coefficients that determine the slopes of the PR and DR lines, a second result that has to be outlined is then the following: *the inclusion of technology-gap variables in the Regulationist-Kaldorian model does not affect the characteristics of stability/instability of the equilibrium. In other words, whether or not the growth regime is stable depends on technological, economic and institutional characteristics typical of the country, and not on the process of catching-up through diffusion of innovative activity. The latter can thus contribute to determine the dynamic equilibrium, but not its stable/unstable features.*

Summing up, as it is clear from fig. 4 the dynamic of technology-gap and the variables INNO and STRUCT determine an initial AP rate of increase (fig. 4a and 4b). This rate can be higher or lower than the one of the equilibrium, determined at the intersection between the PR and DR line (fig. 4c). The convergence toward the equilibrium, finally, is not automatic, but it is only realized if the stability condition is verified. Thus, according to these analytical properties of the model, a sustained period of economic growth can only be realized if the rate of productivity increase obtained through the diffusion of innovative activity can activate a process of stable cumulative growth. If the growth regime is not stable, on the other hand, even an initial high rate of productivity determined by the diffusion of international technology is not sustainable over time. In other words, according to this framework, what matters for growth is the structural compatibility over time between the process of creation and diffusion of innovative activity, on the one hand, and some technological, economic and institutional characteristics of the country in a given historical period, on the other.

Fig. 4: dynamics of the technology-gap (a), average productivity (b) and cumulative growth (c): a stable case.



As a further step, it is interesting to study the effects of a change over time of the technology-gap variables on the equilibrium. As stated above, in the equilibrium both AP* and X* depend on the coefficient α (y-intercept of the PR line), which in turn depends on the coefficients representing the technology-gap idea (that is: a3, a4 and a5). More precisely, it is interesting to analyse the direction of the effects of the technology-gap variables on such dynamic equilibrium. In fact,

these effects can be positive or negative according to the relative slopes of the PR and DR lines.
The effect on AP* can be measured by the first derivative of the PR equation with respect to α:

$$\partial AP^*/\partial\alpha = (1 + \beta) / \beta\delta,$$

that is positive for:
$\beta>0$; $\delta<0$; or:
$\beta>0$; $\delta>0$; $1>\beta\delta$; or:
$\beta<0$; $|\beta|<1$; $\delta>0$; or:
$\beta<0$; $|\beta|<1$; $\delta<0$; $1>\beta\delta$.

On the other hand, the effects on X* can be measured by the first derivative of the DR equation with respect to α, that is:

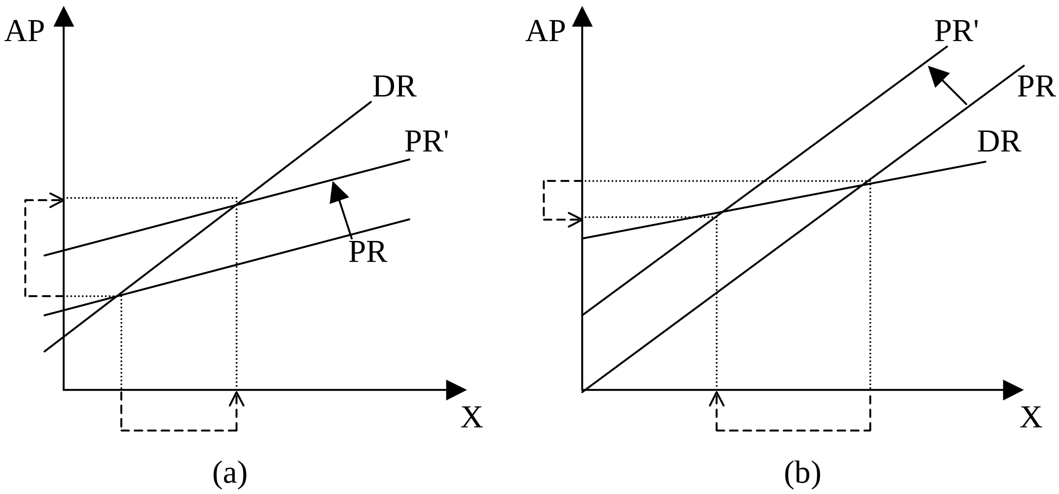
$$\partial X^*/\partial\alpha = (\gamma-\delta) / (1-\beta\delta),$$

that is positive for:
$\gamma>0$; $\delta>0$; $\gamma>\delta$; $\beta<0$; or:
$\gamma>0$; $\delta>0$; $\gamma>\delta$; $\beta>0$; $1>\beta\delta$; or:
$\gamma>0$; $\delta<0$; $|\gamma|>|\delta|$; $\beta>0$; or:
$\gamma>0$; $\delta<0$; $|\gamma|>|\delta|$; $\beta<0$; $1>\beta\delta$.

Thus, a third result must be outlined: *the change over time of the coefficients that measure the technology-gap idea (for example: a higher rate of diffusion from abroad; or a higher rate of creation of innovative activity) can have positive or negative effects on the dynamic equilibrium (AP*; X*) of the growth regime according to the relative slopes of the PR and DR lines; in turn, these slopes depend on the technological characteristics of the system, the prevailing type of investments and the distribution of the increases in average productivity between profit earners and wage perceivers.*

This can be easily seen from fig. 5: in fig. 5a we have a stable equilibrium, and an upward shift of the PR line determines a new equilibrium with higher AP* and higher X*; in fig. 5b, on the other hand, we have an unstable equilibrium, and the same upward shift determines a new equilibrium with lower AP* and lower X*.

Fig. 5: effects of a higher rate of creation or diffusion of innovative activity in the stable (a) and unstable (b) cases.



On the whole, the analytical properties of the model outlined in this section can be sum up in the following way: the inclusion of the technology-gap variables in the Regulationist-Kaldorian model affects the equilibrium rates of change AP* and X*, through the change in the y-intercept of the PR line; in turn, the technology-gap variables do not affect the features of stability/instability of the equilibrium, which are only determined by the relative slopes of the PR and DR lines. Hence, an higher rate of diffusion or creation of innovative activity in a country determines a higher and stable rate of productivity increase only if it is "sustained" by the technological characteristics of the system, by the prevailing type of investment of firms and by the distribution of the productivity increases between profit earners and wage perceivers. In other words, what matters for growth is not just innovation, accumulation or distribution, but their structural compatibility over time. Many different growth regimes are theoretically possible, but only some of them lead to a cumulative-technology-gap led growth.

4. Empirical evidence for Spain, 1960-1997

In order to test the suitability of the "technology-gap approach to cumulative growth" model to explain the process of economic growth in more advanced countries, we are in particular interested in answering the following two questions:

- Does the model explain uneven growth between advanced countries?
- Is the model stable or unstable over time, considering the last 35-40 years?

The present section tries to answer these questions for the case of Spain in the period 1960-1997. Why just Spain? As a first experiment with the model, I thought that the Spanish case was interesting for the following three reasons.

First, it is an example of how the model can be tested using time series data for a single country. The advantage of testing the model for a single country is that historical and institutional peculiarities typical of that country turn out to be useful in interpreting the econometric results. The disadvantage, however, is that the results obtained are difficult to generalise to other countries. That is why I consider important to extend in future works the empirical test of the model to a set of advanced countries, in order to investigate similarities and differences in the growth regimes between them, more than just explaining a single country evolution.

Second, Spain is a country that is lagging behind the technological frontier, but at the same time its recent performances in terms of technological catch-up and economic growth are rather positive. It seems then a good case to analyse in order to investigate the compatibility of the technology-gap led growth with the possibility of cumulative causation, that is a process of interaction between growth in productivity and growth in demand.

Third, regarding more specifically the stability of the model over time, the Spanish case is particularly interesting as an example of a country in which institutional peculiarities and historical events affect the path of economic performance, possibly determining a structural break in the main economic regularities from one period to another. In fact, in a few years many historical events and institutional changes determined radical transformations in Spanish economy: the two oil shocks (1973 and 1979), the end of the political regime of Francisco Franco (1975), the strong change in fiscal and monetary policy since the "Moncloa" agreement (1977), the first stable socialist government (1982), and finally the entrance in the EEC (1986). Thus, a radical new political and economic system emerges in Spain after the international economic crises of the seventies and the internal transition toward democracy; the aim of the present section is just to investigate whether these changes affect the stability of the model in the period 1960-1997.

Given these historical and institutional peculiarities, the whole sample has been divided in two periods: first (1960-1975) and second period (1982-1997).

The choice of how to split the sample has been based on the historical and institutional changes just mentioned; symbolically, the last year of the first period (1975) represents the end of the political regime, while the first year of the second period represents the beginning of a stable democracy (1982).

The model has then been estimated for each period, also testing whether the hypothesis of structural break between 1960-75 and 1982-1997 can be significantly accepted. More precisely, for each period first the structural form of the simultaneous equations model has been estimated using a 2SLS estimator for each single equation, as a suitable method of estimation for overidentified equations[4]; then, the sub-reduced forms for productivity and demand (the PR and DR equations) have been estimated, again with the 2SLS method.

[4] In fact, both the rank and order conditions confirm that all the equations are overidentified.

Table 1: results of the estimations for the first period, 1960-1975.

EQUATION	DEPENDENT	CONSTANT	X	C	RW*N	PROF	EER	AP	INNO	R^2
1	AP	-1,27	1,05 (14,3)						0,045 (3,99)	0,98 (0,97)
2	X	2,35		0,87 (11,4)						0,93 (0,92)
3	C	-2,02			0,67 (6,61)	0,40 (3,85)				0,95 (0,94)
4	GI	-3,65	1,35 (2,66)							0,41 (0,35)
5	EXP	79,3					89,03 (1,63)			0,21 (0,13)
6	PROF	1,07						0,84 (3,17)		0,53 (0,47)
7	RW	0,16						1,12 (7,19)		0,85 (0,83)
8	P	-7,56						1,08 (5,49)		0,79 (0,76)
PR	AP	-1,74	1,06 (10,4)							0,91
DR	X	2,61	0,87 (9,97)							0,91

Table 2: results of the estimations for the second period, 1982-1997.

EQUATION	CONSTANT	AP	X	AP_0	AGR	MAN	MOT	U	POPD	INNO	R^2
AP				-0,91 (2,37)	-0,29 (2,22)				1,43 (3,77)	0,48 (4,39)	0,98 (0,94)
AP	0,17			-0,039 (2,18)	-0,077 (2,77)	-0,053 (1,72)	0,0034 (1,75)	-0,00096 (1,92)	-0,03 (1,50)	0,03 (1,95)	0,68 (0,40)
PR	291,6		8,23 (0,68)								0,041
DR	20	0,017 (0,37)									0,012

Table 3: Chow test for the hypothesis of a structural break.

EQUATION	1	2	3	4	5	6	7	8	PR	DR
F	8,99	25,94	11,98	24,85	8,05	23,13	23,99	6,90	25,39	25,99
Structural break	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The results for the first period are presented in Table 1.

Regarding the structural form, all the equations show a high degree of overall significance, as shown by the R^2 in the last column of the table. All the estimated coefficients included in the original model turn out to have the expected signs, but some of them are not statistically significant, and therefore they are not reported in the table.

Equation 1 shows a strong and highly significant relationship between the overall rate of growth of demand and the rate of growth of average productivity, known as Kaldor-Verdoorn effect. In turn, the rate of growth of demand is mainly dependent on aggregate consumption (equation 2), which is affected by both, the dynamic of real wages of employees and the one of profit of firms (equation 3). In turn, the increases of these two components of social distribution are significantly and strongly driven by the dynamic of average productivity itself (equation 6 and 7). On the other hand, the aggregate demand does not seem to be significantly affected by gross investments and net exports; so that equation 4 (which shows investments as demand-driven, according to a typical Keynesian accelerator mechanism) and equation 5 (which shows net exports as mainly dependent on the effective exchange rate) loose importance in the overall picture.

Furthermore, the inclusion of technology-gap variables in equation 1 does not seem to significantly improve the model: the only variable that shows a weak but significant relationship with productivity is INNO, as measured by the share of patents on GDP. On the other hand, the other variables typical of technology-gap empirical works, such as the initial average productivity (AP_0, as a measure of the potential for diffusion, equivalent to the variable GAP specified in the model in section 2 and 3) and some structural factors (STRUCT, that affect the extent to which this potential for diffusion is realized), both turn out to have not significant estimated coefficients. This result is not surprising: according to the technology-gap framework, in fact, the diffusion of innovative activity from abroad requires that the economy is open to international trade. But the Franquist Spain is a closed economy, so that the diffusion of innovation from abroad through international trade is obviously not the main way to obtain productivity increases, at least in the years 1960-1975.

Regarding the sub-reduced forms for productivity and demand (PR and DR equations), both estimation turn out to be highly significant (R^2 = 0,91). The single coefficients are both positive and highly statistically significant, confirming the results obtained for the structural form. As shown in fig.6, the magnitude of the slope of the DR line is higher than the one of the PR line, so that the stability condition for the growth regime is verified.

Summing-up the results obtained for the structural and the sub-reduced forms of the model, the overall picture of the Spanish growth regime that seems to emerge for the period 1960-1975 is straightforward: in a close and rigid economy, the only potential for Spanish growth is internal. Strong productivity increases are obtained through dynamic economies of scale and, more generally, through the enlargement of the market size (Kaldor-Verdoorn effect); in turn, the dynamic positive performance of demand is sustained mainly by the aggregate consumption, which is dependent on the distribution of average productivity increases to wage perceivers and profit earners. The interrelationships between productivity, consumption and aggregate demand activate a cumulative causation process, and determine a stable equilibrium with positive but moderate rate of increases of AP* and X* (see fig.6).

Turning now to the second period (1982-1997), the results are presented in Table 2.

Regarding the structural form, only the equation 1 shows an overall high degree of significance (R^2 = 0,98). All the other equations estimated (2-8) have a very low R^2, and therefore are not presented in the table.

Given this general bad performance of the structural form of the model for this second period relatively to the very good performance for the first period, the hypothesis that has been put forward is that of a structural break in the main economic regularities that sustained the growth regime during the years 1960-1975. In order to investigate this hypothesis, a Chow test has been performed to check out the stability of the model between the first and the second period. The results of this test, presented in Table 3, show that for all the 8 equations of the structural form the hypothesis of stability of the model is rejected at a very high degree of significance.

Then, given this structural break of the model, what are the characteristics of the new growth regime that seems to emerge in the period 1982-1997?

A first answer is given by the only significant equation of the structural form, that is the one for average productivity (table 2, first row). While the coefficients a_2 representing the Kaldor-Verdoorn effect becomes not significant (coherently with the findings of the empirical works by Boyer, Vivarelli and Pini relative to other OECD countries for the same period), the coefficients representing the idea of technology-gap turn out significant and with the expected signs. In particular, the increases in productivity are obtained in this second period firstly through the innovative activity internally created (INNO, measured again as share of patent on GDP), and secondly through the diffusion of innovations developed elsewhere; the potential for this catching-up process through diffusion is higher the lower the initial average productivity of the country (AP_0); and the extent to which this potential is realized is higher the higher is the social capability (here proxied by the share of employment in agriculture, AGR, and by the population density, POPD).

A confirmation of the hypothesis of technology-gap led growth is given by the second equation for AP reported in table 2 (second row), in which the model estimated is the same, but the data used are regional data from the Eurostat Regio database for 16 Spanish regions for the same period, 1982-1997[5]. The results of this experiment show that even at regional level the technology-gap idea significantly explains the productivity increases in the medium-long run; in fact, most of the coefficients (typical of technology-gap cross-country or cross-regions estimations) turn out to be significant and with the expected sign (and in particular AP_0, AGR, U[6] and INNO).

[5] The idea of testing the technology-gap idea on regional data is taken by the recent works by Fagerberg and Verspagen (1996) and Fagerberg, Guerrieri and Verspagen (1999).

[6] U is the rate of unemployment, often used in the technology-gap empirical works as an indicator of institutional failure, thus negatively correlated with growth.

Regarding the sub-reduced forms for productivity and demand (PR and DR equations), the results of their estimation are presented in the third and fourth row of Table 2, although both the overall significance and the significance of the single estimated coefficients are low.

The estimated coefficient α, representing the y-intercept of the PR line, is now much higher than in the previous period. Given the analytical properties of the model discussed in section 3, we may conclude that this upward shift of the PR line is determined by the increased importance for the Spanish economy of the technology-gap variables, that start to spur economic growth since the beginning of the 80s.

However, another property of the model discussed in section 3 is that these technology-gap variables do not affect the relative slopes of the PR and DR lines and thus the stability/instability of the equilibrium. How to explain then the higher slopes for both relationships, that determine a stable equilibrium with a higher AP* but a lower X*? (see fig.6).

As we know from section 3, the relative slopes of the PR and DR lines are determined by the technological characteristics of the system, by the prevailing type of investments, and by the social distribution of the increases in productivity. Given a general knowledge of the evolution of the Spanish economic system in the last 15-20 years, an interesting hypothesis could then be the following.

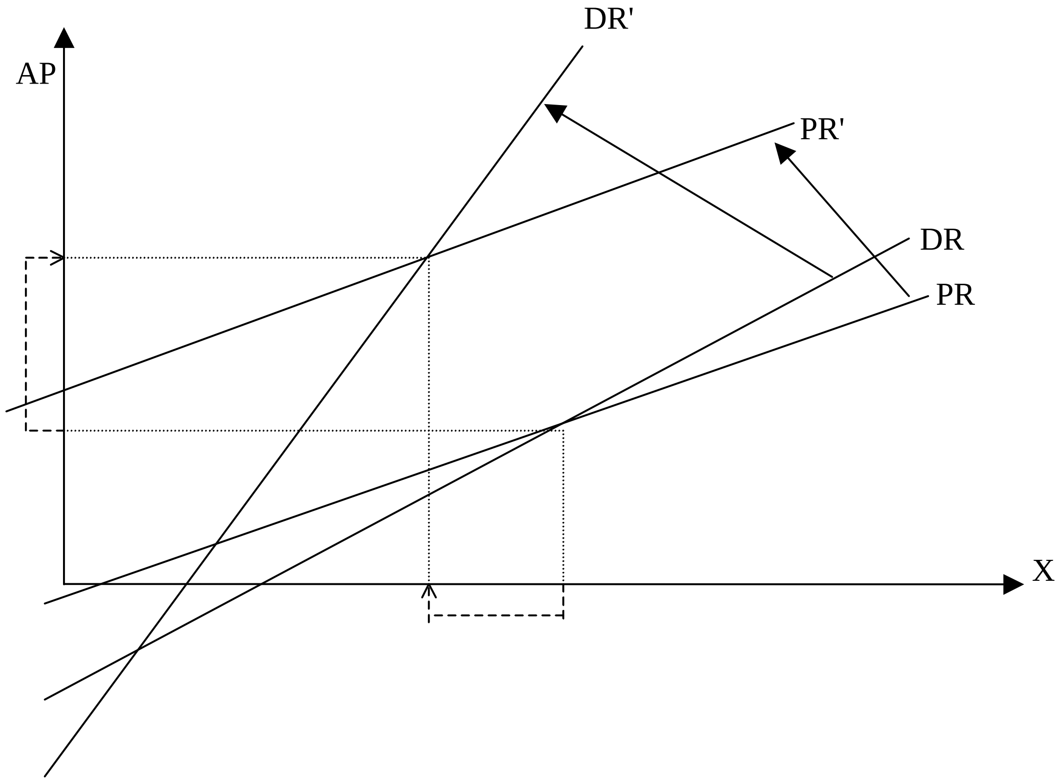
After the international economic crisis of the 70s and the internal transition toward democracy, the strategy used by the economic authorities to report under control the rapid growth of nominal variables (prices and wages) and to get out of the economic crisis determines two consequences: first, it determines a new pattern of distribution of the increases in productivity, that mainly sustains higher profits of firms in the second period, rather than real wages as in the first; second, it determines a new way of formation of investments, more dependent now on profits of firms ("classical" investments), rather than on aggregate demand as in the first period ("Keynesian" investments). On the whole, these two transformations could explain the higher slopes of the PR and DR lines, and

thus the position of the new stable equilibrium with a higher AP* and a lower X* (see fig.6).
Unfortunately, given the low overall significance of equations 2-8 of the structural form, it is not possible to confirm with a high degree of certainty that this hypothesis is a good explanation for the radical changes in the relative slopes of the PR and DR lines between the first and the second period.

Summing up the results relative to the second period, a radical new growth regime seems to emerge after the economic crisis and the political transition. The increases in productivity are not anymore obtained through the Kaldor-Verdoorn effect, but rather through a rapid process of technological catching-up via the diffusion of innovative activity developed abroad and via the creation of new technologies by the national system of innovation and private firms. On the other hand, all the equations defining demand, its components and the dynamic of distribution between wage perceivers and profit earners, loose statistical significance and theoretical importance in the overall picture. The hypothesis of coexistence of technology-gap growth with a new cumulative causation process sustained by the interactions between "classical" investments and productivity, although appealing and reasonable, cannot be confirmed at a high level of significance.

On the whole, it seems that in the Spanish case there has been a structural break with the transformation from a Kaldorian cumulative growth regime led by internal consumption, in the first period (1960-1975), to a technology-gap growth regime, in the second period (1982-1990). Hence, as a general conclusion for the case of Spain, the Kaldorian cumulative causation process and the technology-gap growth appear to be alternative rather than complementary explanations of economic growth. It is then necessary in future works to extend the empirical test of the model to a set of advanced countries, in order to investigate whether or not this conclusion is common to other countries.

Fig. 6: the Spanish growth regime: changes between the first (1960-1975) and the second (1982-1997) period.



5. Conclusions

The purpose of the present paper has been to investigate the possibility to compound in a unique formalization two different but complementary theories of technical change and macroeconomic growth, that is the Kaldorian idea of cumulative causation and the technology-gap approach to economic growth.

In section 1 the main linkages between macroeconomic aggregates have been considered. In a first step, the French school of "regulation" has been presented, as an interesting framework to compound the main relationships between institutions, technology and the economy (section 1a). This approach may turn out to be useful for our purposes, as it tries to bridge the gap between the evolutionary perspective of innovation studies and institutional and historical aspects. Given such a general framework, the main long-run macroeconomic relationships between growth in average productivity and growth in demand have been considered in section 1b, in which the Regulationist-Kaldorian idea of cumulative growth has been put forward. However, as observed in section 1c, such a framework is unable to explain the process of catching up through the diffusion of innovation created in more technologically advanced countries, so that its complementarity and integrability with a technology-gap view of economic growth has been explored in sections 2 and 3.

More precisely, in section 2 the structural form of this model of "technology-gap approach to cumulative growth" has been presented; and in section 3 the characteristics of the sub-reduced forms for the dynamic of productivity and demand and the main analytical properties of the model have been discussed.

The main findings of these sections can be sum up in the following way: an higher rate of diffusion or creation of innovative activity in a country determines a higher and stable rate of productivity increase only if it is "sustained" by the technological characteristics of the system, by the prevailing type of investment of firms and by the distribution of the productivity increases between profit earners and wage perceivers. In other words, what matters for growth is not just innovation, accumulation or distribution, but their structural compatibility over time. Many different growth regimes are theoretically possible, but only some of them lead to a cumulative-technology-gap led growth.

As a first experiment, the model has been empirically tested for the case of Spain in the period 1960-1997. The results of the estimations show that there has been a structural break with the transformation from a Kaldorian cumulative growth regime led by internal consumption, in the first period (1960-1975), to a technology-gap growth regime, in the second period (1982-1990). Hence, as a general conclusion for the case of Spain, the Kaldorian cumulative causation process and the technology-gap growth appear to be alternative rather than complementary explanations of economic growth.

It is then necessary in future works to extend the empirical test of the model to a set of advanced countries, in order to investigate whether this conclusion is common to other countries, or rather it is peculiar to the evolution of the Spanish growth regime.

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