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Endogenous growth theory twenty years after: a critical assessment

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Introduction*

Some years ago I found one ‘key’ of the origins of endogenous growth literature (EGT) in the dissatisfaction that emerged in the late fifties with one result of the neoclassical growth model by Robert Solow (1956), that is the independence of the growth rate of the economy from the saving ratio, the ratio between the (full employment) saving supply and output, a variable subject to policy influence, e.g. by tax treatment favourable to saving and investment (Cesaratto 1999a, 1999b). I pointed out the difficulties met both by the earlier and the new generations of endogenous models in trying to relate the growth and saving rates (see also Serrano & Cesaratto, 2002). In the meanwhile the literature on EGT has been enriched by further models and empirical verifications, that have been endeavoured to face those difficulties. In this paper I will reassess my early conclusions about EGT in the light of the most recent contributions. In this paper I shall distinguish among three generations of EGT models: the old from the sixties; the new from the late eighties; and the most recent from the second half of the nineties. As we shall see, EGT models can be divided in two fields: those who defend the Solowian approach (semi-endogenous models) and those who try to depart from it (full endogenous models).

Quite relevant to corroborate the interpretation of EGT put forward in my earlier contributions was a paper by Marving Frankel, published in 1962 six months later than the more well known Arrow’s learning-by-doing model, that I ‘rediscovered’ guided by the key to EGT that had just come to my mind.[1] Frankel observed that in the Harrod-Domar model, where a production function $Y = aK$ is used (where a is the output-capital ratio), the rate of economic growth depends on the saving ratio s according to the well known Harrodian formula $g = s/v$, where $v = 1/a$.

* This is a preliminary and incomplete version. Also the English language has not been revised.

1 I firstly evoked Frankel’s contribution in Cesaratto (1995). Frankel’s forerunner paper was later ‘rediscovered’ by Cannon (2000) who, however, fails to locate Frankel’s original contribution in the context of the troubles met by the old and new EGT.

Economists, he argued, “have found such models attractive because of their relatively simple structure, because of the emphasis they give to capital accumulation as an ‘engine of growth’ – an emphasis with deep routes in economic thought – and because of their pragmatically satisfying results” (1962, p.996). However, he continued, “the production function $Y = aK$ has nothing interesting to say about resource allocation or income distribution. Worse than this, as a general statement of the resources required in production, it is positively wrong, as any one-factor production function must be” (ibid). On the opposite, the most agreeable Cobb-Douglas production function, although satisfactory from the point of view of “resource allocation or income distribution”, in a growth context does lead to a growth rate that depends on the rate of growth of the labour force and where the investment rate – that in this marginalist context coincides with the saving rate – does not affect neither the aggregate growth rate nor, through productivity growth, that of output per worker (ibid, pp.996-997). Labour productivity growth could be introduced into the model, but its sources remained “exogenous” in the distinctive sense that it does not depend upon the endogenous saving choices of the community (or of a representative agent)[2]. The same unhappiness with regard to this specific result of neoclassical Solow’s model was expressed in those years by other authors (cf. Cesaratto 1999a, 1999b for the references).

In this regard we may start by asking whether the relationship between the investment (saving) ration and the growth rate is just a theoretical supposition – although one ‘with deep routes in [traditional] economic thought’ -, or is also a proved empirical fact. In this respect in section 1 I shall first consider the recent controversy on the empirical evidence on this relation. It sounds that most of the results confirm the relation, an outcome unfavourable to Solow’s prediction of its absence in the secular equilibrium. Solow’s model did not deny it, however, in the transition from one to another secular equilibrium, so that I will briefly look in section 2 to some recent defences of Solow’s model based on the length of the transition towards the steady state. Given the frailty of this defence, we shall then look in section III at proper EGT models recalling Frankel’s and Arrow’s seminal and archetypal models, not for the sake of history of thought, but since new and recent EGT has not moved a single step beyond the stage set by those earlier models, if not by adding further theoretical and empirical considerations to lean in favour of one or the other possible approaches displayed on that podium. This was one earlier conclusion on EGT, and I shall have not reasons to change it but just to update in the present work (although I respect to the richness of the debate over the last twenty years). More importantly, the archetypal models posed some problems that have passed to new and recent EGT. However, these troubles have not passed unnoticed due in

[2] It is widely recognised that to get the sense of EGT it is irrelevant if the saving rate is taken as given, or if choices are analysed through a Ramsey model. The latter would just add maths but no substance (see e.g. Mankiw, 1995, pp.279-280).

particular to the influential contributions by Charles Jones that in the light of those difficulties, not surprisingly, argues in favour of sticking to the traditional Solow's growth framework. The most recent generation of EGT models has countered Jones's criticism by approaches introducing another battery of *ad hoc* assumption that, however, also remind to the archetypal, as we shall point out in section V. After having discussed in section VI Jones' neo-Solowian perspective, in the final remarks, I will deal with a methodological defence of the neoclassical growth modelling according to which one should not be too critical of the analytical or empirical limitation of single models, but rather pick up the insight provided by each of them. In view of this remark, I will emphasize the relevance of the Sraffian and Keynesian criticism of neoclassical theory.

I. Econometric growth theory

Recent and earlier presentations of growth theory including Jones (2002) and Solow (1970) have focused over the explanation of the famous Kaldorian six 'stylized facts' of economic growth that, as they are well known, it is pointless to recall here. To this list, two additional stylised fact may be added that growth models may aim to explain that are, however, more controversial: a positive correlation between the investment (saving) rate, that is the ration between investment (saving) and output, and the rate of economic growth, both in aggregate and per-capita terms, respectively. Not surprisingly, among those who deny these two additional stylised facts we found the supporters of the Solowian view and, on the opposite side, those who feel uneasy with this approach. The debate has focused on the empirical relation between the investment rate (I/Y), taken in a close economy as a proxy of the saving rate (*s*),[3] and per capita growth rate (g_y).[4] We shall see that most contributions find an empirical correlation between I/Y and g_y. Defendants of Solow's model have found various ways to shield their master's results.

In an earlier study, Hill (1964) examined the mentioned relation in a group of industrialised countries over the period 1954-62 and found a significant correlation (particularly strong for the larger economies) between I/Y and aggregate growth (g_Y), and also with g_y especially once

[3] After Feldstein & Horioka (1980) empirical results, some scepticism has emerged amongst neoclassical economists regarding the influence of foreign capital on domestic investment.

[4] The fact that neoclassical economists focus upon only one of the two additional stylised facts should not come as a surprise. As known, the aggregate growth rate is given by the summation of the growth rate of the workforce plus labour productivity growth. In a neoclassical full-employment model, the workforce grows at a natural demographic rate *n*. That the aggregate growth rate should adjust to the (exogenous) growth rate of the workforce irrespective of the investment (saving) rate is something that the neoclassical *Weltanschauung* cannot put into discussion, so that the discussion centred over the rate of technical change. By contrast, for non orthodox economists it is the aggregate growth rate that is more important since they believe that market economies are not, on average, in full employment. Productivity growth is also important, of course, to measure the competitiveness of a country and as a source of job displacement.

investment in machinery and equipment was considered. More recently, this kind of investment has been the object of some much quoted papers by De Long and Summers (1991, 1992). They also found that productivity growth is positively associated to high investment in equipment in a large sample of rich and developing countries over the Second World War II period.[5] Abel (1992, p.200) assigns to De Long-Summers' finding the status of 'new stylised fact'.

In their influential paper, Mankiw, Romer and Weil (MRW, 1992; see also Mankiw 1995) show that Solow's model, once 'augmented' to include 'human capital', is able to explain a good deal of the variations among countries in per capita income *levels* (not growth rates). They propose a production function like:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$$

where H represents 'human capital' and A the traditional exogenous technical progress (hereafter we shall omit the time subscript in the equations), and $\alpha + \beta < 1$. According to MRW this equation would lead to good predictions of those variations on Solowian lines, that is based on differences in the saving rates and in population growth, without recurring to exogenous (or endogenous) technical change.[6]

These results concern the differentials in the levels of per capital income, but not the growth rates. In this respect MRW acknowledge the *lait motive* of EGT, that 'countries with a higher saving rate grow persistently faster and that they will not converge to a same steady state growth path even if they have the same technological endowment' (ibid., p.421-422). Recall that according to Solow's model countries with similar s and technology would still show different growth rates when starting from different initial per capita capital (income) levels, although they will in the long run converge towards their common growth rate. Taking advantage of this result, Mankiw (1995,

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[5] These authors attribute big importance to differences in the price of equipment goods across countries. A high saving ratio associated to a low price of equipment would generate high productivity growth (e.g. De Long & Summers, 1991, pp.484-485). Yet the causes of the low prices of capital equipment are not clearly explored by these authors. They reject an accelerator explanation of growth, whereby it is growth that leads to an high investment shares, because this would be associated, in their view, to a higher equipment price not to the lower one showed by their data (e.g. De Long & Summers, 1991, pp.473-474; 1992, p.176).

[6] Without 'human capital' the traditional model would only partially explain those inter-country variations (Mankiw 1995, pp.282-284) The reason to include 'human capital' is that without it Solow's model would still well explain the mentioned variations, but with an income share α accruing to capital over two-third (against a usual value of one third). A high value of α would be justified once the returns to educated labour are assimilated to capital's returns. The economics of the model is that a higher 'human capital' component would lead to a higher per capita income and saving supply; the latter does in turn lead to a higher per capita income (MRW, 1992, p.417; Mankiw, 1995, p.290). Although in their model there is a touch of endogenous growth, in the sense that the accumulation of 'human capital' is an endogenous decisions, the model is not able to generate endogenous growth (that is the endogenous decisions to accumulate physical of 'human' capital do not affect the rate of growth (the model would become a full endogenous model with $\alpha + \beta = 1$, see the production function adopted by endogenous models below in sections III and IV). We put 'human capital' in inverted commas given the shaky nature of this magnitude, cf. Steedman 2001).

p.278) maintains that: "The inability of saving to affect steady state growth (…) might appear inconsistent with the strong correlation between growth and saving across countries. But this correlation could reflect the transitional dynamics that arise as economies approach their steady states'.[7] In addition, MRW (1992) approvingly quote Barro (1989) that there is no much evidence of a convergence across countries in the sense that poorer countries (those starting with a lower per capita capital endowment) do not generally tend to grow faster and catch up richer countries. They introduce, in this regard, the concept of *conditional convergence*, thereafter entered in textbook expositions, that countries do not converge towards a common growth rate, but each one toward her own one.[8] So, they conclude, growth rates can differ both (i) as countries are in 'transitional dynamics', and this may explain the relation between s and g_y; and (ii) because they converge towards different secular paths, and this is might be explained by the differences in s and population growth (*n)* (MRW, 1992, p.423).[9]

Critical of De Long-Summers results is Jones who argues that whereas in the main economies the share on GDP of both total and equipment investment has increased, (per capita) output growth rates 'have fallen, if anything, over the post-war era' (Jones, 1995b, p.508). Jones's idea seems to be that although De Long-Summers can be right to envisage a cross-country correlation between I/Y and g_y, for each country over a period of time it is not however true that a

[7] The empirical results about convergence towards secular growth reported by these authors (e.g. Mankiw, 1995, pp.284-285) suggest a faster convergence towards the steady state than that predicted by Solow's model. Assuming a higher value of the capital share α, obtained again by considering part of labour as 'human capital', would make the predictions of the 'augmented' Solow model closer to those data (ibid, p.291; MRW, 1992, p.428).

[8] '[T]he neoclassical model predicts that each economy converges to its own steady state, which in turn is determined by its saving and population growth rates' (Mankiw, 1995, p.284).

[9] It should be observed that these authors do not attribute much importance to international differences in technological endowments to explain the divergences of per capita income levels growth across countries, although this sounds strange if we compare the actual techniques in use in poor and rich countries, respectively. They seem to explain this arguing that although the production function is the roughly same in all countries, since 'knowledge …travels, around the world fairly quickly' (Mankiw, 1995, pp.300-301) the specific technique - say spades or tractors - used in each country depends on their stage of growth. This, in turn, affects factors' supply: 'To use the neoclassical model to explain international variations in growth requires the assumption that different countries use roughly the same production function at a given point in time. …change [of techniques] should be viewed as a movement along the same production function, rather than as a shift to a completely new production function' (ibid., p.281). The 'augmented' Solow model would help again. The different investment in 'human capital' would explain the divergent ability across countries to assimilate superior production functions. All neoclassical growth literature never ever mentions that the acquisition of superior foreign technology and education is a costly process in terms of balance of payments. According to non-orthodox theory, what can be called the 'foreign liquidity constraint', the necessity to collect enough international currencies to finance the acquisition of foreign embodied and disembodies technology, is one main economic obstacle to economic growth.

increasing I/Y leads to a higher g_y.[10] Critical of Jones is Li (2002) who conducts time-series regressions over 24 OECD countries over 1950-1992 and five industrialised economies over 1870 to 1987 finding that total investment is positively related to growth in more than half of the cases. Jones's outcome would be different since they rely on durable investment only and because the focus on the U.S. would be misleading (ibid, p.97).

Comparing their results to those by De Long-Summers, Blomstrom, Lipsey, Zejan (1996) find that the 'long term relationship' between I/Y and g_y 'were due more to the effect of growth on capital formation than to the effect of capital formation on growth', as argued by De Long-Summers (ibid, p.269). This sounds of course more in line with less orthodox theory. Vanhoudt (1998) is not surprised by Bolmstrom et al. results since in Solow model a rise in the saving ratio *s* is followed by a sudden rise in the growth rate followed by its decline towards its steady state level. No surprisingly then, statistical tests would suggest a negative effect of saving on growth.[11] A similar result is obtained by Attanasio, Picci e Scorcu (2000, e.g. pp.198-199),[12] while a more ecumenical outcome is attained by Podrecca and Carmeci (2001) according to whom the causality can go in both directions. A halfway position is also held by Madsen (2002) whose results on 18 countries over the period 1950-1999 would show that investment in equipment does cause growth, whereas non-residential investment in buildings and structures is caused by economic growth (this appears perplexing to a non orthodox economist who would see investment in equipment as demand induced, and construction works as an autonomous component).

Bernanke and Gurkaynak (2001) present empirical results strongly in favour of a positive influence of I/Y on g_y.[13] The two authors also show that the saving rate (I/Y), but also population growth, are positively correlated with total factor productivity (TFP), contrarily to the

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[10] Charles Jones was still a student at MIT when, in his Siena doctorate lectures on growth, Solow (1992, p.85) mentioned, not surprisingly approvingly, Jones' forthcoming results that, he reports, were obtained 'before [Jones] had read De Long-Summers's paper'.

[11] 'Since the mentioned Granger causality test control for lagged growth, it is not surprising that positive Granger causality from saving to growth does not show up' (ibid, p.78.

[12] It is impressive how much Keynesian thought has been lost by these economists that explain the 'dynamic link running from growth to investment' arguing that '[h]igher growth might driven saving up, leading in turn to higher investment' (ibid, p.183). Elsewhere they admit, and their results do not exclude, a 'Granger causation running from investment to saving'; however, they continue, 'the exact mechanisms at work are hard to spell out in detail, if an increased demand for capital goods stimulates saving – maybe through interest rate effects or the endogenous development of the financial instruments that permit the mobilisation of saving – saving might adjust to investment' (ibidem). No mention by these authors of concepts such as the investment accelerator or the Keynesian multiplier (for a Keynesian adjustment mechanism of saving to investment in a long run framework cf. Garegnani 1992).

[13] As MRW (1992), Bernanke and Gurkaynak use the Penn World Tables, a multicountry data set by Heston and Summers (MRW over the years 1960-1985, BG 1960-1995).

Solow model's prediction that TPF should be exogenous to factor accumulation. This would show that endogenous mechanism, saving or fertility decisions, have external or scale effects such to determine endogenous rather than exogenous growth. In their comments David Romer and Mankiw remark their thesis that economies are not necessarily on their steady state.

While it sounds that most of the empirical outcomes is in favour of a positive association between the investment (saving) rate and g_y (e.g. Mankiw, 1995, p.302), much effort has been paid by both fronts to check this correlation and see whether other variables would play a more significant explanatory role. Opinions tend however to converge on the idea that these exercises are of limited value since they are seriously sensitive to the variables included or excluded, the time span, the country considered and whatever else.[14] We may therefore stand with Mankiw (1995, p.308) when he argues that: 'Basic theory, shrewd observation, and common sense are surely more reliable guides for policy'. Let us therefore go back to 'basic theory' starting from the old EGT models.

II. **Arrow, Frankel and the AK model.**

Which strategies were open to neoclassical growth theory to endogenise growth? As well known, according to Solow's model the secular growth rate is given by: $g_Y = n + h$,where *n* is the growth rate of the labour force and *h* is technical change. There is little space to endogenise *n*, although a number of authors have explored the relation between fertility choices and growth. More obvious was the exploration of possible relations between saving choices and technical progress. Clearly, for the neoclassical economists the saving rate was a main determinant of capital accumulation, but because of the decreasing marginal productivity of capital, for a given a labour supply, a higher saving rate could not persistently raise the accumulation rate that, at the end, had to adjust to the exogenous rate of growth of the workforce (in physical or efficiency units). On the other hand, it was this adjustment that permitted to Solow to conclude that full employment was the long run rule overcoming the opposite conclusions by the Harrod-Domar (HD) model – who however, as cleverly pointed out by Frankel, offered a saving-led growth formula. Notably, in the HD model substitutability amongst 'production factors' is ruled out.

Frankel (1962) proposed a new growth model able to preserve the distributive role of the Cobb-Douglas production function, but in which the growth rate depends on the investment rate as

[14] So we hear Solow saying that: 'the main fact about these empirical studies' is that '*they are not robust*' (1992, p.78, italics in the original). Similarly, Mankiw (1995, pp.307-308) states that: 'Using these regressions to decide how to foster growth is …most likely a hopeless task. Simultaneity, multicollinearity, and limited degree of freedom are important practical problems for anyone trying to draw inferences from international data. Policy makers who want to promote growth would not go far wrong ignoring most of the vast literature reporting growth regressions'. Other sceptical views include Rodrik (2005), who also quote some other critical surveys, and XXX (2008).

in the HD model. The trick, that has became a sort of *cliquet* far all the endogenous growth theory up to now, was to craft a relation between labour augmenting technical change and the saving rate. In the recent literature this has been done, following Arrow, Phelps, Uzawa and other authors from the sixties, by linking labour productivity growth to externalities from (the endogenous) capital accumulation, or by relating it to surrogate saving decisions as those associated to the resources devoted to R&D or education that also imply diversion of resources from present to future consumption. In the new EGT literature a short cut has instead been taken by those economists that have just come back to HD through the so-called *AK* model, not surprisingly in view of Frankel's just recalled account of the neoclassical growth theory dilemma. Frankel's model is particularly intriguing in this regard.

As recalled, given a production function $Y = AK^{1-\alpha}(HL)^{\alpha}$, where H represents labour augmenting technical progress,[15] the growth rate of the economy is given by the summation of the growth rates of the labour force n plus that of the labour augmenting technical progress h. Let us then assume with Frankel that H depends on per-worker capital endowment, that is:

$$H = (K/L)^{\gamma} \qquad [1]$$

what Frankel names 'modifier', where (rather miraculously) Frankel set $\gamma = 1$. In order to preserve competition, technical change takes the form of an externality due to (per capita) capital accumulation.[16] Suppose then that the saving rate s rises. According to Solow's model K/L would thus rise and so H. Technical progress is thus clearly 'endogenous'. Substituting $H = K/L$ in the production function yields $Y = AK$.[17] Logarithmic differentiation gives $\hat{Y} = \hat{A} + \hat{K}$ (where the 'hat' stays for growth rate). Assuming no exogenous technical progress, that is $\hat{A} = 0$, and since $\hat{K} = sA$,[18] then $\hat{Y} = sA$. Interpreting A as the inverse of the capital-output ratio v, we get $\hat{Y} = s/v$, that is the well-know Harrod's warranted growth equation. Per capita growth is: $g_y = s/v - n$.[19]

[15] As known, the stability of the neoclassical growth model implies that technical change assumes this form. This is of course a further limitation of this model (cf. e.g. Serrano & Cesaratto, 2002, p.9)..

[16] "If one enterprise alone were to add to its capital, it would encounter diminishing returns to that factor. But when all do so, all are beneficiaries of compensatory shifts in the modifier" (ibid, 1004).

[17] Frankel used 'a' instead of 'A'.

[18] As $\dot{K} = sY = sAK$.

[19] Frankel maintains that is reasonable to assume that $s/v > n$ (1962, p.1003 e 1005 footnote).

Frankel succeeds therefore to retain both the neoclassical production function, with its ‘nice’ distribution properties, and Harrod’s growth equation with its ‘deep routes in economic thought’. Of course Harrod’s and Frankel’s models are only superficially similar.[20]

Six months before Frankel’s paper, Arrow (1962) had published another, more famous, article on endogenous growth that, however, failed to deliver endogeneity.[21] The technical progress function (hereafter TPF) selected by Arrow was

$$H = K^{\gamma} \qquad [2]$$

where Arrow sets $\gamma < 1$. The idea, not dissimilar from Frankel’s own, was that the experience from capital accumulation brought about an externality on the design of new machinery and, as a result, on the efficiency of the labour force. Substituting in the production function and taking the log derivatives obtains an aggregate growth rate equal to:

$$g = \frac{n}{1-\gamma} \qquad [3]$$

This is clearly an exogenous rate that depends on the labour force growth rate. It is not an encouraging result, although Arrow defended it by arguing that it “seems to be that under full employment, the increasing labor force permits a more rapid introduction of the newer machinery” (1962, p.166). Note that in this model the production function shows increasing returns to scale but, nonetheless growth is still exogenous. This is not surprising given that $\hat{H} = \gamma\hat{K}$: that is capital accumulation is not such to generate a parallel increase in the labour efficiency, so that growth will run out of steam without an exogenous growth force.[22]

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[20] In particular, the source of endogenous growth in Harrod derives from the fact that growth is constrained from the capital side only – at least assuming that labour is abundant and that there is no possibility of factors’ substitution in production. That is $\hat{Y} = \hat{K}$, where $\hat{K} = sY/K$. The source of endogenous growth in Frankel is in technical change function. Look at the production function $Y = AK^{1-\alpha}(HL)^{\alpha}$. Suppose for a start that *L* is constant and normalised to 1. A raise of *s* is such that *K* and *H* raise by the same proportion and so *Y*. There are not decreasing returns to the variation of *K* (for a given *L*) because the variation of *K* implies a corresponding variation of *H*, that is of the amount of labour in efficiency units, so that *K* and *HL* can proceed, so to speak, in parallel. Note that there are not decreasing marginal returns to capital accumulation because labour in efficiency units accumulate *pari passu* with the capital stock so that no relative factors’ scarcity, the source of marginal decreasing returns, does arise. Suppose then that $n > 0$. On the one side this positively affect output *Y*, but it also correspondingly negatively affect *H*, the net effect is nil, and capital accumulation and the amount of labour in efficiency units *HL* can till proceed in parallel. Not surprisingly labour growth does not affect the aggregate growth rate as much as in Harrod. Of course, it affects g_y with regressive effects: a raise of *n* reduces the rate of technical change (see Serrano & Cesaratto, 2002, p.19).

[21] We refer here to a simplified version attributed to Sheshinsky (1967).

[22] In other words, there are still marginal decreasing returns to capital. What it is necessary to generate endogenous growth is that there are not decreasing returns to capital or to any other factor that can be

While Arrow did not assume $\gamma \geq 1$ then? Suppose that $\gamma = 1$. The production function would then look $Y = AKL^{\alpha}$. Supposing no exogenous technical change ($\hat{A} = 0$), the growth equation would look like $\hat{Y} = \hat{K} + \alpha n$. A positive labour growth rate ($n > 0$) would clearly lead the economy outside a uniform secular growth rate (e.g. Ramanathan, 1982, pp. 95-96, Serrano & Cesaratto, 2002, p.17). As rather harshly commented by Cesaratto & Serrano (2002, p.18): 'Therefore if the labour force grows we see here that, rather than accumulate capital more quickly to seize the externality, what rational agents should do is to save very little and generate a demographic explosion, which in any case need not be too big because any positive rate of growth of the population quickly leads the economy to growth rates that tend to infinity! The result is even more disputable than that of the learning by doing model in which, due to the increasing returns of the economy, a constant rate of growth of the labour force generates a positive per capita growth rate. The reason for this even less reasonable result is that the learning by doing model still retains the decreasing returns to capital, which guaranteed that a constant positive growth rate of the population failed to accelerate the growth rate continually, since there was a counteracting tendency for the capital-output ratio to increase.'

One can now appreciate why the particular shape of Frankel's modifier permitted to preserve the gravitation towards a secular uniform growth even with $\gamma = 1$ and $n > 1$: while with $\gamma = 1$ the externality from capital accumulation is sufficient to determine a parallel raise of labour in efficiency units, a positive growth in physical labour has no net effect on growth for the reasons explained above.[23]

As known, the famous AK model of new EGT can be regarded as an Arrow model with the strong assumption $\gamma = 1$ and $n = 0$.[24] In this case we are back again to the HD model since $\hat{Y} = \hat{K}$ and $\hat{K} = sA$, where $A = Y/K$, that is $\hat{Y} = sA = s/v$. The trenchant comments by Solow were that: 'The essence here is that there is no primary factor, labor has disappeared', and 'It is rather amazing. …modern literature is in part just a very complicated way of disguising the fact that it is going back to Domar, and, as with Domar, the rate of growth becomes endogenous' (1992, p.18 and 32 respectively).

III. Transitional dynamics

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accumulated. This can obtained by assuming very strong IRS, or by specific functions that govern the accumulation of the 'accumulable factor': capital, 'knowledge', or 'human capital'.

[23] An akin 'modifier' was advanced by Conlisk (1967): see Cesaratto (1995), fn. 24 and (1999b), pp.251-252.

[24] Romer (1987) and Rebelo (1991) are usually quoted in this regard (cf. e.g. Jones, 2002, 162-163).

As seen, MRW and other economists accommodate Solow's model to the empirical results, generally favourable to a positive association of I/Y and g_y, by relying on a sluggish 'transitional dynamics'. In the earlier days of neoclassical growth theory a fast time-convergence towards the steady state was regarded as validating the description of secular growth provided by Solow, while presently - virtue out of necessity - a slow convergence rate is seen as supporting that model insofar as during the transition the saving (investment) rate, and the policies that affect it, do influence g_y. As well known, the seminal contribution of the speed of convergence was Ryuzo Sato (1963) who showed that it was a slow process. A relevant assumption that affects the sped of adjustment concerns the capital share (α). Having in mind the standard graphical representation of Solow's model and using a Cobb-Douglas,[25] the curvature of the $sy = sk^{\alpha}$ function hinges on the value of the capital share α: given an, say, upsurge in s that shift upward the sy curve, the higher α the farer away is the new stationary level of k from an initial k_0.[26] As seen above, MRW rely on 'human capital' to raise the capital share to two-third of output so as to obtain a slower convergence rate. An analogous suggestion was advanced by Conlisk (1966, p.553 and passim) who notes: 'Human capital is accumulated by diverting resources from other uses; and the amount of human capital accumulated depends on the amount of resources diverted. Hence, logically, human capital should be included in the factor *K*, and not in the factor *L* …If human capital is included in *K*, then a substantially larger value of α is called for than if human capital is not included in *K* ', as the numerical examples confirm (see also Ramanathan 1982, pp.245-248, to which we refer for a wider discussion). More recently, King & Rebelo (1993) have shown that convergence can be faster, so as to rule out a role for policies in Solow's model. The intuition is that if an economy is hit by a shock that reduces her capital stock, the marginal product of capital would be very high. Rational savers would react by increasing their saving supply thus accelerating accumulation and the convergence towards the steady state. According to King & Rebelo this result is not favourable to Solow model in so far as 'transitional dynamics …cannot account for important part of sustained cross-country

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[25] As known, given the neoclassical growth equation $\dot{k} = sf(k) - (n+\delta)k$ (standard notation), the secular equilibrium is were $\dot{k} = 0$, that is were $sy = (n+\delta)k$.

[26] The intuition provided by Ramanathan (1982, p.246) is that when α is high and capital relatively more important in production, if capital (saving) becomes more abundant, the scarce factor, labour, takes more time to limit growth (the marginal product of capital falls more slowly): 'the exogenous labor input …bottlenecks the growth rate. …if the share of capital is larger, then firms can substitute capital for labor and thus evade the bottleneck for longer period of time'. As noted by Jones (2002, p.159), in the limiting case of $\alpha = 1$ and constant labour, the case of the AK model, the production function is a straight line and the marginal product of capital never falls, so that we have an endless transition, a 'perfect' endogenous growth situation.

differences in rates of economic development (ibid., p.929). Slower convergence speeds could be obtained, but 'even if one makes agents very unwilling to substitute over time', at the price of very high initial marginal product of capital of the order of 500% or more (ibidem).[27]

To sum up, as often, the conclusions of different authors do strongly depends upon the value of the chosen analytical functions and on the value attributed to the parameters, while the empirical tests do not provide unequivocal results. While this would be a cheap criticism, since this happens in most fields of the discipline, including in non orthodox fields, it is worth noticing the switch of position in the Solowian camp, from seeing a fast convergence as a confirmation of the practical relevance of the secular neoclassical path to defending a lethargic gravitation to show the relevance of policy in a Solowian context. Given the host of special assumptions that EGT models have to make to bring endogenise growth home, neo-Solowian economists have a point in sticking to their well established framework stressing the length of the transitional dynamics. There are two questions, however. A long transition process presupposes a high capital share by including the accumulation of 'human capital' along that of physical capital, what is analytically a shaky operation if one think of the insurmountable troubles that neoclassical theory has to overcome in aggregating and measuring in value traditional capital goods. Secondly, as we shortly see, neo-Solowian models present explanations of the growth sources that may also be considered little promising.

IV. The new EGT and its neo-Solowian critics

Simplifying a bit, new EGT has taken two roads: one was to follow Arrow's contribution to link increasing returns to capital accumulation in a way summarised by the *AK* model already mentioned at the bottom of section II. The other was to see the source of EG in the R&D (or education) effort. The second route was anticipated in the sixties by Phelps, Shell, Uzawa and others.[28] The troubles with both these directions are similar, so it is not really necessary to deal with them separately. In order to grasp this similarity let us look at the exposition and criticism by Charles Jones. Jones' theoretical work on neo-solowian lines has perhaps been the most influential in the last ten years or so, paralleling the earlier empirical contribution by MRW. Indeed, the first influential contribution by Jones has been also empirical.

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[27] In spite of this, Solow (2000, pp.164-165) seems to applaud to King-Rebelo's point about a *fast* convergence rate, likely because he regards it as a confirmation of the practical relevance of the secular growth rate predicted by his model. Rather inconsistently, in his Siena doctoral lectures (1992, p.82) Solow argues that De Long-Summers' results about the influence of the investment rate on growth might be due to a *slow* convergence path, so as not to disconfirm his model.

[28] Cf. Cesaratto (1999a, 1999b), Cesaratto & Serrano (2002).

In a number of papers Jones (1995a; 1995b; 2003) summarized a number of 'R&D based models' (defined 'R/GH/AH models')[29] through the following equations:

$$Y = K^{1-\alpha}(HL_Y)^{\alpha} \qquad [4]$$

$$\dot{H} = \delta H^{\phi} L_H^{\lambda} \qquad [5]$$

$$L = L_Y + L_H \text{ and } L_H = s_H L$$

where the symbols are by now obvious to the reader. R/GH/AH models typically assume $\phi = 1$ and $\lambda = 1$. As it is clear applying these assumptions to the TPF [5],

$$\frac{\dot{H}}{H} = \delta s_H L \qquad [6]$$

The growth rate is endogenous as it hinges upon the term s_H that indicates the choices of the community between using labour for direct production or for the production of 'ideas'. The trouble with equation [6] is that a positive growth in the scale of the R&D labour force, due *cet.par.* to a positive growth rate of the labour force, will correspondingly raise the productivity growth rate, what the good sense would lead to reject. Jones has named this as 'strong scale effect' (or 'growth scale effect').[30] In a particularly influential paper, Jones (1995b) showed that while the U.S. per capital growth rate had been approx constant over the period 1880-1987 (1.81 % annually), the number of R&D scientists had increased five-fold. Similar results apply to other OECD countries. Therefore, Jones concluded: '[t]hese models predict that growth rates should be proportional to the level of R&D, which is clearly falsified by the tremendous rise in R&D over the last 40 tears' (1995b, p.513). The parallel with Arrow's (1962) model is clear (Jones 1995a, fn.10; Cesaratto 1995): as much as the assumption of $\gamma = 1$ in Arrow's TPF led that model into troubles in that it could not accommodate a positive growth rate of the labour force, in the present 'class' of R&D models the assumption $\phi = 1$ and $\lambda = 1$ leads to similar difficulties.

V. Modified modifiers

In an exemplary clear paper Jones (1999) summarises his criticism to the R/GH/AH models and extends it to another 'class of models', the Y/P/AH/DT models that has tried to save

[29] After the contributions by Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992).

[30] A definition of strong scale effects is the following: 'In models that exhibit "strong" scale effects, the growth rate of the economy is an increasing function of scale (which typically means overall population or the population of educated workers)' (Jones 2004, p.38). We have 'weak scale effects' when 'the level of per capita income long run is increasing function of the size of the economy' (ibid). The problems with the R/GH/AH models and with some of the earlier generation of EGT models were pointed out in various places of my 1995 paper. Of course these problems were well known before Jones (and me).

endogenous growth without incurring in the 'scale growth effects'.[31] These models are thus synthesised. Suppose that output *Q* is composed by a variety *B* of consumption goods *Y*, all produced in the same amount, that is $Q = BY$.[32] Simplifying equation [4], each product is produced using labour L_Y and a stock of 'ideas' *H*: $Y = H^{\sigma} L_Y$. In turn, the variety B depends on the population level according to a function like $B = L^{\beta}$. Finally, and this is the key assumption, the stock of ideas evolves according to the TPF:

$$\frac{\dot{H}}{H}\delta\frac{L_H}{B} \qquad [7]$$

The rationale of having the term *B* in the TPF is that population growth has two effects. On the one hand it has a positive effect on the production of ideas through a larger amount of L_H labour, but, on the other hand, it also leads to a greater variety of products, so that the amount of L_H per product line does not increase. As above, the amount of labour devoted to the generation of ideas depends on the endogenous preferences of the community about the shares of L_Y and L_H respectively: $L_H = sL$ and $L_Y = (1-s)L$. The TPF can be therefore written as:

$$g_H = \delta s L^{1-\beta}.$$

Given these assumptions, the aggregate output growth is given by: $g_q = g_B + g_y$. The first term on the left hand side is $g_B = \beta n$. With regard to the second term, since each product grows in aggregate at a rate: $g_Y = \sigma g_H + n$, per capita growth will be: $g_y = \sigma g_H + n - n = \sigma g_H$, or: $g_y = \delta s L^{1-\beta}$. We get therefore an aggregate output growth rate equal to:

$$g_q = \beta n + \sigma \delta s L^{1-\beta}.$$

If we assume with the Y/P/AH/DT models that $\beta = 1$ to obtain

$$g_q = n + \sigma \delta s \qquad [8]$$

we see that growth does depend on the endogenous preferences of the community expressed by the term *s*, and growth is positive even with zero population growth. There are no growth scale effects since the term L has disappeared from the growth equation:

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[31] After the models by Young (1998), Peretto (1998), Aghion & Howitt (1998), Dinopolous & Thompson (1998)

[32] We leave aside aggregation problems and focus only on the assumptions concerning TPFs that assure stable growth. In the specific example, the various goods are produced using labour only, so an aggregation problem does not seem to arise. Otherwise one can maintain that the *Ys* represents varieties of a same good, say corn.

At this point, watchful readers, having registered that what distinguishes the Y/P/AH/DT's TPF from R/GH/AH's one is the term *B*, that with $\beta = 1$ is equal to *L*, will have noticed that this is similar to the distinction between Arrow's and Frankel's TPFs.[33]

Jones's (1999, pp. 142-143) criticism points to the *ad hoc* nature of the assumption $\beta = 1$. Indeed, with $\beta < 1$ the number of sectors would grow less than proportionally with population, so that the model would still exhibit growth scale effects. With $\beta > 1$ the number of sectors would grow more than proportionally with population, and this has a negative effect on productivity growth as a rising L_H workforce would be spread over an even more rapidly rising number of sectors. Asymptotically growth would then still depend upon population growth. This is indeed the standard criticism raised against new EGT since its very beginning (Cesaratto 1999b, p.788).

Besides the analogy between Frankel's and Y/P/AH/DT's TPF, what Jones fails to notice in his otherwise illuminating paper is the similarity of Y/P/AH/DT's equation [8] to the TPF proposed by Lucas' (1988) in another seminal paper of the new EGT, in turn similar to Frankel's modifier as showed by Serrano & Cesaratto 2002, pp. 22-24).[34] In Lucas we find a TPF like:

$$\dot{H}/H = \vartheta z$$

where $z = L_H / L$ is the share of labour devoted to education, R&D or the like. Notably, the difference with equation [6] is that *L* appears at the dominator, as much as in Frankel's equation [1] and Y/P/AH/DT's equation [7]. As the latter TPFs, Lucas' TPF does indeed fit well in the Solow's model without perturbing its main features (Lucas 1988, p.19-20). [35] As argued in Serrano & Cesaratto (2002, p…): in these models 'the increase of efficiency does not depend on knowledge

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[33] Respectively: $K = H$ (Arrow with $\gamma = 1$) and $H = \frac{K}{L}$ (Frankel); $\frac{\dot{H}}{H} = \delta L_H$ (R/GH/AH) and $\frac{\dot{H}}{H} = \delta \frac{L_H}{B}$ (Y/P/AH/DT).

[34] Jones quotes in passing Frankel in 2002, p.162 ,fn. 5.

[35] Jones (1995a, p.762-63; 2004, pp. 42-43) does not regard Lucas' TPF an appropriate solution since the idea that the absolute number of R&D employees matters for technical progress would be lost in the Lucas' TPF, only the share on total workforce do indeed matter (we shall come back on this, that Jones names 'Mozart effect', soon). In addition, the empirical evidence is that in the U.S. a threefold raise in the R&D effort (*z*) would have not been followed by a parallel increase in the secular growth rate (the same would apply to other countries).

accumulation itself, but on knowledge accumulation per worker (in close analogy with the Frankel modifier that enabled efficiency to grow with the quantity of physical capital per worker)'.[36]

VI. Neo-Solowian (semi-endogenous) models

Having thus pointed out both the troubles with the R/GH/AH models (growth scale effects) and with Y/P/AH/DT models (ad hoc assumptions in order to avoid the growth scale effects), Jones proposes a model that avoids the growth scale effects although at the price of sacrificing endogenous growth. Let us reconsider equation [5]: $\dot{H} = \delta H^{\phi} L_H^{\lambda}$. Jones assumes $\phi < 1$ and $\lambda < 1$. His explanation of these assumptions are as follows (e.g. Jones 1995a, pp.764-766; 2002, pp. 99-100). The simplest TPF inspired by P.Romer would be: $\dot{H} = \bar{\delta} L_H$, that is the number of new 'ideas' is proportional to the number of individuals engaged in R&D activities. The term $\bar{\delta}$ measures the rate at which new ideas are caught. $\bar{\delta}$ can in turn be seen as a function of the ideas already discovered: $\bar{\delta} = \delta H^{\phi}$. Now, if $\phi > 0$ this means that the generation of new ideas is a positive function of the stock of earlier ideas – that is past discoveries open the way to new ones, the 'standing on shoulder effect'-, whereas $\phi < 0$ would correspond to the 'fishing out' case in which new discoveries are arduous to be done over time - the most obvious but breakthrough discoveries are done earlier. If $\phi = 0$, the two facts precisely compensate each other. Finally, the exponent $\lambda < 1$ in the equation [5] suggest that there might be duplications in R&D. Jones (1995a, p.766) argues that $\phi > 0$ is a plausible assumption, whereas the value $\phi = 1$ assumed by R/GH/AH would be an arbitrary condition.

Given equation [5] and the assumptions $\phi < 1$ and $\lambda < 1$, the growth rate of the stock of ideas is given by:

$$\dot{H}/H = \delta L^{\lambda}/H^{1-\phi} \qquad [9]$$

Along a balanced growth path the ideas growth rate, $g_H = \dot{H}/H$, should be constant. This implies that, taking the logarithmic derivatives of both sides of equation [9] it must be: $0 = \lambda \dot{L}_H/L_H - (1-\phi)\dot{H}/H$. It is reasonable to assume that the number of ideas hunters does grow at the same rate of population, that is $\dot{L}_H/L_H = n$, so that we have:

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[36] Alternatively the similarity between Lucas and Frankel can be seen by writing $\dot{H} = jzLe$, where $e = H/L$ measures the 'per capita' amount of knowledge. The endogenous rate of technical change would be $\dot{H}/H = jz$.

$$g_H = \frac{\lambda n}{1-\phi} \qquad [10]$$

In Jones' parlance (2002, p.106), this model would show 'weak scale effects' or 'level effects' in so far as it shows 'the somewhat surprising implication that this eliminates the long-run growth effects of policy'. With $\phi = 1$, as note above, policy is effective, but 'this assumption generates the counterfactual prediction that growth rates should accelerate over time with a growing population'. The similarity of equation [10] with Arrow's growth equation [3], and of the conclusions drawn on their basis (see above section II), is striking as Jones fully acknowledge (e.g. 1995a, fn.10, p.768), so that the origin of his 'surprise' is mysterious.

VII. Millenarian explanations of Mozart production

Jones fervently defends the idea that productivity growth depends on population growth (e.g. 2002, pp.103-104). After all, this is the idea, humans are the ultimate fuel of the search process, and it should not be surprising that a larger population growth has a positive effect on the generation of new ideas. Jones' favourite quotation is from Phelps (1968, pp.511-512) according to which: 'One can hardly imagine …how poor we would be today were it not for the rapid population growth of the past to which we owe the enormous number of technological advances enjoyed to day. …If I could re-do the history of the world, halving population size each year from the beginning of time on some random basis, I would not do it for fear of losing Mozart in the process'. One might certainly argue that by cutting by half the German speaking population in the eighteen and nineteen centuries would risk to loose many of the greatest musicians ever, but that could be done to other populations of comparable size, at that or other times, without much fear of losing any sort of talent. Ruling out genetic factors, something seems missing.[37] Jones (2004, pp. 48-56) discusses these possible objections at some length. Looking at different world regions over the very long run, 12,000 years or so, it appears some relation between population size at the beginning of the period and their technological rank measured at the year 1000/1500 or so (before the European exploration broke the isolation of different areas). The rationale of this correlation (ibid, p. 56) would lay in the following virtuous circle: at the beginning a small population could generate ideas only over long periods of time. Low productivity and subsistence levels kept population constant. However, once one idea was produced subsistence levels and fertility rise, causing a larger population. This in turn facilitates the production of new ideas over shorter lapses of time and so on and so forth.[38]

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[37] May be what is relevant is the diffusion of musical learning amongst the population, so that the number of Mozarts could be increased by fostering musical education (for a similar remark see Temple, 2003, p.506).

[38] Limitating himself to his 'weak scale effects', Jones (2004, p.45) seems to arrive to the point of suggesting higher fertility as a way to raise per-capital income. He defends this stance arguing that this

This kind of reasoning certainly facilitate the construction of nice mathematical models, however it is difficult to think that this kind of explanation can be no more than one aspect of some more complex historical process.[39] In addition, Jones recognises that the most recent experience seems to disconfirm this explanation since 'countries with the most rapid rates of population growth – many in Africa – are among the countries with the slowest rates of per capita income growth' (Jones, 2004, p.50). This would be due, according to Jones, to the 'different levels of human capital and different policies, institutions, and property rights' and we should rely on 'econometric evidence that seeks to neutralize these differences' (ibidem). Some 'econometric evidence' is presented in order to confirm the idea that one factor to be 'neutralised' is openness to international trade. This in turn would be associated to openness to international 'flow of ideas'. Once controlled for both trade and institutional quality, the evidence would suggest a significant elasticity of GDP per worker with respect to the size of the workforce. In my opinion this is not enough to dissipate some scepticism with regard to Jones' thesis. Indeed, one thing is to argue that economic growth is accompanied by population growth, on the other hand it is difficult to attribute to regard the later as a main cause of recent episodes of economic development. Over a millennium perspective population configurations might certainly be a significant factor, amongst others structural factors, to explain secular backwardness (dispersed population in the vast territory of Africa is quoted in this respect as an explanation of its backwardness). Whether this is a useful perspective to explain the secular economic delay of China and her recent rocketing economic growth is doubtful.

Concluding remarks

Modern mainstream growth theory seems therefore split into two camps: those who favour endogenous models with their policy effectiveness over long-run growth, although at the price of special assumptions such as the knife-edge value in the exponents of the TPFs, or zero population growth - this is avoided by the use of the various *ad hoc* modifiers *a là* Frankel -; and the neo-Solowian economists (semi-endogenous models) which limit the policy impact over the transition periods and attribute a questionable role to population growth in explaining not only aggregate growth (which sounds quite odd to a Keynesian economist), but even productivity growth. Senior economists such as Frank Hahn (1994, p.1) have been quite critical of the 'backward reasoning' employed by the new EGT in selecting their TPFs: the description of reality is bended in order that it fits a steady state growth model, and not the other way round as it would appear natural. Indeed, too much attention is paid to long run 'balanced' growth, notes Temple (2003, p.501 and passim) in

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would be a way to endogenise growth by making it dependent on the policy choices of the community over fertility.

[39] An author often quoted for having pointed out a number of material geographical and biological factors that affected the millenarian process of growth differentiation among world regions is Diamond (1997).

an stimulating article, whereas empirically we do not really know whether the economy is moving along a steady state or, may be, converging to it.[40] Balanced growth requires the very peculiar knife-edge assumptions recalled above even in the exogenous Solowian framework (ibid, pp.499-500). Temple quotes here a point made by Jones (2004, pp.60-64) that what is required for steady state growth is the *linearity* in the TPFs, whether of the exogenous Solowian variety or of the endogenous species.[41] Once we are not obsessed with balanced growth, Temple concludes, these knife edge assumption my be taken at their face value, as simplifying hypothesis to make theoretical explorations that provide different perspectives of reality: ‘growth models are often best seen as laboratories for thought experiments, and apparently competing frameworks can form a useful complement to one another’ (Temple, 2003, p. 508). This is a sensible position, that may also explain the sense of accomplishment that, after all, mainstream growth economists display with regard to the past twenty years of revival of growth theory. Of course, if we pass from the academic results to the capacity to provide practical policy suggestions the bottle would appear half full, to be generous, as Temple (ibid, p.501) or Mankiw (1995, p.309) are next to admit.

We may finally ask ourselves if a different approach, alternative to neoclassical theory, would provide a more satisfactory explanation of economic growth. In this regard should be easily appreciated by non orthodox economists that neoclassical growth theory – in any of its ramifications - is the natural victim of the capital theory critique. Alternative theoretical accounts of capital accumulation appear more amenable to the stylised facts that conventional growth analysis is at pain to allow for. This is the case of the relation between the investment rate and the growth rate (cf. Serrano & Cesaratto, pp.25-27). The decisive role of aggregate demand, both in the short and in the long run periods, as the key of economic growth, is of course the differentia specifica, of non orthodox schools (Garegnani, 1992). On the supply side, no doubt that the introduction of technical progress in growth models, including those of non orthodox orientation, is a very artificial operation that may be useful for some purposes, but that cannot be the basis for a satisfactory account of a phenomenon whose understanding does require, in my opinion, historical research rather than economic modelling. But, after all, this true as well with regard to the historical and geopolitical sources of aggregate demand in the real episodes of economic growth.

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[40] The only ‘piece of evidence we have for the existence of a balanced growth path is that the real interest rate does not display any clear trend’ (ibid, p.507). Note that it is only within neoclassical theory that a constant real interest rate requires balanced growth, in particular the constancy of the relative proportions of labour (in efficiency units) and capital.

[41] Also exogenous technical progress requires a linear TPF, e.g. $m = \dot{H}/H$.

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