TECHNOLOGICAL DIFFERENCES AND CONVERGENCE IN THE OECD*

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En el cuarto trimestre de 1991 la Dirección General de Planificación abrió una línea de estudio sobre el crecimiento comparado de la economía española y la convergencia con las economías más desarrolladas. Los trabajos elaborados dentro de esta línea se publican en inglés para que puedan ser leídos por los estudiosos de esta materia más allá de nuestras fronteras. En breve tiempo estará disponible una traducción castellana.

Hasta la fecha se han publicado otros tres documentos de trabajo dentro de este programa:

D-92006: "Long-Run Economic Growth in Spain Since the Nineteenth Century: An International Perspective". Leandro Prados de la Escosura, Teresa Daban y Jorge Sanz.

D-93002: "Spain's Gross Domestic Product 1850-1990: A new Series". Leandro Prados de la Escosura.

D-93003: "Growth, Convergence and Macroeconomic Performance in OECD Countries: A Closes Look". Javier Andrés, Rafael Doménech y César Molinas.

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I. Introduction.

The empirical growth literature has focused in recent times in testing the main proposition of the neoclassical growth model. The absolute convergence proposition states that faster capital accumulation in poor countries will eventually lead them to reach the richer ones' per capita income. Endogenous growth models, on the other hand, contain alternative explanations (other than exogenous technological progress) for a non stationary per capita income; in these models, the convergence property only holds for a particular parameter set.

Mankiw, Romer and Weil (1990) argue that the Solow model, suitably augmented to include human capital as an accumulable factor, explains rather well the convergence process. According to their results, each country moves towards its own steady state per capita income level, growing faster the lower its starting conditions. Differences in the steady state depend only on deep parameters, such as the share of output devoted to capital accumulation and the augmented rate of population growth, as long as all countries in the sample share the same technology. Some authors have recently questioned this latest assumption; in particular Durlauf and Johnson (1992) (DJ thereafter), claim that 'solowian' economies need not have the same technological parameters. If this is the case, convergence among countries with similar production functions is called *local convergence* (whether of the conditional or absolute class) as opposed to *global convergence* that might take place if all countries share the same technology[1]. These authors propose a sample splitting procedure to isolate the so called *technological clubs*. Once these homogeneous country groups have been established, the explanatory power of the augmented Solow model is enhanced, and they cannot reject the hypothesis that convergence *within* each group is faster than *among* groups.

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[1] It should be noticed that for countries to converge to the same steady state, they must have the same technology as well as similar savings and population growth rates.

DJ splitting criteria relies on each country's initial income and human capital. Our guess is that this procedure may produce inadequate sample splits, since the initial conditions may not be a good proxy for the available technology in a particular country. Hence, the aim of this paper is twofold. We first present an alternative splitting method to identify the existing technological clubs; we claim that this procedure uses the sample information more efficiently and avoids some of the less pleasant features of DJ's criteria. We then apply this procedure and find that the maintained assumption of a common technology among the OECD countries (from 1960 to 1990) does not hold. We identify at least two different groups inside the OECD with markedly different technological parameters. The Solow model explains reasonably well the evolution of the *less advanced technology* countries and yields a low convergence rate. Convergence inside the *more advanced technology* group of countries is much faster, although the implausible parameter values obtained cast some doubts on the validity of the Solow model to account for the long run evolution of this *club*.

The paper is organized as follows. Section II contains a quick remainder of the augmented Solow model, as well as some implications of the common technology assumption. The data set and the econometric methodology are described in section III. In section IV we discuss the theoretical and econometric implications of different splitting criteria. In section V we estimate the Solow model for each technological club and identify the most relevant parameter differences. In the last section we summarize the main findings of our work and we advance some lines for further research.

II. The 'augmented' Solow model.

Let us consider an economy producing one good (Y), using a constant returns to scale technology in three factors (Mankiw et alia (1990)), physical capital (K), human capital (H) and efficient labour (AL). The i_{th} country production function can be written as

$$Y_t = \theta\, K_t^{\alpha}\, H_t^{\beta}\, (B_t L_t)^{\gamma} \qquad \alpha + \beta + \gamma = 1 \tag{1}$$

or in intensive form,

$$y_t = \theta\, k_t^{\alpha}\, h_t^{\beta} \tag{1'}$$

where lower case letters represent magnitudes expressed in units of efficient labour. If we call *g* the rate of growth of labour augmenting technical progress, *n* the rate of population growth, s_h and s_k the share of total output devoted to accumulate human and physical capital and δ the depreciation rate, we can write the factor accumulation equations as:

$$B_t = B_0\, e^{gt} \tag{2}$$

$$L_t = L_0\, e^{nt} \tag{3}$$

$$\frac{dk}{dt} = s_k\, y_t - (n+g+\delta)\, k_t \tag{4}$$

$$\frac{dh}{dt} = s_h\, y_t - (n+g+\delta)\, h_t \tag{5}$$

Solving the model, the (starred) steady state solution takes the form,

$$k^* = \left[\frac{\theta\, s_k^{1-\beta}\, s_h^{\beta}}{n+g+\delta}\right]^{1/\gamma} \tag{6}$$

$$h^* = \left[\frac{\theta\, s_k^{\alpha}\, s_h^{1-\alpha}}{n+g+\delta}\right]^{1/\gamma} \tag{7}$$

Plugging (6) and (7) in (1') we get the steady state level of output per unit of efficient labour,

$$y^* = \left[\frac{\theta \ s_k^{1-\beta} \ s_h^{\beta}}{n+g+\delta}\right]^{\alpha/\gamma} \left[\frac{\theta \ s_k^{\alpha} \ s_h^{1-\alpha}}{n+g+\delta}\right]^{\beta/\gamma} \qquad (8)$$

taking logs and rearranging terms, steady state per capita GDP can be represented as in (9), where A_0 represents the initial conditions of technical progress[2].

$$\log(\bar{y}_{T+t^*}) = A_0 + gt^* + gT - \frac{\alpha+\beta}{\gamma}\log(n^*+g+\delta) + \frac{\alpha}{\gamma}\log(s_k^*) + \frac{\beta}{\gamma}\log(s_h^*) \qquad (9)$$

The Solow model also explains the convergence rate of one economy to its steady state level at any particular point in time *T*,

$$\frac{d\ \log(y_T)}{dt} = \lambda\ [\log(y_{T+t^*}) - \log(y_T)] \qquad (10)$$

Which means that the economy closes the gap with respect to its steady state at a constant rate λ so that,

$$[\log(y^*) - \log(y_{T+\tau})] = e^{-\lambda\tau}\ [\log(y^*) - \log(y_T)] \qquad (11)$$

where $\lambda = (1-\alpha-\beta)(n^*+g+\delta)$.

From (11) we may derive the conditional convergence equation (12) which has been the focus of most recent work in the empirical growth literature,

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[2] Where

$$A_O = \frac{\alpha+\beta}{\gamma}\log\theta + \log B_O$$

$$\log(\bar{y}_{T+\tau}) - \log(\bar{y}_T) =$$

$$= g\tau + (1 - e^{-\lambda\tau}) \left[A_0 + gT - \log(\bar{y}_T) - \frac{\alpha+\beta}{\gamma}\log(n^* + g + \delta) + \frac{\alpha}{\gamma}\log(s_k^*) + \frac{\beta}{\gamma}\log(s_h^*) \right] \qquad (12)$$

Most variables in (12) are not observable but can be easily approximated by long run averages of their empirical counterparts (i.e. current savings rate or population growth, etc.). This expression is usually estimated using multicountry data sets, since single country series are not long enough and after averaging we are left with too few observations (usually not more than six or eight per country); this procedure is necessary to avoid degrees of freedom limitations. However, it should be noticed that this approach implies imposing the hypothesis of common technology across the countries in the sample, i.e

$$\alpha_i = \alpha,\ \beta_i = \beta,\ \gamma_i = \gamma,\ g_i = g,\ A_{0i} = A_0 \qquad \forall i$$

In the next section we discuss the implications of relaxing this latter assumption and introduce a first test of the common technology hypothesis. As we shall see, even within the club of the world's most advanced countries, we find evidence that this restriction might be inappropriate.

III. OECD: a homogeneous group?

3.1. Data and econometric issues.

The econometric testing of the convergence proposition has been usually carried out throughout the estimation of either the linear or the non linear version of equation (12)[3]. In this paper we have only tried the non linear specification and impose as many theoretical restrictions as possible, given the available sample. Furthermore, unlike most previous work in this field we do not impose the *g* value to be 0.02, but rather we estimate it and test whether or not it is the same across groups of countries[4].

Most series in our data set (all but the human capital series) come from the OECD National Accounts, 1960-1991. All variables have been homogenized using the 1990 purchasing power parities published by the OECD, and are expressed in 1985 international dollars. We proxy s_k with the percentage of total investment (both private and public) with respect to real GDP, and s_h with Kyriacou's (1991) human capital index, calculated as the average years of schooling in the labour force. Five year periods are taken as the appropriate time span; hence, we have six observations for each country and steady state rates (s_k, s_h, n) are five year averages[5]. The last component of each of these averages is the observation in $t+\tau$, which introduces a potential simultaneity bias. Hence we have estimated our models by instrumental variables methods, either non linear two (NL2LS) or three stages (NL3LS) using first lags as instruments of endogenous variables,

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[3] See Barro and Sala-i-Martín (1991), Mankiw et alia (1990) and Durlauf and Johnson (1992), for instance. In all these papers, equation (12) is estimated either in linear or non linear form for multicountry data sets. For a test of the convergence hypothesis among OECD countries see also Dowrick and Nguyen (1989) and Dolado et alia (1993).

[4] With the exception of Hotz-Eakin (1992), most papers also impose the parameter *g* to 0.02.

[5] The range of T is {1960, 1965,..., 1985} and τ equals five in (12).

although the investment rate in human capital is considered exogenous[6]. To compute the implicit convergence rate (λ_{imp}), we shall consider the point estimate of the human capital share[7] (β) whenever its t ratio is above 1.0.

3.2. Preliminary results.

There is solid empirical evidence of convergence in per capita GDP among OECD countries. Nevertheless, Durlauf and Johnson argue that if technology is different across countries we should identify different *technological clubs* and proceed to estimate the model within each of them. Their *sample splitting* procedure is based upon each country's initial conditions and, using the Summers and Heston (1991) data set, they find evidence of two different technologies inside the OECD.

According to their assumptions, technological non convexities cannot be observed, but can be identified on the basis of initial per capita income and human capital; hence, they set up a non parametric procedure to split the sample to achieve the best fit[8]. After having selected the cut-off level of per capita income and literacy the sample is divided in different groups and the model is estimated for each of them. Each country belongs to the

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[6] A comprehensive study of the long run features of the OECD economies can be found in Andrés, Doménech and Molinas (1993). In that paper there is a more detailed description of the data set as well as a check of the robustness of the main results to alternative estimation methods.

[7] In Andrés et alia (1993), it is shown that this variable is significant once differences in average growth across periods are controlled for. One interpretation that can be given to this result is that the human capital influence upon growth takes time to show up, and hence it might be the case that changes in the labour force average years of schooling are weakly correlated with current growth rates.

[8] Actually, DJ use two sequential techniques. First, they exogenously chose the number of splits and then determine the cut-off level of per capita income and literacy as to maximize the likelihood function. Second, they use the 'regression tree' technique in order to find the optimum number of splits.

club defined by its initial conditions, regardless of its final achievement; this seems quite unsatisfactory if one observes the sizable movements that have taken place along the OECD ranking from 1960 to 1990.

It can be argued that these movements are simply the outcome of the convergence process and that selecting the clubs according to the end of period per capita income would imply a sort of tautology since convergence would be tested among countries that have effectively converged[9]. However, since we are interested in testing the common technology hypothesis, we should try to put together those countries which are most likely to share the same parameters. In this case the final position in the per capita income ranking is a better proxy of the true production function than the starting one.

In table 3 we present some econometric results which illustrate these points. In the first column we present the estimation of the basic model in (12) imposing a common technology for all OECD countries. The estimated α is slightly higher than expected, whereas β is lower and weakly significant; the rate of growth of technical progress is 2.3%. The implicit convergence rate, evaluated at these point estimates, is 2.5%, which lies within the range of values obtained in the literature[10]. The initial technological conditions are also well estimated.

These results are only valid conditional upon the common technology hypothesis. However, the changes in the per capita income ranking suggest that this hypothesis might not hold. In table 1 we can identify some countries that have maintained their position in the OECD per capita ranking and some which have not. In the first group we can include Turkey, Greece, Portugal, Spain, etc. among the poorest countries, and Switzerland and USA

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[9] See the De Long's (1988) critique to Baumol's (1986) work.

[10] Notice that imposing the value of g at 2%, the convergence rate would be a 20% smaller. In Andrés, et alia (1993) the model with time dummies yields convergence rates in the range of 2% to 2.6%.

among the richest; in the second group we find Japan and Iceland moving upwards and New Zealand, Australia and the UK, which have gone in the opposite direction. Underneath this change in relative position we find true differences in economic performance over the long run. Whereas 1960 per capita income in New Zealand was almost 80% that in the USA, it has been reduced to the 55% in 1990. During this period, Iceland's per capita income relative to the USA has increased from 45% to 80%. It is hard to admit that only differences in saving rates and population growth may explain why Iceland's per capita income is now 25% higher than that in New Zealand while it was a half of it in 1960.

In columns 2 to 5 we find evidence of different technologies in the OECD[11]. We have split the sample in two halves, containing respectively the twelve poorer and richer countries according to their per capita income in 1960 (cols. 2 and 3) and 1990 (cols. 4 and 5). We have then a system of two non linear equations in which we can impose the same technology (equations 2 and 4), or estimate a different parameter set for each group instead (equations 3 and 5). Estimating by three stage least squares (NL3LS) we expect to get more efficient estimators, provided that there is contemporaneous correlation among shocks hitting the different subsamples. If we do not choose the adequate sample split, the increase in efficiency might be very small. However, at this point we are merely interested in testing whether the common technology hypothesis holds for more or less *ad hoc* splits, and to check the robustness of subsample estimates to alternative splitting criteria.

If technology was common for all OECD countries, NL3LS estimation of any system of equations should not reject the null of parameter homogeneity. In column 2 we can appreciate non negligible efficiency gains of the system estimation; $\hat{g}$ and $\hat{\beta}$ are now significant although point estimates do not change very much. In column 3 we present the estimated model imposing only

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[11] See also Andrés et alia (1993) for differences in the convergence model across subsamples.

the cross equations restrictions on *β* and *g* which are not rejected by the data. Point estimates reveal sizable differences both in $\hat{A}_0$ and $\hat{\alpha}$, and hence in λ_{imp}; as expected, the initial state of knowledge (B_0) as well as other scale parameters (θ) are smaller in *poor* countries, and so is the convergence rate. On the other hand differences in $\hat{\alpha}$ are counterintuitive since they point to a higher capital share in *poorer* countries.

A similar exercise, based upon the 1990 ranking, is reported in columns 4 and 5. In this case the rejection of the null hypothesis of common A_0 and α values is overwhelming, as can be appreciated in the corresponding χ^2 statistics. The point estimates also reveal remarkable differences in $\hat{A}_o$ (2.12 for *rich* countries versus -9.57 for the *poorer* ones) as well as an implausible value for the capital share in the *rich* countries subsample. We can also see how the overall fit for this subsample worsens substantially if we impose the same parameter values, whereas this does not happen for the group of *poor* countries. As expected, the differences in the convergence rates are much bigger; the implicit rate is 2.5% in the *poor* countries group, whereas it is 6.5% among the *richer* ones.

We can draw several conclusions from these exercises. First there are reasons to reject the common technology assumption among the OECD countries. The method we have followed so far to split our sample is *ad hoc* but this does not affect our conclusions; if technology was the same the null hypothesis should not have been rejected regardless of the splitting procedure. Second, the parameter estimates are non robust to the choice of alternative dates to do the split. Finally, these results cast some doubts on the validity of the Solow model for the *rich* country group. It is important to see how dependent these results are on the splitting procedure, in the next section we put forward an alternative method to select homogeneous country groups, which makes a more efficient use of the available information.

IV. Technological non convexities as individual effects.

In a highly integrated economic area is not easy to explain why all countries do not have access to the same technology. Durlauf and Johnson (1991) argue that the production function might not be the same at different levels of economic development; in other words, there are some technologies that may not be operative until a given level of physical and/or human capital has been achieved. Hence openness and trade are not enough to ensure a common technology across countries. This argument leads DJ to select their *homogeneous technology clubs* on the basis of some proxies for the level of development at a particular point in time. In this section we give some reasons why these *technological discontinuities* may occur across countries, and discuss their policy and econometric implications in order to propose an alternative splitting method.

4.1. Technological thresholds: theoretical approach.

Let us consider the production function in (13) expressed in per capita terms,

$$\bar{y}_{i,t} = \theta_i(z_{it}) \left[B_{0i} e^{g_i t}\right]^{\gamma_i(z_{it})} \bar{k}_{i,t}^{\alpha_i(z_{it})} \bar{h}_{i,t}^{\beta_i(z_{it})} \qquad (13)$$

where $z = \{k, h\}$. The parameter set $\{\theta, \alpha, \beta, \gamma\}$ is dependent on the level of physical and human capital per unit of efficient labour. DJ present two examples of these threshold effects, that can be represented considering a simpler production function without human capital, as follows:

$$\bar{y}_{i,t} = \begin{cases} \theta_1 \, B_0^{\gamma_1} \, e^{g_1 \gamma_1 t} \, \bar{k}_{1,t}^{\alpha_1} & \text{if } k_{1,t} < k^u \\ \theta_2 \, B_0^{\gamma_2} \, e^{g_2 \gamma_2 t} \, \bar{k}_{2,t}^{\alpha_2} & \text{if } k_{2,t} > k^u \end{cases} \qquad (14)$$

Two justifications for this threshold effect are offered in DJ's paper. The first one is based on Romer's (1986) learning-by-doing process, according to which, the efficiency of labour increases with experience. Cumulative capital stock, which is the outcome of all past investment decisions, is a good proxy for this experience (Sala-i-Martin (1990)), since each generation of new machines incorporates the necessity of additional skills to operate them. This process does not have to be smooth, but it usually takes sizable increases in the capital stock to produce significant changes in the efficiency with which inputs are used. This means that there might be some threshold levels of capital (k^u) that the economy must overcome to achieve a more productive technology. This is represented by a move from technology F_1 with parameters $\{\theta_1, B_0, g, \alpha, \gamma\}$ to $F_2\{\theta_2, B_0, g, \alpha, \gamma\}$ where $\theta_1<\theta_2$.

An alternative explanation for this technological non convexity is based on Azariadis and Drazen's (1990) notion of human capital externalities. This is a more general case than the previous one, and appears when some minimum level of productive factors is required to have access to more advanced technologies. Once this levels are achieved the economy moves from one technology $F_1\{\theta_1, B_0, g, \alpha_1, \gamma_1\}$ to a more productive one $F_2\{\theta_2, B_0, g, \alpha_2, \gamma_2\}$, characterized by a completely different set of parameters, in particular, with different factor shares.

These two cases can be easily represented in a diagram. Our purpose is to show how they may give rise to multiple steady state equilibria, even for similar saving and population growth rates, provided the threshold is defined not in capital or in capital per capita levels, but in capital per unit of efficient labour. Following Romer and Azariadis and Drazen, DJ claim that one economy has access to a particular technology once it has accumulated a minimum *level* of physical (K^u) and/or human capital (H^u). This is a good description of the non smooth process of knowledge accumulation, which characterizes the dynamics of economic development. However, if the turning points are defined in *levels* there cannot be *technologically different* steady states among countries[12]. Notice that in the steady state, the capital stock is growing at a non negative rate ($n+g$) and hence, sooner or latter all countries will cross the *threshold level* pointing to a higher steady state. This is so even if we define the threshold in per capita terms, in this case the growth rate in the steady state is still non negative (g) and there is a unique steady state given by the most advanced technology, although the transition process towards it is not smooth[13]. This *natural* transition among technological clubs does not take place if we define the threshold in capital per units of efficient labour instead. In this case we can get proper multiple equilibria and the transition from one of these to another needs to be exogenously engineered.

The argument is portrayed in Figure 1, where we have depicted two production functions (F_1 and F_2); if we assume that all countries have the same behavioural parameters (s_k,s_h,n,δ), they will tend towards E_1 or E_2 depending on their initial capital labour ratio. As time goes by all per capita ratios are growing as to reach their steady state levels and any particular economy never crosses the cut-off point ($\bar{k}^u$) in either direction. The policy implication of this non convexity is that economies in low steady state equilibria can only move into a more advanced club through *temporary*

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[12] By 'technologically different' we mean that the steady state are different because of differences in the production function (i.e. even for similar savings and population growth rates).

[13] In this case, it is no longer true that the growth rate of per capita income is continuously decreasing as we approach the steady state. In fact, income can be growing for a while at a rate n+g until the threshold level is reached, then income starts growing faster since the economy is far from its new steady state. This jumps occur any time the economy hits its binding capital or capital per capita threshold level.

incentives to save and invest over and above what the representative agent would chose to.

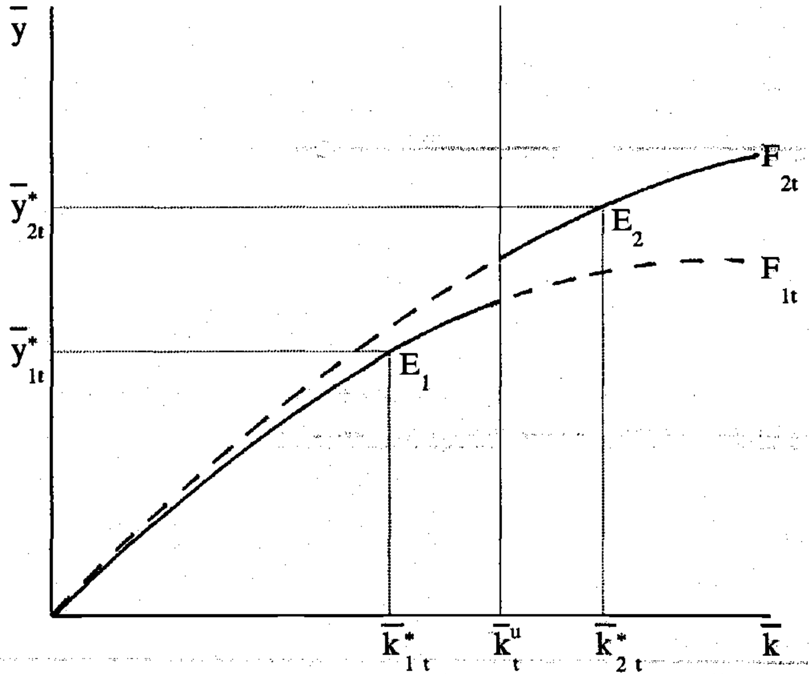

Figure 1

The way economies get trapped into different technological clubs according to this interpretation also justifies the splitting procedure based upon variables observed at a particular point in time. Actually, the production function is the same for all countries although it presents a discontinuity at $\bar{k}^u$; hence, economies in more advanced technological clubs must have higher ratios than less advanced ones[14]. If we do not select the proper cut-

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[14] And so, richer countries in 1960 should belong to more advanced clubs than the poorer ones.

off level (for instance, if we choose this cut-off y^c either below $\bar{y}_1^*$ or above $\bar{y}_2^*$) we may (wrongly) have different technologies in the same club but it is still true that if country *2* enjoys a more advanced technology than country *1*, the latter can never be estimated to be in a more advanced club than the former one. Nevertheless, even in this simple case, initial conditions based criteria may be misleading. If some countries can move from one technological regime to another[15] or, at least, if some can do faster than others, the composition of technological clubs defined on the basis of the initial conditions might have nothing to do with the one based on the end of period. There are good reasons to believe that choosing on the basis of countries revealed performance, can be most reliable.

There is an alternative explanation of the existence of locally convergent country groups. Accumulated knowledge in 1960 (B_{0i}) was not the same across all OECD countries[16]; this discrepancy may lead to persistent differences across countries unless is compensated by differences in the rate of labour augmenting technical progress. Consider two countries *1* and *2* with exactly the same behavioural and technological parameters except B_0, such that $B_{01} < B_{02}$.

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[15] Either because of intrinsic dynamics if the turning point is defined in levels or due to the success of investment promoting policies.

[16] Notice that for these initial conditions to be the same we would have to consider different starting years across countries, identifying the moment (t) for which country 1 has got the same level of accumulated knowledge than country 2 in 1960 (i.e. $B_{1t} = B_{2,1960}$). This would be an alternative way of looking at the convergence problem, to see whether or not truly similar countries have converged starting from different ratios of human and physical capital per capita. An approach close to this can be found in Prados de la Escosura et alia. (1993).

$$\bar{y}_{i,t} = \begin{cases} \theta\, B_{01}^{\gamma}\, e^{g\gamma t}\, \bar{k}_{t}^{\alpha} & \\ & \text{where: } B_{02} > B_{01} \\ \theta\, B_{02}^{\gamma}\, e^{g\gamma t}\, \bar{k}_{t}^{\alpha} & \end{cases} \qquad (15)$$

According to expressions (6), (7) and (8) we have that despite both countries move towards the same steady state, the country with more efficient labour force will enjoy a higher level of per capita income.

$$\left[\frac{Y_1}{B_1 L_1}\right]^{*} = \left[\frac{Y_2}{B_2 L_2}\right]^{*} \Rightarrow \left[\frac{Y_1}{L_1}\right]^{*} < \left[\frac{Y_2}{L_2}\right]^{*}$$

Again, the two inputs case (at a given date *t*) can be represented as in Figure 2. Unlike the non convexity discussed earlier, in this case there is not an accumulation threshold that the economy must overcome to have access to a more advanced technology. If initial technological conditions are different, *lagging* countries will always move towards lower steady state income than *leading* ones. If the former wish to achieve the same steady state income than the latter, they must keep a *permanently higher investment effort*. Hence if technological catching-up does not take place, convergence in per capita income would require a higher saving rate for less advanced countries. Whenever this time invariant effect is present, it is no longer the case that the ranking of countries, according to the level of per capita income at a particular date, will coincide with the technological ranking. As can be seen in Fig. 2, the cut-off point y^c might leave country *2* into a less advanced technological group, than country *1* characterized by lower initial conditions[17].

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[17] Again, in this case, the chance of a wrong splitting based in the level

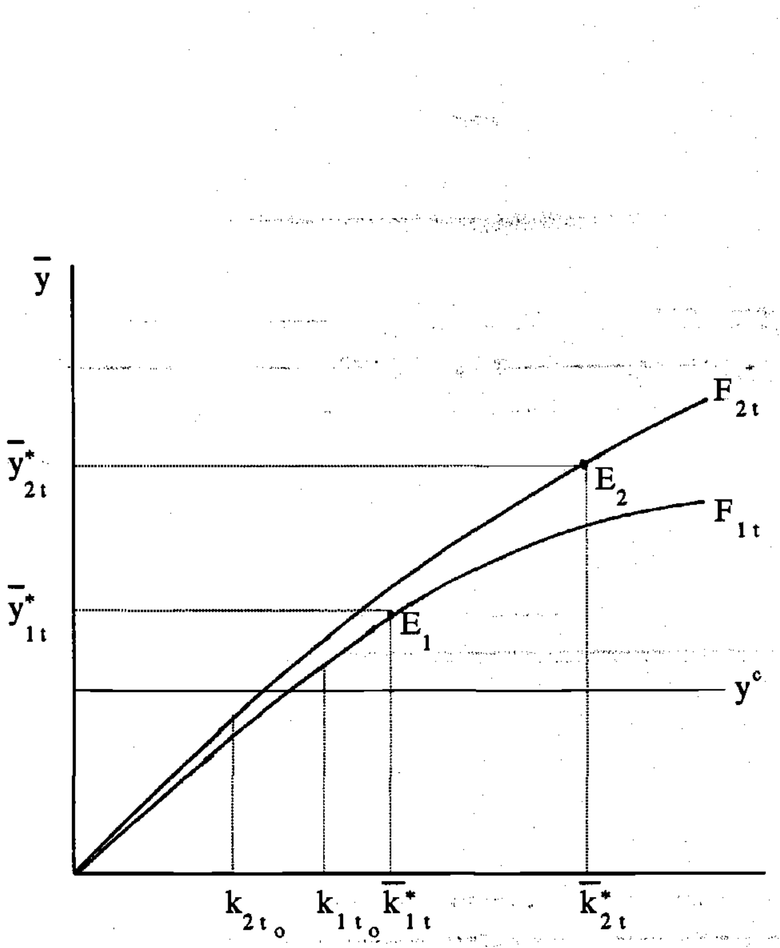

Figure 2

This policy implication ought to be qualified if technical progress is endogenous. Less advanced countries could close the gap with more advanced ones not only through higher savings but also by introducing innovations at a higher rate. We could define a catching-up equation like (16)

$$g_{it} = \bar{g} + \varepsilon(B^{max}_{it} - B_{it}) \tag{16}$$

and in this case as time goes by, all economies would achieve the same technological capability. In the endogenous growth literature this possibility has been considered in North-South models (Grossman and Helpman

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of income per capita at a particular point in time, will diminish as we approach the true steady state. Hence an end of period based splitting would be most reliable.

(1991)) in which the North innovates and the South may introduce these innovations at a faster rate[18].

Despite the importance of this time invariant effect, estimating the model allowing for individual effects is not enough, since technological differences may arise in any of the parameters in (13). One strategy could be to estimate the parameter set for each country and set up some criteria to define homogeneous country groups. Working with five year averages makes us to run very quickly in severe degrees of freedom limitations, so that we have chosen a two step procedure. First, we focus in one particular parameter to split the sample; second, we estimate and test the common technology assumption among country clubs, under the maintained hypothesis of a common technology within each group. There are two reasons to focus in the constant term A_0 of (12), first, in the Romer's case θ is higher as we move from backward to advanced technologies, furthermore if α, β, γ also differ across countries we could expect the share of labour to be higher for lagging technologies. Second, if initial conditions matter, a lower B_0 should characterize lagging country groups. If the capital thresholds are defined in level terms, so that countries have access to leading technologies as time goes on, we still expect to find a true time invariant idiosyncratic effect in B_0, which may help to place each country on its appropriate club.

4.2. Technological clubs in the OECD.

We first estimate equation (13) including an individual effect for each country in search for differences in A_0. In fact the restricted model without individual effects in A_0 is rejected against the unrestricted one; however, testing all possible combinations of countries to find homogeneous

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[18] We shall not pursue this possibility further at this stage, nevertheless in the regression models we shall allow for the possibility of different 'g' values across countries.

groups is lengthy and not much informative[19]. An alternative way to asses differences in A_0 is to follow a sequential procedure to estimate (13) including a country dummy each time to find which countries have significantly different initial conditions.

The first round revealed that only Turkey was different from the OECD average with a significantly lower $\hat{A}_0$. There are two options here, either to exclude Turkey from the sample or to maintain it but controlling for a different constant term. If differences were only related to the initial conditions, the second option would be preferred, but, as column 1 in table 4 shows, excluding Turkey leads to a non negligible change in the estimated parameter set. Turkey is so different from the rest of the OECD countries that when we include it in the sample the differences among the other countries are somehow hidden; however, after Turkey has been dropped off the sample, the remaining countries do not belong to the same club either. The second round allows us to identify Greece as the country with the worst initial conditions or low A_0 (i.e. with a significantly negative dummy). Again, as it is shown in column 2, the estimated parameters change when both Greece and Turkey are excluded, although at this stage not formal test is tried yet.

In successive rounds Portugal, Ireland, New Zealand and Spain displayed a significantly lower than average estimated $\hat{A}_0$. At each stage the model was estimated for the survivor countries, the results being summarized in columns (3) to (5). As we move from left to right in table 4, it becomes clear that at least two completely different technologies coexist inside the OECD. As *lagging* technology countries are excluded, $\hat{A}_0$ becomes positive and more significant and $\hat{\alpha}$ falls towards zero; at the same time, the rate of technical progress gets higher and more significant, and the rate of convergence is three times larger than the one for the OECD as a whole (7.6% *vs.* 2.5%).

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[19] This would imply trying a large number of combinations, without taking into account differences in parameters other than A_0.

We have so far identified six countries with lower than the average initial conditions. Once they have been removed, differences at the other end of the distribution start to show up. In fact, in the next three runs, we could not reject that USA, Canada and Switzerland (in this order) had above the average initial technological conditions. As in the case of lagging countries, the exclusion of technologically leading countries, has sizable effects upon the estimated parameters. Removing these three countries lowers $\hat{A}_0$ and makes $\hat{g}$ higher. The evolution of $\hat{\alpha}$ is still a puzzle, as we find it slightly increasing as we are left just with intermediate countries.

In table 2 we present the final splitting we have chosen after having applied our procedure. We have defined three technological levels that we have called, rather imprecisely, *lagged, leading* and *intermediate*. Our procedure does not have to lead to an equally sized distribution across clubs. In fact, the splitting we trust most is that in two groups (Turkey, Greece, Portugal, Ireland, New Zealand and Spain *vs.* the remaining eighteen countries) or else the one in three unbalanced groups (isolating USA, Canada and Switzerland from the eighteen *non lagging* countries). Had we done so, we could have proceeded to estimate the different parameters by single equation methods (such as NL2LS). However, we have chosen to impose the restriction of eight countries in each group to jointly estimate the three technologies by more efficient methods and to test the common technology restrictions on each single parameter[20].

It should be noticed that the resulting country groups resemble considerably the *ad hoc* splitting we did in section III on the basis of the end of period per capita income. Provided we have used all sample information efficiently, it would be rather surprising to find in the *lagging technology club* one country which ended up being among the richest in 1990 (such as Japan, for instance), and vice versa. Our procedure allocates countries closely to

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[20] Unreported NL2LS results for the unbalanced groups case are rather similar to the ones presented here.

their final position in the OECD ranking; countries moving upwards in the per capita income ranking can be viewed as starting abnormally far from their steady state (due to some specific shock) or as having overcome all the technological thresholds on their way to a higher steady state.

V. Estimating different technologies

In table 5 we present single equation estimates of the convergence equation with alternative methods of controlling for differences in the constant term. Estimating the model for the OECD as a whole (column (1)) we find significant differences in $\hat{A}_0$ among *lagging, intermediate* and *leading countries*[21]. This exercise also reveals some differences with the basic model (column 1 in table 3); in particular, there is a significant increase in the estimated convergence rate (from 2.5% to 3.4%). However, as we have seen, differences may also arise in other parameters, as the results in columns (2) to (5) confirm.

The initial technological condition, or accumulated knowledge in a broad sense, is lower in lagging (-9.49) than in the more advanced (2.40) countries, while the estimated constant term for the intermediate countries lies somewhere in between those (0.69). The estimated share of human capital ($\hat{\beta}$) is never significant, while the share of physical capital ($\hat{\alpha}$) falls as we move from less advanced (0.64) to intermediate and more advanced countries (0.23 and zero respectively). This monotonic change in the estimated parameters as we move upwards in the technological ranking does not hold for the rate of advance of technical progress; this rate is higher among intermediate countries (8.6%) than in any other group; and is even non significant among lagging countries. This leads to remarkable differences in the rate of convergence within each country group, the highest being three times larger than the lowest. In columns (5) and (6) we have brought together the sixteen non lagging countries, with (col. (6)) and without (col. (5)) controlling for constant term differences across them; in both cases we appreciate significant differences with the lagging countries group, as well as within the advanced group.

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[21] Helliwell and Chung (1992) find evidence of different constant terms across income groups in a linear specification of the convergence equation.

How could we interpret these results?. First, the increase in the rate of convergence in all three groups with respect to the OECD average is not surprising, since we are dealing with more homogeneous groups. Second, it should be noticed that the higher point estimate of the convergence rate among intermediate countries is mainly due to the faster catching-up process. In fact, according to the definition of λ, the smaller estimated $\hat{\gamma}$ should have yielded a lower implicit convergence rate for the intermediate group than for the more advanced one[22]. However, the faster catching-up process within this group (enhanced by the similitude among these economies and their relatively high technological standard that enables them to incorporate new technologies rather quickly) makes possible a higher rate of convergence. Finally, the estimated parameters for the non lagging countries seem quite astonishing, in particular those for the more advanced countries. It seems evident that the common technology assumption fails to hold, although a formal test is postponed until later.

Nevertheless, there is not a straightforward interpretation of the fall in the capital share as we move upwards in the technological ranking. It might be argued that this value simply reflects true differences in factor shares; however, this is counterintuitive since, as DJ argue, we should expect higher efficiency in the use of capital in more advanced countries[23]. Furthermore, estimated factor shares are far from the average ones obtained from the OECD National Accounts, close to $\{1/3, 1/3, 1/3\}$ (Mankiw et alia. (1990)). An alternative explanation for this result could be found in the small variation in steady state variables among leading countries. Andrés et alia. (1993) find that the inclusion of these variables adds no explanatory power to convergence regressions among rich countries, whereas the opposite happens in poor country samples. As long as steady state variation is

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[22] Since there are not significant differences in population growth rates (n).

[23] In fact this claim should be taken cautiously; if differences in θ and B_0 matter the productivity of capital might still be higher in more advanced countries even if α and β were lower.

necessary to identify α, β, γ and g, it might well be the case that technological parameters are not fully identified in these groups[24]. Finally, a failure of the Solow model for this group of countries cannot be denied. The convergence proposition is not only a feature of the constant returns Solow model, but it can also be derived from endogenous growth models under suitable parameter values. If this is the case, the convergence equation is simply misspecified and the estimated values are not reliable; the strong convergence pattern we find within the most advanced club might be explained by forces other than the ones built in the basic exogenous growth model.

We finally present a system estimation of the three convergence equations. In column 1, table 6, we estimate the system of three convergence equations, one for each technological club, by NL3LS and imposing the common technology assumption all over the parameter set. The choice of the three country groups makes not much difference as far as the point estimates is concerned; comparing this equation with column 1 in table 3, we obtain substantial efficiency gains and more precise parameter estimates. As should be expected, given the composition of the three technology clubs, the estimated model resembles more that in table 3 column 4, since our procedure puts more weight in the final achievement rather than in the initial conditions of each country. However, the resulting split yields marginal improvements in the estimation of A_0, β and α.

This common technology hypothesis can be tested in a number of ways. In column 2 we estimate the alternative system of equations in which no cross equations restrictions have been imposed. The system estimation confirms the evolution of individual parameter point estimates, as we move from one homogeneous group to another. $\hat{A}_0$ rises steadily and $\hat{\alpha}$ falls as we move from low to high technology club; $\hat{g}$ is the same for backwards and advanced

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[24] It is noteworthy that Durlauf and Johnson (1992) obtain plausible parameters values for all subsamples. Our guess is that this could be explained by the fact that the split based upon initial per capita income leaves highly different countries in the same group: for instance, Japan and Sri Lanka in the second group or USA and Venezuela in the first one.

countries and is much higher for intermediate ones. Finally, the implicit convergence rate is higher within all three groups than for the OECD as a whole, reaching a value of 9.3% within the intermediate technology group.

The difficulty to accept the cross equations restrictions can be appreciated in the significant improvement in the overall fit of the unrestricted model. As expected, the standard error falls in all three equations but, it does so more remarkably in the leading and intermediate groups (0.072 and 0.074 *vs.* 0.056 and 0.064 respectively). Formal χ^2 tests lead us to conclude that the less advanced countries do really have access to a different technology than the others, while this difference is not statistically significant between intermediate and leading countries[25]. These differences can be attached to huge differences in $\hat{\alpha}$ and $\hat{A}_0$ among the eight less advanced countries and the rest of OECD members, whereas it cannot be rejected that β (this due to the imprecise estimates) and g are alike across countries. Letting α and A_0 free and imposing the same β and g across countries, the results in column (3) confirm these differences among lagging countries and the rest of the OECD. Both, point estimates and formal χ^2 tests lead us to conclude that the technology available to less advanced countries is clearly different of that in the leading ones. The convergence rate is also different across these groups, although the estimated rate among the non lagging countries is now smaller[26] which means that we have put together countries with different structural features.

We have carried out several exercises to test the robustness of our results. Defining smaller technological clubs, for instance, leads to a more imprecise estimation in which the common technology assumption is rarely rejected. The observations of Turkey and, to a lesser extent, USA are very

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[25] The corresponding statistics being:

$\chi(4)^{LG,LD}=16.89$ (p=0.002), $\chi(4)^{LG,I}=12.89$ (p=0.01), $\chi(4)^{LD,I}=7.3$ (p=0.12)

[26] 6.4% vs. 7.9% and 9.3% respectively, when intermediate and leading countries were defined as different technological clubs.

different from the rest of the OECD countries, hence, most of the variance in estimated parameters across clubs might be explained by these *outlayers*. We have tested this possibility in a number of ways and the best specification is presented in column 4. Even controlling for different constant terms for these two countries, the model does reject the common technology hypothesis with significant differences both in $\hat{A}_0$ and in $\hat{\alpha}$. Turkey presents poorer initial conditions than the lagging countries average, whereas USA does slightly better than the rest of the OECD countries. It is interesting to notice how differences in convergence rates still hold, although both rates increase somewhat once we have controlled for the two extreme observations in the sample. Even in this case, the rate of convergence among advanced countries is twice as large as that among the backwards ones.

VI. Concluding Remarks.

The results presented so far are consistent with the existence of at least two different technologies inside the OECD. This casts some legitimate doubts upon the interpretation of previous works in which the assumption of a common technology has been usually imposed but seldom tested. A remarkable exception is the paper by Durlauf and Johnson (1992) who take technological non convexities as a possible explanation for such differences. These authors claim that some threshold effect in accumulated factors may be at work, so that countries would move towards different steady states, even if they had similar accumulation rates.

In this work we argue that these threshold effects may not be the unique cause of technological differences; even if they are present they are not likely to be the most important ones, since most threshold effects can be overcome as time goes on, unless we define them in a rather peculiar way. Countries are likely to differ in the unobservable initial conditions, since accumulated knowledge at a particular point in time is not homogeneous across countries. If this is the case, and unless an effective process of technological catching-up is at work, these differences in initial conditions work as time invariant country specific effects that lead to persistent differences in the *level of factor productivity* across countries and that must be controlled for in empirical models.

These differences may arise in any of the parameters in the production function. However, since they affect the constant term in an unambiguous manner we design a test of the common technology which operates in two steps. First, we select the countries belonging different technological clubs on the basis of the estimated constant term. Second, we set up a system of equations and test which parameters are alike across country groups. Besides the technological differences, our results suggest that the simple constant returns Solow model might not be able to give full account of the long run performance of OECD economies. In particular, if we take out of the sample the less advanced countries, the estimated parameters get rather implausible values despite the extraordinary high rate of convergence.

There are two natural extensions to the work presented in this paper. First, although the empirical evidence shows that the results obtained in convergence equations are quite robust to alternative definitions of the dependent variable, using per worker rather than per capita GDP may yield different results. In any case, the results discussed so far indicate that the estimated technology is less reliable in those countries with less unemployment and unemployment variation (i. e. the most advanced ones). Poorer countries in which unemployment has risen sharply, on the other hand, display much more sensible parameter values. Our guess is that changing the definition of the dependent variable should not change substantially the evidence of a failure of the constant returns Solow model to account for the long run behaviour of richer economies.

A second extension should be addressed towards a further refinement of the splitting method, to allow for the possibility of countries being in different regimes at different periods. Some preliminary results suggest that choosing the countries at the lower tail of the distribution in each period does not change the results we have reported in this paper. A more efficient use of the information to select the technology clubs can be attempted applying standard switching methods to estimate the technological parameters across regimes.

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TABLES

Table 1: Ranking of countries by per capita income levels.

1960	1965	1970	1975	1980	1985	1990
TURKEY	TURKEY	TURKEY	TURKEY	TURKEY	TURKEY	TURKEY
GREECE	PORTUGAL	GREECE	PORTUGAL	GREECE	PORTUGAL	GREECE
PORTUGAL	GREECE	PORTUGAL	GREECE	PORTUGAL	GREECE	PORTUGAL
SPAIN	IRELAND	IRELAND	IRELAND	IRELAND	IRELAND	IRELAND
JAPAN	SPAIN	SPAIN	SPAIN	SPAIN	SPAIN	SPAIN
IRELAND	JAPAN	ICELAND	ITALY	N.ZEALAND	N.ZEALAND	N.ZEALAND
ICELAND	ITALY	ITALY	JAPAN	JAPAN	ITALY	ITALY
ITALY	FINLAND	JAPAN	ICELAND	ITALY	BELGIUM	AUSTRALIA
FINLAND	AUSTRIA	NORWAY	NORWAY	U.KINGDOM	U.KINGDOM	NETHERLANDS
NORWAY	NORWAY	FINLAND	U.KINGDOM	FINLAND	NETHERLANDS	U.KINGDOM
AUSTRIA	BELGIUM	AUSTRIA	FINLAND	BELGIUM	JAPAN	BELGIUM
BELGIUM	ICELAND	BELGIUM	AUSTRIA	NETHERLANDS	FINLAND	AUSTRIA
FRANCE	FRANCE	U.KINGDOM	BELGIUM	AUSTRIA	AUSTRIA	FINLAND
NETHERLANDS	NETHERLANDS	CANADA	N.ZEALAND	DENMARK	FRANCE	NORWAY
CANADA	CANADA	N.ZEALAND	GERMANY	SWEDEN	GERMANY	SWEDEN
GERMANY	U.KINGDOM	FRANCE	NETHERLANDS	FRANCE	SWEDEN	FRANCE
DENMARK	GERMANY	GERMANY	DENMARK	AUSTRALIA	AUSTRALIA	ICELAND
U.KINGDOM	AUSTRALIA	NETHERLANDS	FRANCE	GERMANY	ICELAND	DENMARK
AUSTRALIA	DENMARK	AUSTRALIA	LUXEMBOURG	LUXEMBOURG	DENMARK	JAPAN
SWEDEN	LUXEMBOURG	DENMARK	CANADA	ICELAND	LUXEMBOURG	GERMANY
LUXEMBOURG	SWEDEN	SWEDEN	AUSTRALIA	NORWAY	NORWAY	CANADA
N.ZEALAND	N.ZEALAND	LUXEMBOURG	SWEDEN	CANADA	CANADA	LUXEMBOURG
SWITZERLAND	SWITZERLAND	SWITZERLAND	SWITZERLAND	SWITZERLAND	SWITZERLAND	SWITZERLAND
USA	USA	USA	USA	USA	USA	USA

Table 2: Technological clubs.

LAGGING COUNTRIES:	INTERMEDIATE COUNTRIES:	LEADING COUNTRIES:
TURKEY	ICELAND	USA
GREECE	NORWAY	CANADA
PORTUGAL	AUSTRIA	SWITZERLAND
IRELAND	BELGIUM	GERMANY
SPAIN	NETHERLANDS	LUXEMBOURG
N.ZEALAND	DENMARK	FRANCE
FINLAND	U.KINGDOM	SWEDEN
ITALY	AUSTRALIA	JAPAN

Table 3

Dependent Variable $\log(Y^i_{t+5}/Y^i_t)$, $i=1,\dots,24$; $t=1960,65,\dots,85$.

	(1) NL2LS	(2) NL3LS	(3) NL3LS	(4) NL3LS	(5) NL3LS
A_0	-6.05	-6.84	-10.03^P	-7.40	-9.57^P
	(3.10)	(3.91)	(3.67)	(3.87)	(3.10)
			-2.41^R		2.12^R
			(1.50)		(2.00)
α	0.48	0.45	0.57^P	0.52	0.59^P
	(4.56)	(6.07)	(6.85)	(5.28)	(5.58)
			0.34^R		-0.06^R
			(4.04)		(0.36)
β	0.11	0.16	0.10	0.11	0.08
	(1.24)	(2.59)	(1.75)	(1.37)	(1.04)
g	0.023	0.027	0.040	0.024	0.033
	(1.57)	(2.12)	(2.25)	(1.81)	(2.47)
λ_{imp}	0.025	0.025	0.025^P	0.023	0.023^P
			0.044^R		0.065^R
$\bar{R}^2$	0.312	0.253^P	0.284^P	0.359^P	0.386^P
		0.233^R	0.294^R	0.291^R	0.463^R
σ	0.077	0.092^P	0.090^P	0.074^P	0.073^P
		0.054^R	0.052^R	0.076^R	0.066^R
DW	2.07	2.22^P	2.27^P	2.07^P	2.07^P
		1.97^R	1.95^R	2.27^R	2.38^R
N.O.	120	60^P	60^P	60^P	60^P
		60^R	60^R	60^R	60^R

NOTES:

Col. (2) and (3):

P:Turkey, Greece, Portugal, Spain, Japan, Ireland, Iceland, Italy, Finland, Norway, Austria, Belgium.

R:France, Netherlands, Canada, Germany, Denmark, United Kingdom, Australia, Sweden, Luxembourg, New Zealand, Switzerland, USA.

Col. (4) and (5):

P:Turkey, Greece, Portugal, Ireland, Spain, New Zealand, Italy, Australia, Netherlands, United Kingdom, Belgium, Austria.

R:Finland, Norway, Sweden, France, Iceland, Denmark, Japan, Germany, Canada, Luxembourg, Switzerland, USA.

Col. (2) and (4):

Joint estimation imposing full restrictions:

Col. (2): $\chi_1(A_0)=6.18$, $\chi_1(\alpha)=2.89$, $\chi_1(\beta)=0.04$, $\chi_1(g)=0.49$.

Col. (4): $\chi_1(A_0)=9.38$, $\chi_1(\alpha)=9.69$, $\chi_1(\beta)=0.18$, $\chi_1(g)=0.26$.

Col. (3) and (5):

Joint estimation imposing g and β to be equal across equations:

Col. (3): $\chi_1(A_0)=4.89$, $\chi_1(\alpha)=4.52$, $\chi_2(A_0,\alpha)=4.95$.

Col. (5): $\chi_1(A_0)=13.84$, $\chi_1(\alpha)=14.07$, $\chi_2(A_0,\alpha)=17.53$.

Table 4

Dependent Variable $\log(Y^i_{t+5}/Y^i_t)$. $i=1,\ldots,24$; $t=1960,65,\ldots,85$.

	(1) NL2LS	(2) NL2LS	(3) NL2LS	(4) NL2LS	(5) NL2LS
A_0	-2.34	-1.65	-1.13	1.34	1.05
	(1.25)	(0.99)	(0.80)	(1.41)	(1.50)
α	0.47	0.39	0.33	0.09	0.15
	(4.17)	(3.37)	(3.09)	(0.74)	(1.65)
β	-0.03	0.02	0.03	0.01	-0.07
	(0.26)	(0.16)	(0.32)	(0.17)	(0.94)
g	0.019	0.023	0.027	0.038	0.062
	(1.48)	(1.71)	(1.97)	(2.66)	(4.21)
D_{USA}					0.25
					(3.00)
λ_{imp}	0.030	0.037	0.043	0.076	0.085
$\bar{R}^2$	0.358	0.349	0.353	0.436	0.474
σ	0.073	0.073	0.069	0.065	0.062
DW	2.14	2.16	2.12	2.30	2.27
N.O.	115	110	105	90	90

NOTES:

Col.(1): Turkey excluded.
Col.(2): Turkey and Greece excluded.
Col.(3): Turkey, Greece and Portugal excluded.
Col.(4): Turkey, Greece, Portugal, Ireland, New Zealand and Spain excluded.
Col.(5): Turkey, Greece, Portugal, Ireland, New Zealand and Spain excluded. D_{USA} is the coefficient of a dummy variable for the USA in A_0.

Table 5

Dependent Variable $\log(Y^i_{t+5}/Y^i_t)$. $i=1,\dots,24$; $t=1960,65,\dots,85$.

	(1) NL2LS	(2) NL2LS	(3) NL2LS	(4) NL2LS	(5) NL2LS	(6) NL2LS
A_0	-3.84	-9.49	2.40	0.69	1.19	1.06
	(2.39)	(2.46)	(2.35)	(0.67)	(1.13)	(1.30)
α	0.39	0.64	-0.11	0.23	0.11	0.11
	(3.72)	(3.45)	(0.58)	(2.13)	(0.83)	(1.04)
β	0.12	0.02	0.03	-0.16	0.01	-0.02
	(1.50)	(0.14)	(0.28)	(0.98)	(0.14)	(0.28)
g	0.030	0.031	0.046	0.086	0.042	0.058
	(1.89)	(1.13)	(2.69)	(3.49)	(2.53)	(3.79)
D_I	0.26					
	(2.17)					
D_{LD}	0.38					0.11
	(3.12)					(2.84)
λ_{imp}	0.034	0.025	0.084	0.095	0.079	0.085
$\bar{R}^2$	0.348	0.346	0.525	0.405	0.418	0.461
σ	0.075	0.081	0.059	0.068	0.066	0.063
DW	2.06	2.20	2.10	2.26	2.24	2.20
N.O.	120	40	40	40	80	80

NOTES:

Col. (1): All OECD countries. D_I is the coefficient of a dummy variable for the intermediate countries and D_{LD} is the coefficient of a dummy variable for the leading countries in A_0.

Col. (2): Lagging countries.

Col. (3): Leading countries.

Col. (4): Intermediate countries.

Col. (5): Leading and intermediate countries.

Col. (6): Leading and intermediate countries controlling for the leading ones.

See Table 2 for a description of which country belongs to each club.

Table 6

Dependent Variable $\log(Y^{i}_{t+5}/Y^{i}_{t})$. $i=1,\ldots,24$; $t=1960,65,\ldots,85$.

	(1) NL3LS	(2) NL3LS	(3) NL3LS	(4) NL3LS
A_0	-8.26 (4.26)	-9.71^{LG} (2.84) 2.14^{LD} (1.97) 0.62^{I} (0.62)	-10.19^{LG} (2.98) $0.89^{LD,I}$ (0.79)	-5.03^{LG} (2.55) $0.90^{LD,I}$ (1.06)
α	0.52 (5.78)	0.62^{LG} (4.04) -0.04^{LD} (0.25) 0.24^{I} (2.41)	0.64^{LG} (5.98) $0.14^{LD,I}$ (1.19)	0.59^{LG} (6.21) $0.18^{LD,I}$ (1.90)
β	0.13 (1.71)	0.05^{LG} (0.40) 0.03^{LD} (0.31) -0.16^{I} (1.06)	0.03 (0.44)	-0.06 (0.92)
g	0.032 (2.20)	0.037^{LG} (1.42) 0.041^{LD} (2.41) 0.086^{I} (3.61)	0.037 (2.84)	0.052 (4.19)
λ_{imp}	0.025	0.029^{LG} 0.079^{LD} 0.093^{I}	0.027^{LG} $0.064^{LD,I}$	0.037^{LG} $0.073^{LD,I}$
D_{TUR}				-0.75 (3.95)
D_{USA}				0.23 (2.81)
$\bar{R}^2$	0.371^{LG} 0.301^{LD} 0.290^{I}	0.415^{LG} 0.575^{LD} 0.464^{I}	0.414^{LG} 0.534^{LD} 0.375^{I}	0.491^{LG} 0.593^{LD} 0.404^{I}
σ	0.080^{LG} 0.072^{LD} 0.074^{I}	0.077^{LG} 0.056^{LD} 0.064^{I}	0.077^{LG} 0.058^{LD} 0.069^{I}	0.072^{LG} 0.055^{LD} 0.068^{I}
DW	2.11^{LG} 2.01^{LD} 2.15^{I}	2.19^{LG} 2.20^{LD} 2.28^{I}	2.18^{LG} 2.17^{LD} 2.23^{I}	2.11^{LG} 2.23^{LD} 2.27^{I}
N.O.	40^{LG} 40^{LD} 40^{I}	40^{LG} 40^{LD} 40^{I}	40^{LG} 40^{LD} 40^{I}	40^{LG} 40^{LD} 40^{I}

Notes to Table 6:

Col. 1: Joint estimation imposing full restrictions.

Col. 2: Joint estimation without cross equation restrictions:

$\chi_1(A_0^{P,LD})=11.05$ $(p=0.001)$, $\chi_1(A_0^{P,I})=8.39$ $(p=0.004)$, $\chi_1(A_0^{R,I})=1.09$ $(p=0.296)$.

$\chi_1(\alpha^{LG,LD})=8.12$ $(p=0.004)$, $\chi_1(\alpha^{LG,I})=4.22$ $(p=0.039)$, $\chi_1(\alpha^{LD,I})=1.97$ $(p=0.161)$.

$\chi_1(\beta^{LG,LD})=0.02$ $(p=0.895)$, $\chi_1(\beta^{LG,I})=1.15$ $(p=0.283)$, $\chi_1(\beta^{LD,I})=1.19$ $(p=0.275)$.

$\chi_1(g^{LG,LD})=0.02$ $(p=0.892)$, $\chi_1(g^{LG,I})=1.97$ $(p=0.161)$, $\chi_1(g^{LD,I})=2.40$ $(p=0.121)$.

$\chi_2(A_0)=11.18$ $(p=0.004)$, $\chi_2(\alpha)=8.50$ $(p=0.014)$, $\chi_2(\beta)=1.41$ $(p=0.495)$, $\chi_2(g)=2.81$ $(p=0.246)$.

Col. 3: Joint estimation imposing β and g to be equal across equations, while A_0 and α are imposed to be equal only for leading and intermediate countries:

$\chi_1(A_0)=9.6$ $(p=0.002)$, $\chi_1(\alpha)=13.0$ $(p=0.0003)$, $\chi_2(A_0,\alpha)=13.5$ $(p=0.001)$

Col. 4: Joint estimation imposing β and g to be equal across equations, while A_0 and α are imposed to be equal only for leading and intermediate countries. D_{TUR} and D_{USA} are the coefficients of dummy variables for Turkey and USA in A_0:

$\chi_1(A_0)=8.71$ $(p=0.003)$, $\chi_1(\alpha)=10.68$ $(p=0.001)$, $\chi_2(A_0,\alpha)=10.92$ $(p=0.004)$