THE DESIRABILITY OF MULTI-EQUATIONAL APPROACHES FOR THE STUDY OF ECONOMIC GROWTH. AN EMPIRICAL EVIDENCE

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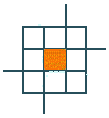

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THE DESIRABILITY OF MULTI-EQUATIONAL APPROACHES FOR THE STUDY OF ECONOMIC GROWTH. AN EMPIRICAL EVIDENCE.

ABSTRACT:

This paper looks at the growth of a varied sample of countries during the period 1985-2000, focusing on three key variables: investment in physical capital, human capital and institutions. The analysis pays special attention to the process of the accumulation of these variables and their interrelationships.

The results show that empirical research on growth should highlight the aspects of the accumulation and interrelationships of factors through the use of systems of equations such as that proposed in this study.

KEY-WORDS**:** Growth, human capital, investment, institutions, models of simultaneous equations.

JEL Classification: 040

RESUMEN:

El artículo aborda el crecimiento de un conjunto de países, centrándose en tres variables claves –la inversión en capital físico, el capital humano y las instituciones- e incidiendo en el proceso de acumulación de tales variables y en las interrelaciones surgidas.

El trabajo pone de manifiesto que las investigaciones empíricas sobre crecimiento deberían incidir en los aspectos de acumulación e interrelación de los factores, a través del planteamiento de sistemas de ecuaciones como el que se propone en este estudio.

La evidencia aportada permite concluir, por un lado, que la calidad institucional, el capital productivo y el aumento de las dotaciones de capital humano han tenido una influencia positiva y estadísticamente significativa en el crecimiento de 45 países durante el período 1985-2000.

PALABRAS CLAVE: crecimiento, capital humano, inversión, instituciones, modelos de ecuaciones simultáneas.

Clasificación JEL: 040

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1. INTRODUCTION

To understand the growth of nations is one of the oldest and most important lines of research in Economics. At the same time, it is one of the areas of study in which it is most complicated to achieve original progress.

For many years, most empirical studies have emphasised two big, intimately related themes: convergence and the identification of the determinants that explain economic growth. The latter tries explore growth factors and their interrelationships. Durlauf, Johnson and Temple (2005) contains an exhaustive survey of the empirical studies carried out and the determinants evaluated. According to these authors, most of the research has proposed uni-equational models whose estimation tends to exaggerate the effect of the determinants of growth. 145 different determinants have been found statistically significant.

The present paper looks at the recent growth of a set of countries, focusing on three key variables –physical capital, human capital and institutions- and paying special attention to the dynamic process of the accumulation of these variables and their interrelationships. Our aim is to overcome the limitations of the empirical research that emphasises the individual analysis of the different sources of growth, without observing their interrelationships or evaluating their joint influence.

The rest of the paper is organised as follows. In the second section, we present a model of simultaneous equations that considers three of the determinants of growth endogenous and we describe the variables used to test it. In the third section, we synthesise the empirical evidence from the data of 45 countries (the only ones for which it has been possible to quantify the theoretical variables) for the period 1985-2000. In addition, a robustness analysis of the model is carried out. The paper closes with a conclusions section.

2. ECONOMETRIC MODEL AND DESCRIPTION OF THE VARIABLES

The econometric model is focused on three of the explanatory variables of economic growth: investment in physical capital, human capital and institutions. The importance of these three factors is supported by an extensive theoretical and empirical literature. Our approach is focused both on the contribution of these three factors and on their processes of accumulation, interrelating them through a system of simultaneous equations.

2.1. Econometric model

The equations of the model for each of the countries included in the research are the following:

GROWTH OF PER CAPITA INCOME = F_1 (INVESTMENT, HUMAN CAPITAL, INSTITUTIONS).

HUMAN CAPITAL = F_2 (INCOME, EDUCATION EXPENDITURE, QUALITY OF EDUCATION, INSTITUTIONS).

INSTITUTIONS = F_3 (HUMAN CAPITAL, DISTRIBUTION OF INCOME)

INVESTMENT = F_4 (INTEREST RATE, INSTITUTIONS)

The model comprises, therefore; four equations that explain the growth rate of the *per capita* income, the human capital, the institutional infrastructure and the physical capital. A system of simultaneous equations has been proposed with the aim of capturing the interrelationships among all the variables.

In the first equation, the growth of the *per capita* income is related to the investment made during the period, the available human capital and the quality of the institutional infrastructure.

With the inclusion of investment, we will test the relationship between the fraction of income destined to gross fixed capital formation and economic growth. The underlying hypothesis is that the percentage of income destined to investment conditions the physical capital per worker and, thus, productivity and the growth of *per capita* income. It is expected, consequently, that the coefficient of this variable will be positive and statistically significant. Remember that the connection between investment and the growth of per capita income has been widely studied and has even led to the formulation of a model, the well-known AK model, which predicts that the growth rate of the *per capita* income is a function of the participation of investment in the GDP[1]. A more exhaustive justification of the inclusion of investment in growth models can be found in Delong and Summers (1991) or in Temple (1998).

Incorporating human capital, we will test the relationship between this variable and economic growth. The idea that the accumulation of human capital is one of the pillars on which growth rests was suggested, among others, by Lucas (1988) who considered that the divergences in the growth rates of countries should be explained basically by the differences in the accumulation of human capital. This idea has been widely incorporated into growth models, as is detailed in Gradstein,

[1] Using empirical evidence it was demonstrated that the high levels of investment of some countries –like those of the OECD- do not correspond to increases in growth rates. See Jones (1995) for more details.

Justman and Meier (2005). Some authors –like Aghion, Howitt and Violante (2002)- state that it is the differences in human capital that condition the capacity of countries to innovate or adapt to new technologies and, therefore, the possibility of approaching the technological frontier. Nevertheless, it is usually considered that this approach and that of Lucas (1988) are really complementary.

There is also widespread theoretical support for the inclusion of the institutional system. North (1990) maintains that the institutions that a country has and the evolutionary process they undergo determine the functioning of their economies. For North, institutions exist because of the uncertainty generated by the relationships between individuals and their function consists of structuring and directing these relationships[2].

In the model proposed, we will test whether institutions influence the growth of countries, on the understanding that they condition the benefits generated by any kind of investment –in physical capital, in human capital or in the development of new technologies- and the appropriation of these benefits. It is supposed that the adequate institutional systems permit the optimisation of the benefits of investment, facilitating the development of new initiatives, providing juridical security and stability, avoiding the unlawful appropriation of the benefits obtained, minimising the costs of protecting against irregular practices, promulgating laws that favour the smooth running of the economy and making sure that these laws are complied with. The beneficial consequences of more advanced institutions will mean, depending on the relationships proposed in the system, greater investment in physical capital, an increase in human capital and more growth.

The second equation explains the human capital in the period on the basis of the *per capita* income, education expenditure, quality of education and institutions.

Our aim is to test, in the first place, whether human capital increases as income does. The underlying idea is that all the elements that make up human capital depend on material resources, both public and private, dedicated to its acquisition and conservation. For example, in countries with higher income levels, more resources can be dedicated to education and health. Moreover, the time that can be devoted to the acquisition of skills is also conditioned by the resources available. For all these reasons, we should expect that the coefficient of the per *capita* income variable in the period be positive and statistically significant.

[2] Similarly, the work by Aghion and Howitt (2005) can be consulted and, to go deeper into the relationship between institutional infrastructure and growth, those of La Porta *et al.* (1999) or Haggard (2003). The empirical evidence about the effects of institutions on growth is varied and includes both the direct and indirect effects, fundamentally through investment. See, for example, the papers of Mauro (1995), Barro (1996), Alesina and Perotti (1996), Knack (1996) or Knack and Keefer (1995, 1997).

Likewise, we will test the relationship between the percentage of the GDP destined to publicly financed education and the human capital. With the incorporation of education expenditure as an explanatory variable, we recognise formal education as one of the elements that characterises human capital, although formal education is considered as a proxy for a broader concept of human capital, as the proposed by Giménez (2005). In any case, we will bear in mind that, although the more developed countries have higher human capital endowments, it is the countries with the lower stocks that, in many cases, make greater investments in education as a proportion of their income.

With the introduction of quality of education, we will verify whether human capital is greater when the education system is better-organised, an idea suggested by authors such as Aghion and Howitt (2005).

Finally, the equation also relates human capital with institutional quality, on the understanding that an adequate institutional infrastructure facilitates the increase of human capital endowments by conditioning both the benefits generated by investment in this factor and its appropriation.

The third equation explains institutional infrastructure through human capital and the distribution of income during the period, supposing that the coefficient of both these variables are positive. It is supposed that human capital is an element that shapes the development of institutional systems, given that education determines, among other related questions, participation in public life, respect for the law, the level of corruption, the fight against illegal activities, the income distribution and the quality of the bureaucratic system[3]. At the same time, it will be supposed that changes in the distribution of income condition the institutional infrastructure and, thus, growth. In our opinion, more inequality in the distribution of income can generate tensions that lead to socio-political instability, corruption, the destabilisation of the markets, the search for speculative activities and pressures to favour the appropriation of income or the imposition of decisions by some sectors. Numerous articles support this reasoning. For example, Perotti (1996) analysed the relationship between income distribution and institutional stability, concluding that very unequal societies tend to be politically and socially unstable, which is reflected in lower investment and lower growth. The mechanisms of transmission between equality and growth would be lower fecundity, higher investment and more education[4].

[3] See also, in this context, Gemmell (1996), Appleton *et al.* (1996), Alesina and Perrotti (1996) and McMahon (1999), among others.

[4] Similar conclusions were obtained by Gupta (1990) and Alesina and Perotti (1996). For Islam and Montenegro (2002), the differences between social classes can generate discrepancies with respect to which institutions are fomented, depending on different class interests. This leads to a negative relationship between inequality and institutional quality.

The fourth and last equation of the model explains investment in physical capital on the basis of the interest rate and institutions. The question of relationship between the interest rate and investment is one of the oldest in economics. It was a primary concern of John Maynard Keynes in his *General Theory of Employment, Interest and Money*. It is expected that the coefficient that accompanies the interest rate variable will present a negative sign.

The link between the quality of the institutional infrastructure and investment processes has also been widely accepted in both the theoretical and the empirical literature. Alesina and Perotti (1996) can be cited in this context. This work explains the accumulation of capital on the basis of the socio-political stability, measured with a wide range of indices. In fact, the studies that try to capture the quality of the institutional system by means of the use of indices and indicators suggest that the quality of the institutional system exercises an indirect effect on growth through different variables and, in particular, through investment. Thus, we expect the coefficient of this variable to be positive.

2.2. Description of the variables

The choice of variables is a primordial problem in any empirical study because those chosen must synthesise the theoretical relationships of the model in the most appropriate way. In research like this the selection of the variables is even more complicated because observations for a large number of countries and years are necessary. In order to validate the model described empirically, we have used the set of variables shown in Annex I. In this Annex the variables are described and the sources used are indicated.

It is necessary to highlight the variable used to measure the institutional infrastructure. This was specifically calculated to synthesise different indicators adequately. In an valuable work on growth and institutions, Aron (2000: 128) states that "*The more recent literature suggests that the appropriate institutional variables to include in investment and growth regressions are those that capture the performance or quality of formal and informal institutions rather than merely describe the characteristics or attributes of political institutions and society or measure their political instability*".

Taking these premises into account, we built an institutional index on the basis of the data provided by Kaufmann, Kraay and Zoido-Lobatón (1999 a, b)[5]. These authors use more than 300 variables about aspects of government to elaborate six aggregate indicators that correspond to six basic concepts: civil liberties, political rights, political instability and violence, government effectiveness, the rule of law and corruption. Using this data, in our work we apply the principal components method to the six indicators to find a single institutional index that contains more than 80 percent of the variation of the variables used[6]. Given the high percentage of information contained in this first component, we opted to use it as the institutional index in the estimation of the econometric model, as can be seen in Annex I.

3. EMPIRICAL EVIDENCE

On the basis of the relationships proposed, a cross-sectional empirical analysis was carried out for the period 1985-2000, with the aim of testing the relationships in a large sample of countries[7]. Given that the interrelationship among all the variables of the model constitutes a basic idea, an econometric technique in line with this reasoning was chosen for the empirical resolution. We opted to resolve the model using the generalised method of moments (GMM),

[5] In recent years, the increasing interest of economists and politicians in institutional questions and their interrelationship with growth has been reflected in a proliferation of indices that attempt to measure different institutional aspects for the highest number of countries in order to obtain homogenous and comparable indicators. The method used by Kaufmann, Kraay and Zoido-Lobatón has the advantage of aggregating a great quantity of information, joining and systematising both individual sources and aggregate indicators. Furthermore, the indices developed have been constructed for a large number of countries, facilitating their inclusion in international studies. For a detailed analysis of the indicators constructed and of the sources used, see Kaufmann, Kraay and Zoido-Lobatón (1999 a and b).

[6] Temple (1999: 148) argues in favour of the principal components method to construct institutional indices of this kind, asserting that "…simple techniques for data reduction like factor analysis and principal components have been largely ignored by recent growth researches. Their use seems to have a great deal of potential, and the renewed interest in social factors aligns well with recent theoretical work, reinforcing the case for further study". Temple and Johnson (1998) use the method to create a social development indicator.

[7] On the convenience of using cross-sectional analysis, Durlauf and Quah (1999) argue that this procedure can be more adequate for approximations to long-term phenomena if it is not possible to work with sufficiently long and representative sub-periods that allow the use of other techniques. Furthermore, it is necessary to point out that working with average values over long periods contributes to the elimination of the cyclical effects in the variables.

which lets us obtain robust estimations[8]. It should also be pointed out that White's matrix was used to correct for the heteroskedasticity found in the second and third equations of the system.

Special attention was paid to the question of the possible endogeneity among the variables on the understanding that this problem could be aggravated if it transferred from one equation of the system to others. The exogeneity of the variables was tested by means of the Hausman Test, the results of which revealed endogeneity problems in the system with a level of significance of 5%[9].

To resolve this inconvenience and achieve consistent and efficient estimators, it was decided to use instrumental variables. In general, the instruments used were the lags of the variables, that is, their average value between the years 1980 and 1984. When it was not possible to use the lags, other instruments were used, as indicated in Annex 1.

The validity of the instruments chosen was tested using the Sargan Test[10]. In the four equations proposed, the values of the statistic allowed us not to reject the null hypothesis of the adequacy of the instruments –at a level of significance of 5%-, given that the R^2 of the auxiliary regressions were practically zero[11].

3.1. Results of the model

The results of the estimation of the model appear in Estimation I of Table 1. It can be seen, in the first equation, that the growth of the *per capita* income during the period is positively related to investment and institutional quality and negatively to human capital endowments. The relationship between investment and the growth of income was as expected: an increase in investment –which leads to a rise in capital stock per worker and, therefore, an improvement in productivity- raises the average income of the population.

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[8] GMM estimation is based upon the assumption that the disturbances in the equations are uncorrelated with a set of instrumental variables. The GMM estimator selects parameter estimates so that the correlations between the instruments and the disturbances are as close to zero as possible, as defined by a criterion function. On the advantages and disadvantages of the application of this econometric technique to systems of equations and the use of instruments, see Frey and Grammig (2006) and Wooldridge (2001).

[9] The test of simultaneity was carried out following the specification of the Hausman test that is found in Gujarati (2003: 727 and following). For an analysis of the test, see Hausman (1976).

[10] See the analysis proposed by Seddighi *et al.* (2000).

[11] The calculation of Sargan Test was carried out following the steps described in Gujarati (2003: 687-8). In all cases, the value of the statistic was inferior to the χ^2 of *r* degrees of freedom, where *r* is the difference between the number of instruments used and the number of explanatory variables.

Table 1.
Estimation of growth with a multi-equational approach.

Estimation I			
Number of countries	45		
PER CAPITA INCOME GROWTH	Coefficient	Stand. Error	Signif.
CONSTANT	-0,0162	0,00637	**
INVESTMENT	0.00082	0.00028	**
HUMAN CAPITAL	-0.00029	0.00012	**
INSTITUTIONAL INDICATOR	0.00012	0.00005	**
R^2	0.24		
HUMAN CAPITAL	Coefficient	Stand. Error	Signif.
CONSTANT	-23.60	7.34	**
INCOME	1.62	0.93	*
EDUCATION EXPENDITURE	-0.536	0.413	
PUPIL/TEACHER	-0.258	0.081	**
INSTITUTIONAL INDICATOR	0.255	0.012	**
R^2	0.75		
INSTITUTIONAL INDICATOR	Coefficient	Stand. Error	Signif.
CONSTANT	53.77	29.40	*
HUMAN CAPITAL	3.11	0.16	**
MIDDLE CLASS	2.02	0.84	**
R^2	0.71		
INVESTMENT	Coefficient	Stand. Error	Signif.
CONSTANT	1.20	2.23	
INTEREST RATE	-0.21	0.11	*
INSTITUTIONAL INDICATOR	0.052	0.005	**
R^2	0.42		

Estimation II			
Number of countries	37		
PER CAPITA INCOME GROWTH	Coefficient	Stand. Error	Signif.
CONSTANT	-0,01711	0,00800	**
INVESTMENT	0.00066	0.00028	**
HUMAN CAPITAL GROWTH	0.01268	0.00434	**
INSTITUTIONAL INDICATOR	0.00005	0.00002	**
R^2	0.23		
HUMAN CAPITAL	Coefficient	Stand. Error	Signif.
CONSTANT	-40.73	8.71	**
INCOME	4.34	1.11	**
EDUCATION EXPENDITURE	0.506	0.471	
PUPIL/TEACHER	-0.263	0.079	**
INSTITUTIONAL INDICATOR	0.218	0.008	**
R^2	0.78		
INSTITUTIONAL INDICATOR	Coefficient	Stand. Error	Signif.
CONSTANT	70.22	25.72	**
HUMAN CAPITAL	3.07	0.15	**
MIDDLE CLASS	1.82	0.81	**
R^2	0.72		
INVESTMENT	Coefficient	Stand. Error	Signif.
CONSTANT	0.555	1.583	
INTEREST RATE	-0.213	0.076	**
INSTITUTIONAL INDICATOR	0.053	0.004	**
R^2	0.42		

Notes: Estimations obtained with GMM.
(**) (*) denotes that coefficients are significantly different from zero at the 5 percent (10 percent) level.

Estimation I also showed that a rise in the institutional index, which leads to an improvement in the quality of the institutions, favoured the growth of the *per capita* income. This aspect should be highlighted because the empirical evidence of the direct effect of institutions on growth has traditionally been ambiguous. Remember, in this context, that Barro (1996) concluded that there was a negative relation between revolutions and *coups d'état* and growth, and that the relation disappeared when property rights were used as a control variable. Nevertheless, Knack and Keefer (1997) using measures of trust and respect for civic rules, found that these measures were positively associated with growth.

The interrelation between growth and institutions is also evident in the results from the fourth equation of the system, given that the institutional variable exercises a positive and significant effect on the investment in the period and the latter has a similar effect on the growth of *per capita* income. We should also note that the effect of institutions on growth was reduced, given that the institutional indicator influenced human capital and, as will be commented later, human capital had a negative relation with the increase of *per capita* income. In any case, the net effect of institutional infrastructure on growth was positive. When considering all the joint effects, an increase of the institutional indicator equivalent to 1 per cent increased the growth rate of the period by 0.000087 per cent.

It is noteworthy that the effect of human capital on the growth of the *per capita* income of the countries was negative, contradicting the conclusions of previous research such as Barro (1991), Levine and Renelt (1992), Mankiw, Romer and Weil (1992) and Benhabib and Spiegel (1992). Nevertheless, it should be pointed out that the relationship between human capital and growth had been ambiguous in Barro and Sala-i-Martin (1999) and Caselli *et al.* (1996) –given that it varied with the level of schooling and the sex of the students- and negative in Pritchett (1996) and Wolff (2000). Liu and Stengos (1999) concluded that the effect of the human capital variable can only be associated with a positive impact on growth when the secondary school enrolment rises above a certain threshold.

In the second equation, the variable to be explained was human capital, approximated by the rates of enrolment in secondary education. It can be seen that the coefficient of average *per capita* income in the period is positive and statistically significant at 10%, a result that reflects that the per capita income determines the quantity of resources that can be dedicated to the accumulation of human capital.

The coefficient of education expenditure –expressed in relative terms, with respect to the GDP– was not statistically significant in the explanation of human capital. It should be pointed out that the correlation between education expenditure as a proportion of the GDP and the rates of schooling is low. This is because the countries with lower human capital are those that need a greater relative investment in

education, which is reflected in a higher weight of education expenditure with respect to the GDP. This may indicate that education expenditure with respect to the GDP does not give a good idea of either the quality of the education received nor of the final quantity spent on each pupil, an effect indirectly reflected by income[12].

On the contrary, the *PUPIL-TEACHER* ratio, which approximates the quality of education, was significant and had a negative sign. This result showed that an improvement in the quality of the service (a decrease in the ratio) positively influenced the accumulation of human capital.

Lastly, we should highlight that an improvement in the institutional infrastructure had a positive and significant effect on human capital. This effect was also confirmed indirectly through increases in income that positively affected investment in education. It can, therefore, be concluded that the results support the idea that institutional quality determines both the cost of investment in human capital and the possibilities of appropriating the benefits obtained.

In the third equation, the variable to be explained was institutional quality. It can be seen that human capital had a positive and significant influence on the indicator of the quality of the institutional infrastructure and, therefore, on investment and growth. Alesina and Perotti (1996) also found, for a wide sample of countries, a positive relation between human capital -measured through the enrolment rate in primary education - and socio-political stability and institutional quality. This corroborates that the level of education determines, among other related questions, participation in public life, respect for the law, the level of corruption, the fight against illicit activities, the income distribution and the quality of the bureaucratic system.

The positive effect of human capital on institutions and, therefore, on economic growth is counteracted by the negative effect of human capital on the growth of the *per capita* income (the first equation of the system). Taking into account the values of the different coefficients, it can be seen that the total net effect of human capital on growth is negative. That is, an increase of 1 per cent in the human capital variable leads to a decrease of -0.000018 per cent in the endogenous variable.

The results of the estimation carried out likewise reveal that a more equal distribution of income, measured through the proportion of the population in the third and fourth income quintile, favoured institutional development and, thus, growth[13].

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[12] Similar results were obtained working with expenditure on secondary education.

[13] Gupta (1990), Alesina and Rodrik (1994), Persson and Tabellini (1994), Perotti (1996, Alesina and Perotti (1996), Wei (2000) and Islam and Montenegro (2002) reached similar conclusions. These papers analyse the effect of the distribution of income on political stability, tax rates, institutional quality, investment and, consequently, on growth.

The fourth and last equation of the system allows us to conclude that investment during the period was positively related to institutional quality, corroborating that the latter conditions both the generation of benefits derived from investment and their appropriation[14].

Lastly, the interest rate spread –lending rate minus deposit rate- presented a negative and statistically significant coefficient. The interpretation could be that an increase in the differential between the two rates reflected a greater risk and, therefore, lower investment[15].

To sum up, the estimation of the system of equations proposed confirms the importance of the factors studied for economic growth and the convenience of analysing the interrelationships that arise among them through models and econometric procedures that capture them.

3.2. On the relationship between human capital and growth

The results derived from the model suggested the convenience of studying the relationship between human capital and growth more deeply, especially since the conclusions of the previous literature were ambiguous and conditioned by the choice of variables to approximate human capital.

As a consequence, we estimated the model introducing the growth of human capital during the period, instead of the level of human capital, into the first equation as the explanatory variable. The results obtained are shown in the Estimation II column of Table 1. It can be seen that the coefficient of the growth of human capital variable was positive and statistically significant, revealing that the countries that grew most during the period were those that most increased, in relative terms, their levels of human capital, measured through enrolment rates[16].

The rest of the variables showed the expected sign and their levels of significance, in general, improved. Only the *EDUCATION EXPENDITURE* variable changed sign, although it continued to be non-significant.

[14] These are similar results to those suggested in Kormendi and Meguire (1985), Scully (1988), Mauro (1995), Knack and Keefer (1995), Alesina and Perotti (1996) and Knack (1996).

[15] Substituting the differential of the interest rates by the lending rate led to similar results.

[16] The estimations were also replicated with another type of indicator of human capital, *average years of schooling in the population*, elaborated by Barro and Lee (2001). Both when using **this** variable and when using the rate of growth of the variable similar results to those commented were obtained.

3.3. Analysis of robustness

One of the principal problems of empirical studies on growth is the possible heterogeneity of the results obtained. This heterogeneity may be a consequence of the use of different data sources. This is a field where divergent data are frequent, due to the low quality of the statistics offered by many countries. Another problem derives directly from the presence of possible outliers within the series[17].

Thus, it is imperative to test the stability of the results. To do so, we carried out two types of analysis. First, we tested whether the relationships remained unaltered when using other statistical sources. Second, we analysed whether outliers had conditioned the results obtained.

3.3.1 Analysis of sensitivity to the definition and sources of the variables

Given that, in the paper, we use an institutional index–elaborated on the basis of six diverse variables-, it seemed reasonable to substitute this index for one of the measures used in other empirical works [18].

We also considered it convenient to extend the sensitivity analysis to the measurement of the *per capita* income, because this variable is the central axis of growth studies and, thus, it is vital that the results of empirical works are consistent when using alternative data sources or variations in their definition of the variables. Along with the change of the definition of the income variable, we also modified the investment variable, measuring it homogeneously with income.

Estimations III and IV -presented in Table 2- synthesise the results achieved on substituting the institutional index by, respectively, the index of Political Rights and that of Civil Liberties constructed since 1973 by Raymond Gastil and both used in numerous papers. Note that a higher value of the indices reflects a decrease in the exercise of political rights and civil liberties, so the expected sign of the variable was, on this occasion, negative, reflecting a higher institutional quality. Also note, that when we introduced the indicators into the model, the sample increased by five countries.

[17] Temple (1999) offers a detailed study of the question.
[18] As well as the sensitivity analysis carried out in this section, we found that the results did not vary when the definition of the variables was changed as commented in notes 12, 15 and 16.

Table 2.
Estimation of growth with a multi-equational approach. Analysis of sensitivity to the sources of the variables

Estimation III			
Number of countries	49		
PER CAPITA INCOME GROWTH	Coefficient	Stand. Error	Signif.
CONSTANT	0.02679	0.01724	
INVESTMENT	0.00204	0.00035	**
HUMAN CAPITAL	-0.00039	0.00018	**
POLITICAL RIGHTS	-0.00636	0.00270	**
R^2	0.16		
HUMAN CAPITAL	Coefficient	Stand. Error	Signif.
CONSTANT	-14.76	10.68	
INCOME	13.92	1.16	**
EDUCATION EXPENDITURE	-0.975	0.764	
PUPIL/TEACHER	-0.283	0.199	
POLITICAL RIGHTS	-8.12	1.26	**
R^2	0.77		
POLITICAL RIGHTS	Coefficient	Stand. Error	Signif.
CONSTANT	4.35	0.71	**
HUMAN CAPITAL	-0.059	0.003	**
MIDDLE CLASS	0.075	0.022	**
R^2	0.59		
INVESTMENT	Coefficient	Stand. Error	Signif.
CONSTANT	26.99	1.09	**
INTEREST RATE	-0.310	0.105	**
POLITICAL RIGHTS	-2.76	0.29	**
R^2	0.24		

Estimation IV			
Number of countries	49		
PER CAPITA INCOME GROWTH	Coefficient	Stand. Error	Signif.
CONSTANT	0.01217	0.01453	
INVESTMENT	0.00186	0.00028	**
HUMAN CAPITAL	-0.00021	0.00016	
CIVIL LIBERTIES	-0.00443	0.00215	**
R^2	0.19		
HUMAN CAPITAL	Coefficient	Stand. Error	Signif.
CONSTANT	-14.73	9.43	
INCOME	13.71	1.05	**
EDUCATION EXPENDITURE	-0.256	0.539	
PUPIL/TEACHER	-0.132	0.163	
CIVIL LIBERTIES	-10.05	1.25	**
R^2	0.79		
CIVIL LIBERTIES	Coefficient	Stand. Error	Signif.
CONSTANT	3.88	0.49	**
HUMAN CAPITAL	-0.052	0.003	**
MIDDLE CLASS	0.076	0.016	**
R^2	0.61		
INVESTMENT	Coefficient	Stand. Error	Signif.
CONSTANT	27.47	0.93	**
INTEREST RATE	-0.165	0.024	**
CIVIL LIBERTIES	-2.62	0.18	**
R^2	0.25		

Estimations obtained with GMM.
(**) (*) denotes that coefficients are significantly different from zero at the 5 percent (10 percent) level.

The results included in Table 2 show that the relationships among the variables of the system remained unaltered, with two exceptions. The first was the *PUPIL/TEACHER* variable -second equation- which was no longer statistically significant. The second exception affected Estimation IV because, with the introduction of the *Civil Liberties* indicator, the *HUMAN CAPITAL* variable was no longer statistically significant, although the indirect influences of human capital were unaltered.

The sign of the coefficient of the institutional variables in Estimations III and IV was as expected, in consonance with the previous results. Nevertheless, the explanatory power of the third and fourth equations diminished, which is evidence that the institutional indicator elaborated is more appropriate for studying the phenomena analysed.

Estimation V –shown in Table 3-, was carried out introducing the data on *per capita* income and investment from the World Bank instead of that elaborated by Summers and Heston (*Penn World Tables*). The sample of countries was the same as the original and, generally, the signs of the coefficients and their significance were maintained, although the *PUPIL/TEACHER* and *MIDDLE CLASS* variables were not significant. We should point out that the use of the World Bank data increased the explanatory power of the growth equation though it reduced that of the investment equation.

Table 3.
Estimation of growth with a multi-equational approach. Analysis of sensitivity to the sources of the variables and to outliers

Estimation V			
Number of countries	45		
WB PER CAPITA INCOME GROWTH	Coefficient	Stand. Error	Signif.
CONSTANT	-0.02870	0.646	**
FORMACIÓN BRUTA CAPITAL	0.00061	0.023	**
HUMAN CAPITAL	-0.00029	0.013	**
INSTITUTIONAL INDICATOR	0.00016	0.004	**
R^2	0.46		
HUMAN CAPITAL	Coefficient	Stand. Error	Signif.
CONSTANT	-29.55	6.00	**
INCOME	1.42	0.537	**
EDUCATION EXPENDITURE	-0.837	0.364	**
PUPIL/TEACHER	-0.116	0.076	
INSTITUTIONAL INDICATOR	0.272	0.010	**
R^2	0.72		
INSTITUTIONAL INDICATOR	Coefficient	Stand. Error	Signif.
CONSTANT	135.88	23.29	**
HUMAN CAPITAL	3.36	0.115	**
MIDDLE CLASS	-0.731	0.551	
R^2	0.71		
INVESTMENT	Coefficient	Stand. Error	Signif.
CONSTANT	17.55	1.55	**
INTEREST RATE	-0.268	0.087	**
INSTITUTIONAL INDICATOR	0.018	0.004	**
R^2	0.16		

Estimation VI			
Number of countries	41		
PER CAPITA INCOME GROWTH	Coefficient	Stand. Error	Signif.
CONSTANT	-0.02068	0.00524	**
INVESTMENT	0.00075	0.00027	**
HUMAN CAPITAL	-0.00017	0.00009	*
INSTITUTIONAL INDICATOR	0.00010	0.00003	**
R^2	0.42		
HUMAN CAPITAL	Coefficient	Stand. Error	Signif.
CONSTANT	-25.27	13.48	*
INCOME	7.67	1.71	**
EDUCATION EXPENDITURE	-0.513	0.920	
PUPIL/TEACHER	-0.753	0.169	**
INSTITUTIONAL INDICATOR	0.144	0.013	**
R^2	0.82		
INSTITUTIONAL INDICATOR	Coefficient	Stand. Error	Signif.
CONSTANT	238.82	75.64	**
HUMAN CAPITAL	3.52	0.215	**
MIDDLE CLASS	-3.65	2.195	*
R^2	0.71		
INVESTMENT	Coefficient	Stand. Error	Signif.
CONSTANT	23.83	3.48	**
INTEREST RATE	-2.02	0.322	**
INSTITUTIONAL INDICATOR	0.018	0.005	**
R^2	0.45		

Notes:
Estimations obtained with GMM.
(**) (*) denotes that coefficients are significantly different from zero at the 5 percent (10 percent) level.

To sum up, the robustness analysis confirmed the general stability of the relationships proposed in the system with two exceptions: the *PUPIL/TEACHER* variable -second equation– and the *MIDDLE CLASS* variable -third equation-. Although both variables were less robust, they were kept in the system for the sake of theoretical coherence.

3.3.2 Analysis of sensitivity to possible outliers

With the analysis of the outliers, our aim was to detect whether they altered the estimations. An outlier was defined as one that was further than three box-lengths away the 25 and 75 percentiles, used as lower

and upper limits, respectively. The box-length contains 50 per cent of the central cases grouped around the median[19].

Following this criterion, we found outliers for four countries of the sample: Bolivia, Botswana, Israel and Uruguay. The variables which showed these outliers were *MIDDLE CLASS* (Botswana), *INTEREST RATE* (Bolivia, Israel and Uruguay) and *PER CAPITA INCOME GROWTH* (Botswana).

The results of the estimation of the system, excluding the outliers, are shown in Estimation VI of Table 3. Note that they are in agreement with the other estimations carried out. Only the variable that measures the equality of the distribution of income (*MIDDLE CLASS*) changes the sign of the coefficient in the third equation, nearly reaching the limits of significance at 10 per cent level. In any case, when estimating by measuring the distribution of income through the Gini index, the sign of the coefficient is maintained and a higher level of equality was accompanied by a higher institutional development, the variable being, in this case, significant at 5 per cent. Nevertheless, we should point out that Forbes (2000) found contrary empirical evidence because, with data from 45 countries corresponding to the period 1960-1990, he concluded that, in the short and medium term, an increase in the level of income inequality in a country positively influenced economic growth.

4. CONCLUSIONS

The analysis carried out shows evidence that the economic growth of countries is a complex phenomenon best approached by means of a multi-equational approach rather than through uni-equational models.

The estimation of the model proposed -using data from 45 countries during the period 1985-2000- allows us to draw four main conclusions.

Firstly, that the variation of the *per capita* income during the period maintained a positive and statistically significant relation with the growth of human capital -though not with the human capital-, the quality of the institutional system and investment. Secondly, that the human capital of the countries analysed depended on their *per capita* income as well as on the quality of their institutions and of their educational systems. On the contrary, public expenditure on education did not have a statistically significant effect on human capital. Thirdly, that human capital and a more equal distribution of income positively influenced the quality of the institutional system. Lastly, that investment was higher, the higher the institutional quality and the lower the investment risks were.

[19] See Tukey (1977) for a justification of the choice of these limits.

With the aim of confirming the solidity of the results obtained, various additional regressions were proposed. The introduction of alternative variables confirmed the general stability of the relationships proposed, although the effect of the equality of the distribution of income on institutional development varied. The robustness of the model was also corroborated when it was estimated without the outliers.

To sum up, the analysis has shown the joint importance that institutions and physical and human capital have had on the economic growth of a varied sample of countries during the period 1985-2000 and the convenience of analysing the joint effect of these factors through systems of equations.

The conclusions for the drawing up of economic policies are clear. On the one hand, the policies have to design an appropriate institutional framework for the carrying out of economic activities that guarantees the civil liberties and political rights of private agents, assures political stability and respect for the law and enhances governmental efficiency. On the other hand, the growth of physical and human capital must be favoured because both these factors are intimately linked to the sustained increase of the *per capita* income of countries.

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Annex 1. Description and statistics of the variables used[20]

CIVIL LIBERTIES: index of civil liberties elaborated by Gastil. Source: Barro and Lee, *Data Set for a Panel of 138 Countries*.

EDUCATION EXPENDITURE: quotient obtained by dividing total public spending on education by income (percentage).

HUMAN CAPITAL GROWTH: growth rate of the variable *HUMAN CAPITAL* during the period.

HUMAN CAPITAL: enrolment in secondary school (percentage of gross enrolment).

INCOME: *per capita* income. Source: Penn World Tables v. 6.1.

INSTITUTIONAL INDICATOR: index elaborated on the basis of the data provided by Kaufmann, Kraay and Zoido-Lobatón (1999 a, b). These authors constructed, on the basis of more than 300 variables on governmental aspects, six aggregate indicators that correspond to the concepts of civil liberties, political rights, political instability and violence, government effectiveness, the rule of law and corruption. From the data of these authors, we have applied the principal components analysis to the six indices to obtain a single component. The institutional index obtained contains more than 80 per cent of the variation of the variables used[21]. The indicator has been constructed with data from around 1997. The low variation of these variables during relatively short periods supports its use in the whole period analysed. The instrument used for this variable has been the lagged *POLITICAL RIGHTS* variable.

INTEREST RATE: differential between the lending rate and the deposit rate.

INVESTMENT: average annual quotients obtained by dividing investment by income, both measured at constant prices. Source: Penn World Tables v. 6.1.

INVESTMENT: quotient obtained by dividing the gross capital formation by income (percentage).

MIDDLE CLASS: proportion of citizens of a country in the third and fourth quartiles of income (most recent data from around 1998). This variable was instrumented using the Gini index.

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[20] Unless otherwise indicated, the data on the variables come from the *World Development Indicators* (World Bank) and correspond to the average of the period.

[21] The equation that results from applying the principal components method is: INSTITUTIONAL INDICATOR = 0.84 * [civil liberties] + 0.88 * [political rights] + 0.94 * [political instability and violence] + 0.87 * [government effectiveness] + 0.93 * [rule of law] + 0.92 * [corruption].

PER CAPITA INCOME GROWTH: growth rate of the variable *per capita* income during the period. The rate was calculated on the basis of the data from the Penn World Tables v. 6.1. With the aim of mitigating the effect of cycles, the growth rate was calculated by the slope of the regression line estimated by OLS using the annual data of the logarithm of the *per capita* income.

PER CAPITA INCOME GROWTH (WB): growth rate of the variable *per capita* income during the period. The rate was calculated on the basis of the data from the World Bank, following the procedure described for the previous variable.

POLITICAL RIGHTS: index of political rights elaborated by Gastil. Source: Barro and Lee, *Data Set for a Panel of 138 Countries*.

PUPIL/TEACHER: ratio calculated for primary education[22].

Descriptive Statistics

	Average	Stand. dev.
CIVIL LIBERTIES	3.58	1.83
EDUCATION EXPENDITURE	4.28	1.75
GROSS CAPITAL FORMATION	21.55	7.35
HUMAN CAPITAL	60.46	36.97
HUMAN CAPITAL GROWTH	0.62	0.95
INCOME	8.561.85	8.364.70
INSTITUTIONAL INDICATOR	321.96	129.22
INTEREST RATE	8.57	8.68
INVESTMENT	16.07	8.93
MIDDLE CLASS	35.50	4.32
PER CAPITA INCOME GROWTH	0.02	0.03
PER CAPITA INCOME GROWTH (WB)	0.02	0.02
POLITICAL RIGHTS	3.44	2.13
PUPIL/TEACHER	30.11	13.24

[22] Although the primary PUPIL/TEACHER ratio refers to data registered in primary education, it can be used as an approximation to the quality of each educational level.

Annex 2. Countries included in the análisis

Estimation I	Estimation II	Estims. III and IV	Estimation V	Estimation VI
Bangladesh	Bangladesh	Bangladesh	Bangladesh	Bangladesh
Belgium	Bolivia	Belgium	Belgium	Belgium
Bolivia	Botswana	Bolivia	Bolivia	Burkina Faso
Botswana	Burkina Faso	Botswana	Botswana	Costa Rica
Burkina Faso	Costa Rica	Burkina Faso	Burkina Faso	El Salvador
Costa Rica	Finland	Burundi	Costa Rica	Finland
El Salvador	France	Central African Rep.	El Salvador	France
Finland	Gambia	Costa Rica	Finland	Gambia
France	Ghana	El Salvador	France	Ghana
Gambia	Greece	Finland	Gambia	Greece
Ghana	Guatemala	France	Ghana	Guatemala
Greece	Israel	Gambia	Greece	Guyana
Guatemala	Italy	Ghana	Guatemala	Honduras
Guyana	Ivory Coast	Greece	Guyana	Ireland
Honduras	Jamaica	Guatemala	Honduras	Italy
Ireland	Japan	Guyana	Ireland	Ivory Coast
Israel	Kenya	Honduras	Israel	Jamaica
Italy	Korea (Rep. of)	Ireland	Italy	Japan
Ivory Coast	Lesotho	Israel	Ivory Coast	Kenya
Jamaica	Luxembourg	Italy	Jamaica	Korea (Rep. of)
Japan	Malawi	Ivory Coast	Japan	Lesotho
Kenya	Malaysia	Jamaica	Kenya	Luxembourg
Korea (Rep. of)	Malaysia	Japan	Korea (Rep. of)	Malawi
Lesotho	Netherlands	Kenya	Lesotho	Malaysia
Luxembourg	Niger	Korea (Rep. of)	Luxembourg	Malaysia
Malawi	Philippines	Lesotho	Malawi	Mali
Malaysia	Portugal	Luxembourg	Malaysia	Netherlands
Malaysia	Sierra Leone	Malawi	Malaysia	Niger
Mali	Spain	Malaysia	Mali	Nigeria
Netherlands	Sweden	Malaysia	Netherlands	Philippines
Niger	Trinidad and Tobago	Mali	Niger	Portugal
Nigeria	Tunisia	Nepal	Nigeria	Sierra Leone
Philippines	Uganda	Netherlands	Philippines	Singapore
Portugal	Uruguay	Niger	Portugal	Spain
Sierra Leone	Venezuela	Nigeria	Sierra Leone	Sweden
Singapore	Zambia	Philippines	Singapore	Trinidad and Tobago
Spain	Zimbabwe	Portugal	Spain	Tunisia
Sweden		Rwanda	Sweden	Uganda
Trinidad and Tobago		Sierra Leone	Trinidad and Tobago	Venezuela
Tunisia		Singapore	Tunisia	Zambia
Uganda		Spain	Uganda	Zimbabwe
Uruguay		Sweden	Uruguay	
Venezuela		Trinidad and Tobago	Venezuela	
Zambia		Tunisia	Zambia	
Zimbabwe		Uganda	Zimbabwe	
		Uruguay		
		Venezuela		
		Zambia		
		Zimbabwe		

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