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HUMAN CAPITAL AND INNOVATION: EVIDENCE FROM PANEL COINTEGRATION TESTS

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Human Capital and Innovation: Evidence from Panel Cointegration Tests

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Panel cointegration techniques applied to pooled data for 27 economies for the period 1960-2000 indicate that: i) government spending in education and innovation indicators are cointegrated; ii) education hierarchy is relevant when explaining innovation; and iii) the relation between education and innovation can be obtained after an accommodation of a level structural break.

Key Words: Human Capital, Innovation, Panel Cointegration.
JEL Classification: O31, O50

1. INTRODUCTION

Endogenous growth theories regard endogenous technologic change as the cause of global growth patterns. According to the seminal paper of Nelson and Phelps (1966) describes growth as being driven by the stock of human capital, which in turn affects a country's ability to innovate or catch up with more advanced countries.

However, this approach raises several empirical problems. First, as pointed out by Krueger and Lindahl (2001), the correlation between growth and education ceases to be significant once we restrict the analysis to OECD countries. Second, the positive

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correlations between education measured by stocks and growth found in the overall country samples, may reflect reverse causalities from growth to education (Bils and Klenow (2000)). Third, all correlations become insignificant once one controls for country fixed effects. (Aghion and Howitt, 2008)

Recently, Vandenbussche, Aghion and Meghir (2006), shortly VAM, addressed these questions suggesting that only the tertiary educational level encourages innovation, whereas the secondary fosters only the imitation of new technologies - such scenario would be an attribute of countries that are far away from the technological frontier. VAM make clear that the relationship between innovation and human capital is neither trivial nor obvious.

The main contribution of this paper is to provide new empirical evidences about the long-term relationship between human capital and innovation. We use new panel cointegration tests, avoiding the reverse causality and fixed effects criticisms, and we employ several alternative measures of human capital to shed light on the links between such variables. Stock and flow variables of human capital will be used in addition to variables from the different educational hierarchies and public investments, testing VAM hypothesis extensively.

Independently of how they are measured, innovation and human capital tend to be non-stationary. Due to such characteristic the use of cointegration techniques becomes necessary for the analysis of any long-term stable relationship. However, the restricted size of the time series limits the cointegration test's power leading to partial and/or ambiguous conclusions.

As consequence, this paper seeks to increase the power of the tests while comparing results between two databases for the period 1963-2000: 27 countries from the Barro and Lee (2001) database, and of 24 countries from the Cohen and Soto (2007) database. To use the data in the most efficient manner, we propose tests which the null hypothesis of cointegration (McCoskey and Kao (1998) test), and extensions with structural breaks (Westerlund (2006) test). Given that innovation is probable caused by several factors, in addition to human capital, the structural breaks should, if they happen, incorporate these factors as well as exogenous shocks.

The paper is organized as follows. Section 2 introduces the econometric methodology. Section 3 presents the results; and Section 4 addresses final considerations.

2. EMPIRICAL METHODOLOGY

Nelson and Phelps (1966) provide a framework which implies a simple long-run relationship between education and innovation, translated into a testable model:

$$I_{it} = a_i + b_i H_{it} + \varepsilon_{it} \tag{1}$$

where I is the innovations of new goods, and H is the required human capital for innovation. For a sustainable relationship between H and I, ε should be stationary, meaning that innovations are cointegrated with human capital. The basic hypothesis of VAM is that only tertiary education has a sustainable relation with innovation. So, if they are correct, tertiary education is cointegrated with innovation, while primary and secondary education are not.

There are numerous cointegration tests such as Engle and Granger (1987), Johansen (1991) and Philips and Ouliaris (1990) documented in the time series literature. However, these tests fail to take advantage of information across countries, which leads to loss of efficiency in estimation. Recently, several authors such as Pedroni (1995), Kao and Chiang (1998) and Kao (1999) have devoted their efforts to develop cointegration tests with panel data. In this article, we employ the LM cointegration tests proposed by McCoskey and Kao (1998) and Westerlund (2006) to test whether a cointegration exists in the estimated equations. Instead of non-cointegration, the null hypothesis is meant to read cointegration in these tests. This is a crucial difference and an important advancement in relation to the tests previously proposed given that it addresses the critique of the non-cointegration null hypothesis being frequently rejected only if a subset of series in the panel is cointegrated. Consequently, the LM test is the most powerful test of cointegration in panel data, as demonstrated by McCoskey and Kao (1999) who conducted simulations for Monte Carlo.

The residual-based test for null of cointegration in panel data proposed by McCoskey and Kao (1998) is an extension of the LM and LBI tests for an MA unit root in the time series literature. For this test, an efficient estimation technique of

cointegrated variables becomes necessary, thus, we use the fully modified ordinary least squares (FMOLS) given that it corrects for the possible serial correlation and weakly exogenous regressors in a cointegrated regression.

The test considers the fixed effects estimation of (1) where $H_{it} = H_{it-1} + u_{it}$; $\varepsilon_{it} = \gamma_{it} + \epsilon_{it}$; $\gamma_{it} = \gamma_{it-1} + \theta\epsilon_{it}$; and I_{it}, H_{it} are independent across cross-sectional units. Therefore, the null of hypothesis of cointegration is equivalent to $\theta = 0$. McCoskey and Kao (1998) derive the limiting distribution for the LM statistic fully modified (FM) estimators in a cointegrated regression and next show that it is free of nuisance and robust to heteroskedasticity. The detailed description of the LM statistic can be found in McCoskey and Kao (1998, 1999) and is not reported here.

Westerlund (2006) extended the McCoskey and Kao test allowing for multiple structural breaks in both the level and trend of a cointegrated panel regression. The breaks are determined endogenously by globally minimizing the sum of squared residuals following Bai and Perron (1998, 2003).

Using sequential limit arguments, it is shown that the test has a limiting normal distribution, i.e. free of nuisance parameters under the null hypothesis. In particular, it is shown that the limiting distribution is invariant with respect to both the number and locations of breaks and that the computation of different critical values for all possible patterns of break points is not necessary.

Given that technological innovation is likely to be caused not exclusively by human capital but by innovation exogenous shocks and other factors, as fully documented in the related literature, structural breaks are expected in the human capital and innovation relationship. Therefore, the Westerlund test allows for the investigation of this long-term relationship in a more precise way.

3. EMPIRICAL INVESTIGATION

3.1. Data Description

This section presents the main features of our data-set. We use a panel data of 27 countries for the period 1963-2000. The 27 countries[1] were chosen through a unit

[1]The countries are:, Australia, Austria, Belgium, Brazil, Canada, China, Denmark, England, Finland, France, Holland, Hon Kong, India, Ireland, Israel, Italy, Japan, Malaysia, Mexico, Norway, New Zeeland, Russia, South Africa, Spain, Switzerland, and Sweden.

root test for each innovation serie of each country. Only countries which the series were not stationary were kept, given that an existing stationarity could disqualify the cointegration tests and countries with a nearly inactive innovatory section would eventually be included.

As a measure of the innovative output within a region we use the count of granted patent applications that inventors residing in each region filed with the U.S. Patent and Trademark Office between 1963 and 2000. As it is generally done in this literature (see Jaffe et al., 1993), each patent is attributed to the first inventor listed in the patent application. Patents have long been considered, not without controversy, as the best measure of output of innovative activity. Although not all inventions are patented, the ones that are patented have to meet minimal standards of novelty, originality and potential use. Therefore patents can be considered a good proxy of "economically profitable ideas" for testing theories on innovation (Bottazi and Peri, 2003).

Additionally, three different types of measures of human capital are used. The first measure is given by per capita public spending in education ($GGEDUC$). Such variable is given as follows:

$$GGEDUC = GEPERC * RGDPL * G \tag{2}$$

where, $GEPERC$ corresponds to the percentage of the government's expenditure in education in relation to the total government's expenditure (source:UNESCO), $RGDPL$ corresponds to the real GDP per capita (constant prices: Laspeyres) adjusted by PPP(base year 2000, source: Penn World Tables 6.1) and G is the total government expenditure as a percentage of the GDP (source: Penn World Tables 6.1).

The second measure of human capital corresponds to the population's average number of study years ($AVGSCH$). The third human capital measurement, as suggested by VAM, seek to evaluate which type of human capital, in relation to the hierarchy, matters for innovation. Such measurements are the average years of tertiary ($yearsT$) and primary-secondary ($yearsPS$) education. The latter were derived from the Barro and Lee (2001) and Cohen and Soto (2007) databases. The Barro and Lee database is the most used in studies that perform comparisons among countries. The

Cohen and Soto database has recently come out as an alternative to the Barro and Lee database since it improves data quality using surveys based on uniform classification systems of education over time, and intensifies the use of information by age groups. There are seven categories of schooling in these databases, so we can define $yearsT$ and $yearsPS$ as:

$$yearsT = (p_6 + p_7)n_6 + p_7 n_7 \tag{3}$$

and

$$yearsPS = \sum_{i=1}^{5} (\sum_{j=i}^{7} p_i) n_i \tag{4}$$

where p_i is the fraction of the population which have reached the level i and n_i is the number of extra years of education which the individual in the category i has accumulated more than an individual in a category $(i-1)$. We have $(n1, n2, n3, n4, n5, n6, n7)$ = (0, 3, 3, 3, 3, 2, 2). The variable $yearsT$ represents the average number of years of education of the tertiary level of the average adult population. Based on these premises, a college graduation contributes with 12 years in the variable $yearsPS$ and 4 years in the variable $yearsT$.

3.2. Empirical Results

The cointegration tests include trend and constants for all the cases. The lags were selected using the Akaike Information Criteria (AIC). The existence of a level break was allowed for the Westerlund test. The results of the tests are presented in Table 1.

The results make clear that it is not possible to reject a long-term relationship between human capital and innovation given that in all variables of human capital the cointegration relationship was obtained. Such results strongly support the hypothesis of the endogenous growth models which state that a public policy toward investment in human capital increases innovations and therefore the economic growth in the long run.

TABLE 1.
LM Cointegration Tests

	McCoskey and Kao	Westerlund		
GGPEDUC	8.06*	3.56		
	Barro and Lee (2001)		Cohen and Soto (2007)	
	McCoskey and Kao	Westerlund	McCoskey and Kao	Westerlund
AVGSCH	11.35*	2.39	18.80*	1.42
YEARST	7.05*	1.94	2.66	1.69
YEARSPS	8.56*	2.34	17.92*	8.76*

(*) null hypothesis of cointegration rejected at 1%

Additionally, all the variables tested were relevant in explaining innovation. As a result we might suppose that public spending in education is productive in the long run, spurs innovation, technical progress, and growth.

There is no indication, from the Barro-Lee database, which sustains the relevance of the educational hierarchy, in opposition to the conclusion obtained by VAM. VAM anticipated that the tertiary education is the driving force of innovations. However, when the Cohen-Soto database is used the results are different from the scenario described above. The results obtained with this database (considered a better database in relation to Barro-Lee) leans toward the positive effect of the innovation hierarchy, meaning that this is indeed a relevant factor when determining innovations. Such results are obtained through the LM test with breaks, of Westerlund, where the tertiary education is very significant when determining innovation while the primary and secondary educational levels are irrelevant.

The traditional McCoskey and Kao test does not provide evidence that there is a cointegration relationship between human capital and innovation for the majority of the variables. That is so because, at 1% level of significance, the cointegration hypothesis is significantly rejected for all the variables, except for the tertiary study, from the Cohen-Soho database.

However, the Westerlund test, which includes a structural break at the intercept, brings up an opposing conclusion. In this case, the cointegration can not be rejected in almost all the cases if only the case of primary and secondary studies of the Cohen-

Soto database is excluded. This result strongly suggests structural breaks in the innovation series which might be caused by different reasons such as global trade openness, exogenous technological and patent legislation shocks. As anticipated by Westerlund, the use of series longer than previous studies should have included break periods. The expanded period, aiming to increase the power of the tests, increases the possibility of having more errors as consequence of breaks, such trade-off is satisfactory resolved by this test.

4. CONCLUSION

The goal of this study is to evaluate the contribution of the human capital to technological innovation. This relationship is key within several endogenous growth models where the human capital, being the driving force behind innovation, is essential to the economic growth and should be prioritized by sustainable growth policies.

To the best of our knowledge, this is the first study that uses cointegration techniques with panel data aiming to investigate this relation and the importance of the educational hierarchy for innovation. Furthermore, the study uses a cointegration panel test recently developed allowing for structural breaks (Westerlund test) and an up-to-date refined human capital database (Cohen and Soto database). These two applications substantially alter the results and are relevant for the question under analysis.

The results significantly show that there is a clear long-run relationship between human capital stock and the quantity of innovation - that is so, only if the possibility of a break level is considered. This relationship is reflected on the cointegration between the number of patents and public spending in education and in the population's average years of education. Moreover, because of the peculiarities of the Cohen-Soto database, we can say that only the tertiary education cointegrates with innovation, the same does not hold true for the primary and secondary educational levels as predicted by VAM.

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