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DOES HUMAN CAPITAL GRANGER CAUSES TECHNOLOGY CHANGE IN ALBANIA?

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Abstract

This paper investigates the causal relationship between gross enrolment rates in secondary education and TFP in Albania by using time series unit root tests and Granger causality test for the period 1979-2014. The results show a strong causality running from TFP to secondary level education at 5 % significance level, but a bi-variate causality is evident when the significance level is 10 %. This means that not only TFP Granger causes gross enrolment rates in secondary education but also gross enrolment rates in secondary education Granger causes TFP in short run equilibrium. By investing more in secondary education we will have a better educated work force, which will increase the overall productivity in the economy, which will help in knowledge development and so by improve the Albanian's future prospects.

Keywords: Secondary education, TFP, Granger causality, VAR

INTRODUCTION

Economists have suggested various channels through which education can affect economic growth. Education is a tool to create disciplined, educated and flexible workforce in the labor market. Nelson and Phelps (1966) argue that investment in human capital measured in terms of education promotes economic growth not only by increasing labor capacity, but it accelerate the rate at which individuals fit and adapt to new technologies. They proposed two specific models related to the process of technology transfer as well as the role that education has on technology. They showed that returns on education would be bigger, as the economy would be more advanced in technology. This suggests that technological progress has implications for the optimal structure of capital in the economy. Another important point from their models is that if innovations (from the most educated workers) produce positive externalities, then education will produces positive externalities too. Due to this interrelationship between education and growth, Nelson and Phelps suggest that the usual and straightforward way of involving human capital (using some proxy as education attainments) as an additional factor of production would represent a non clear definition of the production process, in particular to the relationship between education and dynamics of production. In his work Lucas (1988) argues that the accumulation of human capital is responsible for sustainable growth and education is the main channel through which human capital is accumulated. Romer (1986, 1990) showed that human capital, which generates innovations, stimulates economic growth. Moreover, there are potential effects running from economic growth to human capital. It is argued that economic growth can lead to accumulation of human capital (Mincer, 1996). Thus, the causality chain between economic growth and education implied by the existing macroeconomic paradigms seems relatively vague. Despite the growing interest in the relationship between education and economic growth, the empirical evidence especially those that use causalilty analysis, are better.

According to empirical literature and based on endogenous theory's implications, Granger's causality relationship may exist between human capital and technological change, and the causality-effect can be derived either from human capital to technological change or from technological changes to human capital. Seen from the theoretical point of view there is no consensus about the relationship between human capital and the technological changes. The conducted studies have continued to yield mixed results where some show causality in one direction while others show a causality relationship in both directions. The causality is not unique and the results are not the same for the countries, due to the various data and methodologies used in each study. Some follow bivariate analysis (Boldin et al., 2008, Dananica et al., 2008, Ljungberg et al., 2009) while others use multivariate methods (Islam et al., 2007; Dauda, 2009) . The other difference in literature is in the different use of proxy for human capital and technological change. The Data used to measure education or human capital is very scarce. For example, Fontvieille (1990) used material expenditures for public education as a proxy for human capita in France. Khalifa (2008), Pradhan (2009), and Chandra and Islamia (2010) used similar proxy (public education expenditures) to analyze the relationship between human capital and economic growth. In some studies exploring the relationship between human capital and economic growth take into account for a short period of time and consequently they can not shed light on long-term relationships (Ljungberg et al., 2009).

In recent decades, special attention has been paid to education in Albania, both by researchers and policymakers. It is clear that a lack of educated people can limit economic growth, but it is unclear that a more educated workforce will boost it. It is also unclear what kind of education contributes most to economic growth; if it is general education, formal training or training at the workplace, and which from the educational levels contributes most to economic growth, such as primary, secondary or high education level. Despite this, there is no empirical evidence on the contribution of education to economic growth (Kule, 2015). Only one important work was carried out by Kule (2015) on this issue. In her doctoral thesis, she used time series data by using number of enrollments in higher education and public spending on higher education for a period of 16 years. Using the OLS analysis, she empirically estimated the positive and important impact that higher education has on economic growth in Albania.

Therefore, in order to gain a better understanding of the economic growth in the long run in Albania, we focus on TFP behavior, as it is argued in the literature that TFP is a crucial determinant for a long-term economic growth. The purpose of this paper is to examine the dynamic relationship between human capital and technological change in Albania by using the VAR model. In this paper, we hypothesize that human capital is the main factor influencing TFP. Therefore, for the purposes of this study, we also propose that: any effect of human capital has on overall economic growth will be transmitted through its effects on TFP. This paper is organized as follows. Next section lays down the proxy that we have used to measure human capital and technology change. Methodology is explained in details in Section three. Section four brings the results of the empirical analysis. Section five concludes.

THE PROXY OF HUMAN CAPITAL AND TECHNOLOGICAL CHANGES

While it is recognized that human capital and technological changes are difficult to measure, theoretical and empirical literature uses some proxy to approximate their effects. In some studies the researchers have used the gross enrolment rates in school to measure the impact of human capital on economic growth. For example Mankiw et al. (1992) empirically examined the Solow growth model with and without human capital as a factor of production. They found that the Solow model that contained human capital was better fitted to explaining the differences in revenue among the countries under study. In their study they used the gross enrolment rates in school as a proxy for human capital. In the same way, Abbas investigated the relationship between levels of education and economic growth (Abbas et al.,2000). He concluded that to increase productivity, human capital is very important for the usage of physical capital, as raising the stock of human capital in one country draws investment in physical capital to accelerate production. Since no single proxy is a perfect proxy, we think that is important to use gross enrolment rates at secondary level of education as a proxy for human capital.

The traditional measure which is widely used in the literature to measure the contribution of technological change to economic growth is represented by Total Factor Productivity (TFP) (Kahn et al., 1998). Lipsey and Carlaw (2004) indicated that "TFP means different things for different researchers". In this study, we are not trying to come up with a new TFP interpretation, but we want to measure it. Due to the nature of our data we have selected the Growth Accounting approach to measure TFP. The growth accounting is a useful tool in determining the relative contributions of factor accumulation and TFP growth; it does not test any significant statistical relationship between the output growth and any of the inputs of the production factors, so it does not offer any test to measure any causality relationship. To calculate the TFP we used the same methodology in our previous study (Alikaj et al, 2018). We consider human capital as an independent production factor, so the Cobb-Douglas production function takes the form:

(1) $Y = AK^{\alpha}H^{\beta}L^{(1-\alpha-\beta)}$

Where Y is total output, K is physical capital, H is human capital, L is labour or employment, and A is total factor productivity. By dividing both sides of equation (1) by L and after some mathematical computations we will have:

(2) $\frac{Y}{L} = A\left(\frac{K}{L}\right)^{\alpha}\left(\frac{H}{L}\right)^{\beta}$ or

(3) $y = Ak^{\alpha}h^{\beta}$

Where $\frac{Y}{L}$, output per worker or economy wide labour productivity; $\frac{K}{L}$ is capital per worker; $\frac{H}{L}$ is average human capital. Finally, by taking the natural logarithm of equation (3) above yields the structural form of the production function as:

(4) $ln(y) = ln(A) + \alpha\, ln(k) + \beta ln(h)$

From this we count $ln(A)$ or TFP per worker as a residual part of the equation (4) above:

(5) $ln(A) = ln(y) - \alpha\, ln(k) - \beta ln(h)$

Another assumption is made to evaluate TFP through the elasticity of production related to physical capital and labor is respectively $\alpha = 0.3$ dhe $\beta = 0.7$. Below we give a full description of the data and variables we have used in our econometric model.

METHODOLOGY

Data sources and Variables' measures

In this paper we have used secondary data and these are time series macroeconomic data for Albania. All the time series data are transformed into logarithmic form in order to have better estimates (Kruschke, 2010). For measuring human capital, we choose as a proxy *the gross enrolment rates in secondary education*. This indicator is derived from the database of World Development Indicators (WDI) of the World Bank. The data was collected for a time period of 35 years, from year 1979 to 2014. To calculate the TFP for Albania we have used the database of the Penn World Table (PWT 9), for the period form 1970 to 2014. Below we give a full description of the variables we have used in this section of the paper and in the econometric analysis.

cgdpo – Real GDP calculated by production method - report the Gross Domestic Product (GDP) based on PPPs in millions of US dollars. This indicator allows comparison of production capacity between countries and over time.

emp - Number of Employees - Based on the Penn World Table (PWT) in which all persons aged 15 years and over , who during the reference week performed a job, even for one hour per week or were not in work but had a job or business from which they were temporarily absent are included.

ck – Reports the levels of physical capital in terms of price at that time (eg, current prices). Capital stock is estimated based on accumulation and depreciation of past investments using the permanent inventory method (PIM).

hc – Provides an index of human capital per person, which is related to the average years of schooling and returns to education. In PWT 8, an index of human capital was estimated using data on the average years of education by Barro and Lee (2013) and rates of return to education by Psacharopoulos (1994).

Yt_worker - in order to obtain real GDP per workers, we have divided real GDP calculated with the current PPP, by the number of engaged persons (in millions).

K_worker - to obtain the stock of physical capital per worker, we have divided the stock of physical capital, by the number of engaged persons (in millions).

enrol_ratio - Gross enrollment rate in secondary education.

ln_AD1 - is the first difference of the time series ln_A_t ($ln\_A_t - ln\_A_{t-1}$).

lnenrol_ratioD1 - is the first difference of the time series lnenrol_ratio ($lnenrol\_ratio_t - lnenrol\_ratio_{t-1}$).

The VAR model and the regression equations

In economics, we can use "models of simultaneous equations" in which it is necessary to clearly identify which are endogenous variables and which are exogenous or predetermined variables (Asteriou & Hall, 2011). Differentiating between variables was criticized heavily by Sims (1980). Sims (1980) indicates that all variables should be treated in the same way and should not have this distinction between endogenous or exogenous variables. They assumed that if there are two time series (x_t, y_t), than the time series (y_t) is affected by past and current time series (x_t); At the same time, time series (x_t) is influenced by the past and current values of the series (y_t) Therefore, based on the assumptions of Asteriou & Hall for the variables in this study, we can write the simple bivariate model as:

(6) $\text{lnenrol\_ratio}_t = \boldsymbol{\beta_{10}} - \boldsymbol{\beta}_{11}\,\text{ln\_TFP}_t + \boldsymbol{\gamma_{11}}\,\text{lnenrol\_ratio}_{t\text{-}1} + \boldsymbol{\gamma_{12}}\,\text{ln\_TFP}_{t\text{-}1} + \boldsymbol{u}_{\text{lnenrol}}$

(7) $\text{ln\_TFP}_t = \boldsymbol{\beta_{20}} - \boldsymbol{\beta}_{21}\,\text{lnenrol\_ratio} + \boldsymbol{\gamma_{21}}\,\text{ln\_TFP}_{t\text{-}1} + \boldsymbol{\gamma_{22}}\,\text{lnenrol\_ratio}_{\text{-}1} + \boldsymbol{u}_{\text{TFP}}$

Where, lnenrol_ratio represents the proxy we have used for human capital in our study, respectively the gross enrolment rates in secondary level education. With the assumption that (lnenrol_ratio, ln_TFP_t) are stationary and ($\boldsymbol{u}_{\text{lnenrol}}$, $\boldsymbol{u}_{\text{TFP}}$) are the terms of the white noise error, the equations (6) and (7) represent a first-order VAR model because the longest lag length is unity.

The Granger Causality Test under the Vector Autoregressive Model (VAR)

Through simple regression analysis, we can measure the degree of linear linkage of a variables depending on other variables, but we can not get information about their causality. If we want to determine if the human capital causes TFP growth; or if TFP growth causes human capital, we should consider this relationship within the concept of Granger's causality (Granger, 1969). Its applicability depends on the charachteristics that time series data have. One of the main charachteristics of the data is that they must be stationary. If the time series is non-stationary then the estimated coefficients (of the economic variables included in the model) based on the Ordinary Least Square (OLS) method may be unreliable and unstable; so regression results may be untrue. For this reason, we use the first differences of the series at the level and the first difference operator is noted by Δ. If we apply Granger's test on the variables of our model then the equations would be:

(8) $\Delta\text{lnenrol\_ratio} = \boldsymbol{\alpha_0} + \sum_{i=1}^{p} \alpha_{1i}\,\Delta\text{lnenrol\_ratio}_{t-1} + \sum_{i=1}^{p} \alpha_{1i}\,\Delta\text{ln\_TFP}_{t-1} + \boldsymbol{v_{1t}}$

(9) $\Delta\text{ln\_TFP}_t = \beta_{\mathbf{0}} + \sum_{i=1}^{p} \beta_{1i}\,\Delta\text{lnenrol\_ratio}_{t-1} + \sum_{i=1}^{p} \beta_{2i}\,\Delta\text{ln\_TFP}_{t-1} + \boldsymbol{v_{2t}}$

Where, (lnenrol_ratio, ln_TFP_t) refer to dependent and independent variables, and ($\boldsymbol{v_{1t}}$, $\boldsymbol{v_{2t}}$) indicate the terms of error assumed to be uncorrelated. Equation (8) assumes that the present value of (lnenrol_ratio) is related to past values of (lnenrol_ratio) and (ln_TFP_t). While equation (9) assumes that the present value of (ln_TFP_t) relates to the past values of both (ln_TFP_t) and (lnenrol_ratio) (Asteriou & Hall, 2011).

EMPIRICAL RESULTS

To achieve the overall goal, the first objective is to discover the existence of short-term and long-term relationships between the gross enrollment rate in secondary education and TFP in Albania. The second objective is to determine the direction of causality between them and this is achieved through Granger's causality method. So, we have followed a three-step procedure to prove the causality. Firstly, the nature of time series has been examined by using unit root tests. Secondly, a co-integrating test on non-stationary variables was carried out to determine whether we have short-term or long-term relationships between variables in the study. Thirdly, we apply the Granger Causality Test under the VAR model.

Unit root testing procedure

To test the stationarity of all variables in the level we have used the Augmented Dickey-Fuller (ADF) Tests, Phillip-Perron Tests, and KPSS Tests. Before applying each test, we used the Akaike (1973) (AIC), (LR), (FPE), (SIC) and (HQ) information criteria to determine the appropriate lag length of the variables in the study. All tests were developed at the 5% significance level. The Table 1 below shows the test results for all the variables in levels.

Table 1: Results of unit root tests of variables at levels

Unit Root Tests					
Variables	Augmented Dickey Fuller (ADF)			Phillips Perron (PP)	Newey-West Bandwidth (KPSS)
	With constant and trend	With constant but without trend	Without constant and trend	With constant and trend	With trend
ln_A	-1.847	-0.795	0.75	-1.896	t > 0.146
lnenrol_ratio	-1.019	-1.386	0.13	-0.792	t > 0.146

The test results in Table 1 reveal that all variables are non-stationary in levels. To determine the order of integration of variables, we created the new variables based on their first differences as follows:

ln_AD1 = $ln\_A_t - ln\_A_{t-1}$

lnenrol_ratioD1 = $lnenrol\_ratio_t - lnenrol\_ratio_{t-1}$

Table 2: Results of unit root tests of variables at first difference

Unit Root Tests					
Variables	Augmented Dickey Fuller (ADF)			Phillips Perron (PP)	Newey-West Bandwidth (KPSS)
	With constant and trend	With constant but without trend	Without constant and trend	With constant and trend	With trend
ln_AD1	-6.72	-6.587	-6.574	-6.72	t < 0.146
lnenrol_ratioD1	-4.035	-3.576	-3.606	-3.875	t < 0.146

The results show that ADF, PP and KPSS tests ***reject*** the null hypothesis H_0 of the unit root on the first difference of the variables, meaning that these variables are integrated in the first order, I(1). This finding implies that there may be one or more interaction vectors between these variables, so the next step in our analysis is to identify the existence of short or long- run relationships between them.

The co-integrated test results

To test the existence of a co-integrating relationship between human capital and technological change, we used the two-step of Engle and Granger's (1987) cointegration test. The results of this test are given in Tables 3 and 4 below.

Table 3: OLS model of TFP and gross enrollment rates in secondary education

```
. reg ln_A lnenrol_ratio

      Source |       SS       df       MS              Number of obs =      37
-------------+------------------------------           F(  1,    35) =    2.07
       Model |  .043126944     1  .043126944           Prob > F      =  0.1588
    Residual |  .728218094    35  .020806231           R-squared     =  0.0559
-------------+------------------------------           Adj R-squared =  0.0289
       Total |  .771345038    36  .021426251           Root MSE      =  .14424

------------------------------------------------------------------------------
        ln_A |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnenrol_ratio |    .326225   .2265894     1.44   0.159     -.133776    .7862259
       _cons |   4.382844   .9979742     4.39   0.000     2.356849    6.408839
------------------------------------------------------------------------------
```

Summing up the results of the Tables 3 and 4, we observe that: under the Engle and Granger (1987) method, the value of the z (t) test in absolute value is (1.126), which is smaller than the critical value of 5% (1,950), so we can not reject the null hypothesis H_0 of a unit root, and conclude that there is not a long-run relationship, they are not co-integrated, and a short-run relationship exist between them.

Table 4: ADF test on residual of the OLS regression (ln_A and lnenrol_ratio)

```
. dfuller uhat,nocons

Dickey-Fuller test for unit root                   Number of obs   =        36

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.126            -2.642            -1.950            -1.604
```

VAR model

Based on this result we have applied the standard model of Granger's causality under the Vector Autoregressive Model (VAR) to determine the causality of this relationship. Through this test we will see if changes in gross enrollment rates in secondary education can cause changes in TFP, or whether TFP changes can cause changes in gross enrollment rates in secondary education or if a dual causality exist in the short run. Before appling the VAR model, firstly, we ensured that we have correctly determined the right length of the lag based on information criteria tests.

Table 5: The lag length in the VAR model

Selection-order criteria
Sample: 1989 - 2014 Number of obs = 26

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-39.8536				.085763	3.21951	3.24738	3.31628*
1	-33.6397	12.428	4	0.014	.072477	3.04921	3.13281	3.33954
2	-31.4603	4.3589	4	0.360	.084011	3.18925	3.32859	3.67314
3	-29.8793	3.162	4	0.531	.102981	3.37533	3.57041	4.05277
4	-24.9444	9.8698	4	0.043	.098995	3.30341	3.55423	4.1744
5	-16.8883	16.112	4	0.003	.076466	2.99141	3.29796	4.05595
6	-9.72354	14.33	4	0.006	.065182*	2.74796	3.11025*	4.00606
7	-7.43274	4.5816	4	0.333	.084361	2.87944	3.29746	4.33109
8	-4.89011	5.0853	4	0.279	.11399	2.99155	3.46531	4.63675
9	2.38143	14.543	4	0.006	.117957	2.73989	3.26938	4.57865
10	8.77429	12.786*	4	0.012	.154235	2.55582*	3.14106	4.58813

Endogenous: ln_AD1 lnenrol_ratioD1
Exogenous: _cons

From the results of Table 5, the FPE and HQIC criteria reach their minimum value for lag (p = 6).

The output of VAR model is included in the Appendix section. From it we can derive two equations. The first equation includes (ln_AD1) as a dependent variable to see if gross enrollment rates at high school are sufficiently important to explain TFP as a dependent variable. The second equation is (lnenrol_ratioD1) as dependent variables to see if TFPs are sufficiently important to explain gross school enrollment rates as a dependent variable.

ln_AD1 = 0.0129 + 0.206 ln_AD1_{t-1} - 0.094 ln_AD1_{t-2} + 0.219 ln_AD1_{t-3} - 0.074 ln_AD1_{t-4} + 0.235 $ln\_AD1_{t-5}^{*}$ + 0.046 ln_AD1_{t-6} - 0.011 $lnenrol\_ratioD1_{t-1}^{**}$ + 0.003 $lnenrol\_ratioD1_{t-2}$ -0.003 $lnenrol\_ratioD1_{t-3}$ - 0.005 $lnenrol\_ratioD1_{t-4}$ + 0.018 $lnenrol\_ratioD1_{t-5}^{***}$ - 0.010 $lnenrol\_ratioD1_{t-6}^{**}$

lnenrol_ratioD1 = -0.174 + 21.39 $ln\_AD1_{t-1}^{**}$ + 12.06 $ln\_AD1_{t-2}^{*}$ + 3.312 ln_AD1_{t-3} + 6.446 ln_AD1_{t-4} + 3.669 ln_AD1_{t-5} - 6.423 ln_AD1_{t-6} + 0.352 $lnenrol\_ratioD1_{t-1}^{**}$ + 0.061 $lnenrol\_ratioD1_{t-2}$ - 0.056 $lnenrol\_ratioD1_{t-3}$ + 0.146 $lnenrol\_ratioD1_{t-4}$ + 0.221 $lnenrol\_ratioD1_{t-5}$ – 0.370 $lnenrol\_ratioD1_{t-6}^{*}$

*Note: ***, ** and * determine the level of significance respectively 1%, 5% and 10%.*

From the results of Table 6 (Appendix) we note that more than 70% of the probability values (p-values) are not relevant to explain ***ln_AD1*** as a dependent variable, although the value of the chi^2 statistic is equal to 51.77 and is statistically important; the probability value is zero at 5% significance level. Moreover, R^2 confirms this result. It determined that only 63.3% of the changes occurring in TFP could be explained by changes in gross enrolment rates, while 36.7% of the changes are unexplained, belonging to variables that are not included in this study.

Meanwhile for the ***lnenrol_ratioD1*** as a dependent variables, the value of the chi^2 statistic is equal to 22.95 and is statistically important; the probability value is 0.02 at the 5% significance level. While R^2 estimates that only 43.3% of the changes occurring in gross enrolment rates at high school can be explained by changes in TFP, while 56.7% of the changes are unexplained that belong to variables that are not included in the study.

After evaluating the VAR model, we have employed the Granger causality test to determine the causality relationship that exists between the variables. According to Granger (1969), the basic idea of causality is that if the prediction of a time series improves by incorporating a second time series in it, then we can say that the second time series has a causal effect on the former. Under Granger's context, gross school enrolment rates would be termed “causal” for the TFP variable if the remaining gross enrolment rates in secondary school are useful for improving TFP forecasting (in future times).

Table 7: The Granger causality test under VAR model

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
ln_AD1	lnenrol_ratioD1	38.832	6	0.000
ln_AD1	ALL	38.832	6	0.000
lnenrol_ratioD1	ln_AD1	10.922	6	0.091
lnenrol_ratioD1	ALL	10.922	6	0.091

Table 4 shows that the probability value of H_0 “that changes in TFP does not cause changes in gross enrollment rates in high school” is equal to 0.00%. Since $p < 5\%$, in this case we reject the H_0 hypotheses, and we conclude that changes in TFP cause changes in gross enrollment rates at high school.

Meanwhile, for H_0 “that changes in gross school enrollment rates do not cause changes in TFP” is equal to 0.091%. Since $p > 5\%$, in this case we can not reject the H_0 hypotheses, and we conclude that the gross tuition rates at secondary school do not cause changes to TFP.

So, the results will depended on the level of significance. If $p = 0.05$, we see that exist only one direction in the short run equilibrium, running from TFP to the gross enrollment rates in high school. But if $p = 0.1$ then we see that a bivariate causality relationship exist, which affect each variable in the short run.

Diagnostics check

After evaluating the VAR model, the next step is to determine if the selected model gives an accurate description of the data and if the model is well-specified. The model will be diagnosed in order to detect errors. This stage is crucial as it confirms the results of the parameter estimates obtained by the VAR model.

Stability test

Through this test we determine whether VAR equations are stable or not. Stability refers to controlling whether the model is a good representation of how time series developed during the sampling period. The general rule in this test is that there would be a problem of stability if any of the remaining calculated modules is very close to one. Technically, the stability of a VAR system is estimated using the roots of the matrix A coefficient polynomial characteristics. Stability in a VAR pattern is indicated by roots that are all less than 1 and are usually shown in a graph. If these conditions do not stand, VAR means that TFP and gross record rates are not jointly ergodic: the shock' effects do not die.

Table 8: Stability test of the VAR model

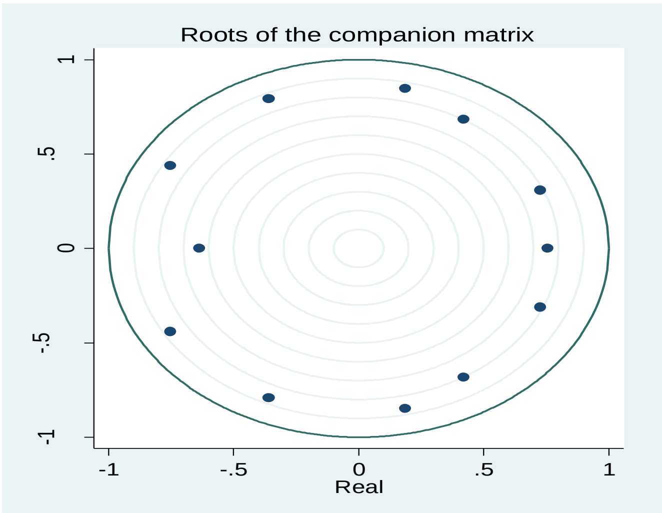
Eigenvalue stability condition

Eigenvalue	Modulus
-.7520414 + .4395579*i*	.871078
-.7520414 - .4395579*i*	.871078
-.3604142 + .7922837*i*	.870409
-.3604142 - .7922837*i*	.870409
.1860719 + .8474036*i*	.867592
.1860719 - .8474036*i*	.867592
.420013 + .6827962*i*	.801637
.420013 - .6827962*i*	.801637
.7263695 + .309989*i*	.78975
.7263695 - .309989*i*	.78975
.7552284	.755228
-.6372126	.637213

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Therefore, the state of stability of the Eigen values shown in the table above indicates that the remaining modules are not very close to 1 which implies that VAR is stable. Below in Figure 1 we provide the unit roots accompanying matrix. None of the Eigen values is close to 1, so we conclude that our system is stable.

Figure 1: Roots of the companion matrix of the VAR model



LM test of autocorrelation

In time series models, the autocorrelation of the residuals values is used to determine the exact fit of the model. After evaluating a VAR model, the residuals should be a white noise and should not have autocorrelation. If autocorrelation is observed between the residuals, then it is implied that there were some information that was not ascertained by the model, such as insufficient lags. The test of Lagrange Multiplier (LM) tests the serial correlation of the residues up to the specified order of the lag. Harris (1995) argued that the lag order for this test should be the same as that of the corresponding VAR. The LM tests the H_0 hypothesis that there is no serial correlation, versus alternative hypothesis H_a, that the residuals are auto-correlated.

Table 9: LM test of the VAR model

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	3.3375	4	0.50302
2	3.3135	4	0.50680
3	1.9080	4	0.75268
4	4.4013	4	0.35442
5	4.5958	4	0.33134
6	2.2190	4	0.69556

H0: no autocorrelation at lag order

From the Table 9 we note that the probability values are greater than 5% ($p > 0.05$) for each lag value, which indicates that the hypothesis H_0 “that there is no autocorrelation in the residues for any of the tested residues” cannot be rejected.

Testing for normality of residuals

To test if the residual of the model have normal distribution we have used the statistics of Jarque-Bera. Jarque-Bera's statistical testing as explained by Mantalos (2010) indicates whether the residues have normal distribution or not. However, the lack of normality of residuals does not cause the co-integration tests and VAR to be invalid. The test results are presented in the Table 10 below.

Table 10: Tests for normality, skewness, and kurtosis of the residuals in the VAR

varnorm

Jarque-Bera test

Equation	chi2	df	Prob > chi2
ln_AD1	0.105	2	0.94897
lnenrol_ratioD1	43.113	2	0.00000
ALL	43.218	4	0.00000

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
ln_AD1	-.08169	0.033	1	0.85506
lnenrol_ratioD1	-1.4329	10.267	1	0.00135
ALL		10.300	2	0.00580

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
ln_AD1	2.761	0.071	1	0.78933
lnenrol_ratioD1	8.1261	32.847	1	0.00000
ALL		32.918	2	0.00000

The single equation and overall Jarque-Bera statistics do not reject the normality value at 5% significance level. The skewness results for ln_AD1 do not suggest non-normality. Kurtosis test statistics, which test the null hypothesis H_0 that the terms of disturbance have kurtosis consistent with normality, do not reject the null hypothesis H_0.

CONCLUSIONS

In this research we want to examine the dynamic relationships between gross enrolment rates in secondary education and TFP in Albania. Based on implications of endogenous growth theory, Granger's causality relationship may exist between human capital and technological change and the causality-effect can be derived either from human capital to technological change or from technological changes to human capital. To evaluate whether there has been any causality relationship between human capital and technological changes in Albania, we have used gross enrolment rates in secondary education as a proxy for human capital and TFP as a proxy for technological change. To analyse this relationship we used time series techniques. The Engle and Granger (1987) co-integration test results indicated that there is not a significant long-run relationship between the gross enrolment rates in secondary education and TFP in Albania. This means that the two variables do not affect each in the long run, but they have causality relationship in the short-run. In this case, we have applied the Granger Causality test under the standard VAR model. The results show a strong causality running from TFP to secondary level education at 5 % significance level, but a bi-variate causality is evident when the significance level is 10 %. This means that not only TFP Granger causes gross enrolment rates in secondary education but also gross enrolment rates in secondary education Granger causes TFP in short run equilibrium. By investing more in secondary education we will have a better educated work force, which will increase the overall productivity in the economy, which will help in knowledge development and so by improve the Albanian's future prospects.

SUGGESTED FURTHER RESEARCH

In this study we have used enrolment rates in secondary level education as proxies to measure human capital. A similar analysis can be done in a macroeconomic level by using different measures of human capital such as government expenditures one secondary or tertiary education and also different education attainments. It will also be interesting to carry out a research in microeconomic level by using vocational training as a proxy for human capital. In this way we can see how the firms respond to technology shocks by offering more or less on the job-training.

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APPENDIX

Table 6: VAR Model

```
. var ln_AD1 lnenrol_ratioD1, lags (1/6)

Vector autoregression

Sample:  1985 - 2014                             No. of obs      =        30
Log likelihood = -18.94069                       AIC             =  2.996046
FPE            =  .0775317                       HQIC            =  3.384534
Det(Sigma_ml)  =  .0121183                       SBIC            =  4.210417
```

Equation	Parms	RMSE	R-sq	chi2	P>chi2
ln_AD1	13	.061025	0.6331	51.7708	0.0000
lnenrol_ratioD1	13	3.2321	0.4335	22.95805	0.0281

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_AD1						
ln_AD1						
L1.	.2059044	.1571002	1.31	0.190	-.1020063	.5138152
L2.	-.0938332	.1362108	-0.69	0.491	-.3608015	.1731351
L3.	.2190992	.1504157	1.46	0.145	-.07571	.5139085
L4.	-.0742514	.1537743	-0.48	0.629	-.3756434	.2271406
L5.	.2348943	.1422813	1.65	0.099	-.0439719	.5137605
L6.	.0463924	.1480115	0.31	0.754	-.2437049	.3364896
lnenrol_ratioD1						
L1.	-.0107006	.0033871	-3.16	0.002	-.0173393	-.004062
L2.	.0032934	.0039049	0.84	0.399	-.0043601	.0109469
L3.	-.0035003	.0035102	-1.00	0.319	-.0103801	.0033795
L4.	-.0049805	.0034774	-1.43	0.152	-.0117962	.0018351
L5.	.0184155	.0034185	5.39	0.000	.0117153	.0251157
L6.	-.0103219	.0037014	-2.79	0.005	-.0175766	-.0030672
_cons	.012982	.0091553	1.42	0.156	-.004962	.0309261
lnenrol_ratioD1						
ln_AD1						
L1.	21.39784	8.32055	2.57	0.010	5.089866	37.70582
L2.	12.0559	7.214177	1.67	0.095	-2.083626	26.19543
L3.	3.311816	7.966514	0.42	0.678	-12.30226	18.9259
L4.	6.445536	8.144397	0.79	0.429	-9.517188	22.40826
L5.	3.668831	7.53569	0.49	0.626	-11.10085	18.43851
L6.	-6.422528	7.839183	-0.82	0.413	-21.78704	8.941988
lnenrol_ratioD1						
L1.	.352109	.1793936	1.96	0.050	.0005041	.7037139
L2.	.0606092	.2068177	0.29	0.769	-.3447461	.4659645
L3.	-.0558977	.1859102	-0.30	0.764	-.420275	.3084795
L4.	.1461257	.1841768	0.79	0.428	-.2148543	.5071056
L5.	.2205854	.1810572	1.22	0.223	-.1342803	.5754511
L6.	-.3700899	.196041	-1.89	0.059	-.7543232	.0141435
_cons	-.1739475	.4848947	-0.36	0.720	-1.124324	.7764286