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THE IMPACT OF EDUCATION ON ECONOMIC GROWTH IN TURKEY

TÜRKİYE'DE EĞİTİMİN EKONOMİK BÜYÜMEYE ETKİSİ

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ABSTRACT

This paper aims to investigate the relationship between per capita school enrolments and per capita economic growth in Turkey over the period 1923-2007. Using the Autoregressive Distributed Lag (ARDL) approach to cointegration, we find evidence of long-run cointegrating relationships between school enrolments and real income. There is evidence of bi-directional long-run Granger causality between real income and school enrolments. There is a uni-directional short-run Granger causality running from enrolments in secondary, high, and technical high schools to real income. The results also suggest that high school enrolments Granger-cause higher education enrolments in the short run. The variance decomposition and impulse response analyses confirm the results of Granger causality tests. Overall, the results indicate that education is a means of long-run economic growth in Turkey and vice versa.

ÖZET

Bu makale, kişi başına okula kayıt olma ve ekonomik büyüme arasındaki ilişkiyi 1923-2007 dönemi Türkiye verileriyle incelemeyi amaçlamaktadır. Otoregresif Dağıtılmış Gecikme (ARDL) yaklaşımını kullanarak, okula kayıt olma ile reel gelir arasında uzun dönem eşbütünleşme olduğu bulunmuştur. Reel gelir ve okula kayıt olma arasında iki yönlü Granger nedenselliği vardır. Ortaokul, lise ve meslek lisesinden reel gelire doğru kısa dönem tek yönlü Granger nedenselliği vardır. Sonuçlar, ayrıca liseye kayıtlarının yüksek öğrenime kayıt olmanın kısa dönemde Granger nedeni olduğunu göstermektedir. Varyans ayrıştırması ve

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etki tepki analizleri Granger nedensellik testlerinin sonuçlarını teyit etmektedir. Genel olarak, sonuçlar eğitimin ekonomik büyümenin bir aracı (ve tersi) olduğunu göstermektedir.

Education; Economic Growth, Cointegration, Granger Causality, Forecast Error Variance Decomposition, Impulse Response.
Eğitim, Ekonomik Büyüme, Eşbütünleşme, Granger Nedenselliği, Öngörü Hata Varyans Ayrıştırması.

1. INTRODUCTION

The relationship between economic growth and education has been one of the central threads of the economic analysis. Theoretical models extensively analyzed the relationship between economic growth and education (see, for example, Solow, 1957; Uzawa, 1965; Lucas, 1988; Romer, 1986, 1987, 1990; Barro, 1991; Barro and Lee, 1993, 1994; Barro and Sala-i-Martin, 1995). Romer (1990) suggests that education is important because some of the educated will create new ideas, which is a direct function of human capital. These knowledge spillovers are a form of externality, which will lead to technological progress, and hence long-term economic growth. Therefore, investment in human capital promotes growth in physical capital and this, in turn, results in economic growth. Human capital accumulation might promote growth through either facilitating technology adaption or human capital might be necessary for the use of technology.

However, being assumed as a crucial factor in economic growth, empirical evidence is mixed and puzzling [see, Johnes (2006) for a survey of recent literature on economic growth and education]. Jorgenson et al. (2000) find a positive contribution of education to economic growth, whereas Benhabib and Spiegel (1994) show that changes in education provide non-significant and sometimes even negative coefficients when entered into a growth regression. Islam (1995) and Caselli et al. (1996) report that the education variables appear with the wrong sign in the growth regressions. Pritchett (2001) finds that changes in schooling have no impact on economic growth. Temple (2001) revisits Pritchett's results and concludes that the aggregate evidence on the education-growth nexus, for a large sample of countries, continues to be clouded with uncertainty. The systematic failure of regressions has led some researchers to question the quality of the education data. Krueger and Lindahl (2001) argue that measurement error in the number of years of schooling is a major cause of the apparent lack of significance of education variable in growth regressions. In estimation, Krueger and Lindahl (2001) split countries into three groups based on education levels. They find a statistically significant positive link between education and growth only for the countries with the lowest level of education. They then explore a quadratic relationship between economic growth and the years of schooling. They find that for low levels of education,

education contributes positively to growth, whereas for high levels of education it depresses the rate of growth.

Soto (2002) discusses the puzzling lack of relationship between education and economic growth in empirical studies and argues that the controversial results may stem from the following reasons: the problem of definition of the education variables, the existence of co-linearity between physical and human capital stocks, and the failure to tackle with measurement error and endogeneity. He further suggests that after dealing with these problems, the neoclassical approach to human capital is strongly supported by the data. Stevens and Weale (2004) note that the lack of correlation between education and economic growth is implied by neither growth models but needs to be explained by the catch-up phenomenon that countries are catching up with each other, but that differences in steady states will arise from differences in educational attainment. Levine and Renelt (1992) suggest that, along with the rate of investment in new capital, education appears to be significant. Hanushek and Kimko (2000) find that the quality of labour has strong causal relationship with economic growth, but it is not related to investment in formal schooling. Similarly, Bosworth and Collins (2003) report that the growth of output per worker is contributed to increases in physical capital per worker and technological progress and only 0.3 % contributed by increases in human capital, as measured by education. Gyimah-Brempong et al. (2006) find that all levels of education have positive effect on the growth rate of per capita income in African counties.

However, there are a few studies which examine the relationship between education and economic growth within a causality framework and report mixed results. De Meulemeester and Rochat (1995) find uni-directional short-run Granger causality running from higher education enrolments to economic growth for Sweden, the United Kingdom, Japan, and France and neutrality between higher education enrolments and economic growth for Australia and Italy. In and Doucouliagos (1997) and Asteriou and Agiomirgianakis (2001) find bi-directional causality between economic growth and primary and secondary school enrolments for the United States and Greece, respectively. Chuang (2000) reports that per capita university graduates Granger-cause income for Taiwan. Self and Grabowski (2003) find a causality relationship between primary education and economic growth for Japan in both the pre-war and post-war periods. They find evidence of Granger causality running from secondary and tertiary education to economic growth for the post-war period and feedback from income to all levels of education in both periods. Self and Grabowski (2004) find a uni-directional Granger causality running from primary education enrolments to income for India. Sari and Soytas (2006) examine the relationship between real income and enrolments in primary, secondary, and high schools, and higher education in Turkey for the period of 1937–1996 in a multivariate framework. They find a long-run cointegrating relationship between real income and educational variables and bi-directional Granger causality between real income and educational variables both in the long-run and in the short-run.

With the exception of the study by Sari and Soytas (2006) for Turkey, scant attention has been given to examining the relationship between economic growth and education within a multivariate framework. This is in spite of the fact that there is a clear conceptual link between the two given that endogenous growth theory has argued that education is the primary engine of growth. The main objective of this paper is to analyze if there is and what is the relationship between economic growth and education. The motivation of this study is twofold: First, despite the importance of human capital stock in the long-term economic growth, scant attention to its empirical analysis in Turkey provides a good rationale to revisit and study the relationship between economic growth and education. Second, our annual data spans the time period 1923-2007 which covers the entire republican era in Turkey.

This research paper makes three contributions to the existing literature on the education-economic growth nexus. Firstly, we examine the education-growth nexus using causality testing within a multivariate cointegration and error-correction framework. Secondly, we employ bounds testing approach to cointegration within the framework of the Autoregressive distributed lag (ARDL) developed by Pesaran and others (Pesaran and Pesaran, 1997; Pesaran and Shin, 1999; Pesaran et al., 2001) that has become popular amongst the researchers. Third, we go further than testing for Granger causality. Through application of variance decomposition analysis and impulse response functions we attempt to explain the total forecast error variance of each of the variables beyond the sample period, in terms of the proportions attributable to innovations or shocks in each variable. Following this introduction, next section gives a brief discussion of the Turkish educational system. The data is discussed in the third section. Econometric methodology and empirical results are set out and discussed in the fourth section, and finally in the fifth section we offer some conclusions.

2. AN OVERVIEW OF THE TURKISH EDUCATIONAL SYSTEM

After the Ottoman Empire deceased, the Republic of Turkey, being to its successor, was founded in 1923. Even though the westernisation of the Turkish educational structure was not a novel process, which was initiated in the late of 18^{th} century, the newly founded Turkish Republic successfully completed the westernisation process by implementing many important reforms, such as the adoption of Latin letters and western calendar and the abolition of Arabic letters, and relinquishing of the conventional schools at all levels of education and establishing of the new ones instead. In Turkey elementary education did not become compulsory until 1923 in which free education was introduced at all levels of schooling in public schools. During the first decade of the Republic, widespread campaigns were introduced to eradicate illiteracy. There has been a big commensurate drop in the rate of adult illiteracy, which has declined from 81.3% in 1935 to 13.5% in 2000, although there was a big gender gap, 6.14 % for males and 19.36% for females (Turkish Statistical Institute, 2008). The accumulation of basic human capital since 1923 has also been rapid. Primary school enrolment rates rose gradually from 2% in 1923 to 15% in 2007, but the enrolments rates are particularly low among girls in the poor regions and many families lack the incentive to send their girls to school, due to both economic and cultural factors. Secondary school enrolment rates increased rapidly from 4‰ in 1923 to 4% in 2007. High school and technical high school enrolment rates increased from 1‰ and 4‰ in 1923 to 2% and 1.7% in 2007. Higher education enrolment rates increased from 2‰ in 1923 to 3% in 2007. In Turkey, education starts with kindergarten (ages 3-6) and continues with primary school (ages 7-12), secondary school (ages 12-15), and high school (15-18) and university. High school education includes general high schools, specialized high schools, vocational high schools, and technical training high schools. Higher education, which includes universities and colleges as well as programs for postgraduates, requires four years for a bachelor's degree, two to three years for a master's degree, and another three to four years for a doctorate. The mandatory eight-year education policy began in the school year of 1997-1998.

3. DATA AND METHODOLOGY

Annual data set for Turkey spans the time period 1923-2007 and includes the rate of growth of per capita real GDP (ln *y*), per capita enrolments in primary school (ln *pri*), in secondary school (ln *sec*), in high school (ln *high*), in technical high schools (ln *thigh*) and in higher education (ln *uni*). Per capita enrolment rates are obtained by dividing enrolments series by total mid-year population. To measure economic growth, empirical studies make use of per capita real GDP growth. Therefore, per capita real GDP (ln *y*) is included to represent economic growth. Per capita enrolment rates of all levels of education are used as proxies for human capital stock, because school enrolment rates or average years of schooling are the standard indicators used to represent human capital stock in the empirical literature. Nevertheless, using enrolment rates or average years of schooling as an indicator of a country's human capital is criticised for it tends to neglect to measure the quality of education within and outside the classroom. A more appropriate measure of human capital stock may be the performance of students on tests in math and science, something that might be called the average level of cognitive skills among those entering a country's work force (Hanushek and Wößmann, 2007). However, international data on student performance is not available for a large number of countries, including Turkey, over a long enough period of time to allow for empirical study, which is why we rely on less informative measures, such as school enrolment.

In 1997 the authorities in Turkey implemented an eight-year mandatory primary education policy, increasing the mandatory education from five to eight years and hence combining primary and secondary education. Therefore, the basic human capital stock, namely the primary and secondary education is represented by primary education after 1997.

However, since we make use of school enrolments rather than graduates, and the decomposition of the data is available both on primary and secondary school enrolments after 1997, we further decompose the basic human capital stock into primary and secondary school enrolments. Both total mid-year population and real GDP series are obtained from *Historical Statistics for the World Economy: 1-2006 AD* (Maddison, 2008) and *Total Economy Database* (The Conference Board and Groningen Growth and Development Centre, 2008). The school enrolment data series of all levels of education are taken from *Statistical Indicators 1923-2007* (Turkish Statistical Institute, 2008). The data series are expressed in natural logarithms.

3.1. Unit Roots Tests

An important preliminary analysis of the models is to test for the order of integration of the variables entering into the models, and to check clearly whether they have a unit root. We present unit root tests for the variables so as to investigate the time series characteristics of the data and consistency in the subsequent econometric modelling. For this purpose, we perform two commonly used unit root tests, namely the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981) and Phillips-Perron (PP) test (Phillips and Perron, 1988), and a relatively new and more powerful generalized least squares (GLS)-detrended Dickey–Fuller (DF-GLS) unit root test proposed by Elliot et al. (1996). The PP test uses the same critical values of the ADF test, which are from MacKinnon (1991), whereas the critical values of DF-GLS test are tabulated in Elliot et al. (1996). Table 1 reports the results of the unit root tests. The statistics for the levels of (ln y_t, ln pri_t, ln sec_t, ln $high_t$, ln $thigh_t$, ln uni_t) do not exceed the critical values (in absolute terms). That is (ln y_t, ln pri_t, ln sec_t, ln $high_t$, ln $thigh_t$, ln uni_t) are integrated at order zero in the levels. When we take the first difference of each of the variables, the ADF, DF-GLS and PP statistics are higher than their respective critical values (in absolute terms). Therefore, we conclude that (ln y_t, ln pri_t, ln sec_t, ln $high_t$, ln $thigh_t$, ln uni_t) appear to contain a unit root in their levels but stationary in their first differences, indicating that they are integrated at order one, i.e., $I(1)$.

Table 1: Results of the Unit Root Tests

Levels						
Statistics	**ln *y***	**ln *pri***	**ln *sec***	**ln *high***	**ln *thigh***	**ln *uni***
τ_T(ADF)	-2.78 (0)	-1.25 (0)	0.77 (5)	1.20 (7)	0.74 (0)	1.14 (0)
τ_μ(ADF)	-0.91 (0)	-1.49 (0)	-0.99 (5)	0.66 (7)	-1.10 (0)	1.16 (0)
τ_T(PP)	-2.91 (2)	-1.26 (3)	0.60 (4)	1.84 (1)	1.46 (8)	1.65 (1)
τ_μ(PP)	-0.91 (2)	-1.81 (3)	-1.04 (4)	-0.97 (2)	-1.87 (8)	1.91 (1)
τ_T(DF-GLS)	-2.37 (0)	0.46 (1)	1.43 (5)	1.05 (7)	1.82 (0)	1.55 (1)
τ_μ(DF-GLS)	-2.16 (2)	-1.81 (1)	-1.20 (5)	-0.98 (7)	-1.44 (0)	0.18 (1)

First Differences						
Statistics	**Δln *y***	**Δln *pri***	**Δln *sec***	**Δln *high***	**Δln *thigh***	**Δln *uni***
τ_T(ADF)	-9.90[a] (0)	-7.31[a] (0)	-4.57[a] (4)	-6.51[a] (0)	-8.30[a] (0)	-5.46[a] (0)
τ_μ(ADF)	-9.95[a] (0)	-7.30[a] (0)	-4.77[a] (4)	-6.97[a] (1)	-8.49[a] (0)	-6.98[a] (0)
τ_T(PP)	-9.90[a] (1)	-7.32[a] (2)	-6.50[a] (2)	-6.36[a] (2)	-8.46[a] (7)	-5.47[a] (3)
τ_μ(PP)	-9.96[a] (1)	-7.31[a] (2)	-6.55[a] (2)	-6.94[a] (1)	-9.80[a] (7)	-6.98[a] (0)
τ_T(DF-GLS)	-3.98[a] (1)	-7.18[a] (0)	-4.11[a] (4)	-6.01[a] (0)	-8.16[a] (0)	-5.25[a] (0)
τ_μ(DF-GLS)	-2.42[b] (1)	-7.35[a] (0)	-4.18[a] (4)	-6.20[a] (0)	-8.59[a] (0)	-6.89[a] (0)

Notes: τ_T represents the model with an intercept and trend; and τ_μ is the model with an intercept and without trend. The maximum available sample is used and varies across the null order. Performing the ADF and DF-GLS unit root tests, the optimum lag length was chosen based on the evidence provided by Schwarz Bayesian Criterion (SBC) - up to 8 lags. To perform the non-parametric correction to the PP statistic, we use the Newey-West adjusted variances with Barlett-Kernel weights. **Δ** is the first difference operator. The order of lags is expressed in the parentheses. Superscript *a* denotes rejection of the null hypothesis at the 1% significance level.

3.2. Cointegration Tests

To examine the long-run relationship among (ln y_t, ln pri_t, ln sec_t, ln $high_t$, ln $thigh_t$, ln uni_t), using ARDL cointegration approach, also known as bounds testing, has certain econometric advantages in comparison to other univariate and multivariate cointegration procedures. Firstly, the bi-variate cointegration test introduced by Engle and Granger (1987) and the multivariate cointegration technique proposed by Stock and Watson (1988), Johansen (1988, 1991) and Johansen and Juselius (1990) may be appropriate for large sample size. Nevertheless, Carruth et al. (2000, p. 289) argue that "single equation methods have been criticized because they ignore the possibility of multiple vectors but, in practice, they can give eminently sensible results (albeit of a reduced form nature) and generate adequate dynamic models". Carruth et al. (2000) suggest that the likelihood of multiple cointegrating vectors does not facilitate the identification of the possible static long-run cointegration between the variables. They further argue that "the possibility of multiple cointegration vectors can lead to severe identification problems, requiring researcher to provide an economic interpretation of the relationships that are identified. Moreover, the number of significant cointegrating vectors found is often dependent on the length of the lags chosen for the VAR, so careful reduction tests are called for" (Carruth et al., 2000, p. 289). Secondly, the bounds testing approach avoids the pre-testing of unit roots. This method does not require that the variables in a time series regression equation are integrated of order one. Bounds test could be implemented regardless of whether the underlying variables are $I(0)$, $I(1)$, or fractionally integrated. Thirdly, the long run and short run parameters of the model are estimated simultaneously to tackle with the problem of endogeneity and simultaneity. The ARDL bounds testing approach to cointegration involves investigating the existence of a long-run relationship using the following unrestricted error-correction models (UECM):

$$\Delta \ln y_t = a_{0y} + \sum_{i=1}^{p} b_{iy} \Delta \ln y_{t-i} + \sum_{i=0}^{p} c_{iy} \Delta \ln edu_{t-i} + \sigma_{1y} \ln y_{t-1} + \sigma_{2y} \ln edu_{t-1} + \varepsilon_{1t} \quad (1)$$

$$\Delta \ln edu_t = a_{0edu} + \sum_{i=1}^{p} b_{iedu} \Delta \ln edu_{t-i} + \sum_{i=0}^{p} c_{iedu} \Delta \ln y_{t-i} + \sigma_{1edu} \ln edu_{t-1} + \sigma_{2edu} \ln y_{t-1} + \varepsilon_{2t} \quad (2)$$

where ln y_t represents the per capita real income, and ln edu_t denotes the particular per capita school enrolment variables under investigation. The parameters *b*, *c* and *d* are the short run coefficients and σs are the corresponding long run multipliers of the underlying ARDL model. ε_{1t} and ε_{2t} are serially independent random errors with mean zero and finite covariance matrix. The hypotheses can be examined by using a non-standard *F*-statistics for investigating a long-term relationship in a multivariate system through testing the significance of the lagged levels of variables. When a long-run relationship exists between the variables, the *F*-test indicates which variables should be normalized. In Eq. (1), where is ln y_t the dependent variable, the null hypothesis of no cointegration between the variables is (H_0: σ_{1y}=σ_{2y}= 0) against the alternative hypothesis of cointegration (H_1: σ_{1y}≠σ_{2y}≠ 0). In Eq. (2), where ln edu_t is the dependent variable, the null hypothesis of no cointegration is (H_0: σ_{1edu}=σ_{2edu}= 0) against the alternative (H_1: σ_{1edu}≠σ_{2edu}≠ 0).

The non-standard bounds *F*-test depends on: (i) whether variables included in the ARDL model are *I*(1) or *I*(0), (ii) the number of regressors and (iii) whether the ARDL model contains an intercept and/or a trend. Two sets of critical values which provide critical value bounds for all classifications of the regressors into purely *I*(1), purely *I*(0) or mutually cointegrated. If the computed *F*-statistics falls outside the critical bounds, a conclusive decision can be made regarding cointegration without knowing the order of cointegration of the regressors. If the estimated *F*-statistic is higher than the upper bound of the critical values then the null hypothesis of no cointegration is rejected regardless of the order of integration of the variables. Alternatively, if the estimated *F*-statistic is lower than the lower bound of critical values, the null hypothesis of no cointegration cannot be rejected.

Bounds *F*-test was applied to Eq. (1) and Eq. (2) in order to test the existence of a long-run relationship. Eq. (2) was also estimated five more times in the same way but the dependent variable each time was replaced by one of the explanatory variables in search of other possible long-run relationship. Bahmani-Oskooee and Goswami (2003) have shown that the results of this stage are sensitive to the order of VAR. As we use annual data, all tests include a minimum of two and a maximum of four lags to ensure lagged explanatory variables are present in the UECM. Gonzalo (1994) suggests that the cost of over-parameterization in terms of efficiency loss is marginal. The lag order of one (VAR = 1) for all of the equations was chosen from unrestricted VAR by means of SBC, whilst ensuring there was no evidence of serial correlation (Pesaran et al., 2001). We employ a model with a restricted intercept and without trend, which is Case II in Pesaran et al. (2001, pp. 300-301). The results of bounds tests are presented in Table 2. Table 2 indicates the existence of long-run cointegrating relationships among the variables in all equations because their calculated *F*-statistics are higher than the upper bound critical value. For the equation when $\ln y_t$ is the dependent variable, F_y (.) = 4.3060 is higher than the upper bound critical value 4.15 at the 1% level of significance. Similarly, for the other equations when the per capita enrolment in primary, secondary, high school, technical high school and higher education variables are the dependent variable, their calculated F-statistics, namely, F_{pri} (.) = 5.3093, F_{sec} (.) = 3.8134, F_{high} (.) = 6.5119, F_{thigh} (.) = 4.2502, and F_{uni} (.) = 4.3518 are higher than the upper bound critical values, respectively. This implies that the null hypothesis of no cointegration among the variables cannot be accepted. Evidence of cointegrating relationships among the variables confirms the robustness of the estimated relationships.

Table 2: The Results of *f*-test for Cointegration

Calculated *F*-statistics		**Conclusion**
$F_y(\ln y_t \mid \ln pri_t, \ln sec_t, \ln high_t, \ln thigh_t, \ln uni_t)$	4.3060[a] [0.001]	H_0: Rejected
$F_{pri}(\ln pri_t \mid \ln y_t, \ln sec_t, \ln high_t, \ln thigh_t, \ln uni_t)$	5.3093[a] [0.000]	H_0: Rejected
$F_{sec}(\ln sec_t \mid \ln y_t, \ln pri_t, \ln high_t, \ln thigh_t, \ln uni_t)$	3.8134[b] [0.003]	H_0: Rejected
$F_{high}(\ln high_t \mid \ln y_t, \ln pri_t, \ln sec_t, \ln thigh_t, \ln uni_t)$	6.5119[a] [0.000]	H_0: Rejected
$F_{thigh}(\ln thigh_t \mid \ln y_t, \ln pri_t, \ln sec_t, \ln high_t, \ln uni_t)$	4.2502[a] [0.001]	H_0: Rejected
$F_{uni}(\ln uni_t \mid \ln y_t, \ln pri_t, \ln sec_t, \ln high_t, \ln thigh_t)$	4.3518[a] [0.001]	H_0: Rejected

Notes: The upper limits of the critical values for the F-test with five explanatory variables are (all $I(1)$ variables) are 4.15, 3.38 and 3.00 at 1%, 5% and 10% level of significance, respectively. Critical values of the F-statistics are obtained from Pesaran et al. (2001, pp. 300-301). Probability values are in square brackets. Superscripts *a* and *b* denote the rejection of null hypothesis of no cointegration at 1% and 5% level of significance, respectively.

3.3. Granger Causality Tests

In this stage, we construct standard Granger-type causality tests augmented with a lagged error-correction term where the series are cointegrated. We augment the Granger-type causality test with a lagged error-correction term for all the equations. Thus, the Granger causality test involves specifying a multivariate pth order vector error correction models (VECM) as follows:

$$\begin{bmatrix} \Delta \ln y_t \\ \Delta \ln pri_t \\ \Delta \ln \sec_t \\ \Delta \ln high_t \\ \Delta \ln thigh_t \\ \Delta \ln uni_t \end{bmatrix} = \begin{bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \\ \tau_5 \\ \tau_6 \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \rho_{11i}\rho_{12i}\rho_{13i}\rho_{14i}\rho_{15i}\rho_{16i} \\ \rho_{21i}\rho_{22i}\rho_{23i}\rho_{24i}\rho_{25i}\rho_{26i} \\ \rho_{31i}\rho_{32i}\rho_{33i}\rho_{34i}\rho_{35i}\rho_{36i} \\ \rho_{41i}\rho_{42i}\rho_{43i}\rho_{44i}\rho_{45i}\rho_{46i} \\ \rho_{51i}\rho_{52i}\rho_{53i}\rho_{54i}\rho_{55i}\rho_{56i} \\ \rho_{61i}\rho_{62i}\rho_{63i}\rho_{64i}\rho_{65i}\rho_{66i} \end{bmatrix} \begin{bmatrix} \Delta \ln y_{t-i} \\ \Delta \ln pri_{t-i} \\ \Delta \ln \sec_{t-i} \\ \Delta \ln high_{t-i} \\ \Delta \ln thigh_{t-i} \\ \Delta \ln uni_{t-i} \end{bmatrix} + \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \\ \phi_6 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \omega_{1t} \\ \omega_{2t} \\ \omega_{3t} \\ \omega_{4t} \\ \omega_{5t} \\ \omega_{6t} \end{bmatrix} \quad (3)$$

In addition to the variables defined above, Δ is the lag operator, ECT_{t-1} is the lagged error-correction term derived from the long-run cointegrating relationship, and ω_{1t}, ω_{2t}, ω_{3t}, ω_{4t}, ω_{5t}, and ω_{6t} are serially independent random errors with mean zero and finite covariance matrix. In each case the dependent variable is regressed against the past values of itself and other variables. The optimal lag length p is based on the SBC. The existence of cointegrating relationships among the variables under consideration suggests that there must be Granger causality in at least one direction, but it does not indicate the direction of temporal causality between the variables. We examine both short-run and long-run Granger causality in a multivariate framework. The short-run causal effects can be obtained by the F-statistics of the lagged explanatory variables in each of the six equations. The significant t-statistics on the coefficients of the lagged error-correction terms indicate the existence of the long-run causal effect. Table 3 summarizes the results of the long-run and short-run Granger causality.

Table 3: Results of Granger Causality Tests

Dependent Variable	**$\Delta\ln y_t$**	**$\Delta\ln pri_t$**	**$\Delta\ln sec_t$**	**$\Delta\ln high_t$**	**$\Delta\ln thigh_t$**	**$\Delta\ln uni_t$**	**ECT_{t-1} (t-stat.)**
$\Delta\ln y_t$	—	1.0429 [0.311]	7.8780^a [0.006]	9.1448^a [0.003]	2.1732^c [0.145]	0.1500 [0.700]	-0.9345^a (-6.4957)
$\Delta\ln pri_t$	0.7209 [0.399]	—	1.4022 [0.240]	0.7331 [0.395]	0.1039 [0.748]	0.2660 [0.608]	-0.8493^a (-5.5704)
$\Delta\ln sec_t$	1.0189 [0.316]	11.1195^a [0.001]	—	3.1768^b [0.079]	0.0063 [0.937]	1.3443 [0.250]	-0.7330^a (-3.0336)
$\Delta\ln high_t$	0.7017 [0.405]	0.7503 [0.389]	1.1366 [0.290]	—	0.8020 [0.373]	1.7698 [0.188]	-0.8355^a (-4.0676)
$\Delta\ln thigh_t$	0.0832 [0.774]	0.8188 [0.369]	0.4168 [0.521]	0.9113 [0.343]	—	0.0075 [0.931]	-0.7142^a (-4.9106)
$\Delta\ln uni_t$	0.0018 [0.966]	1.3942 [0.242]	0.6224 [0.433]	3.4710^b [0.066]	1.7239 [0.193]	—	-0.9340^a (-5.4463)

Notes: Probability values of the F-statistics are in square brackets. t-statistics of the ECT_{t-1} is in parentheses. Critical value of t-test is 2.66 at the 1% level of significance. Critical values of F-statistics are 3.65, 2.53 and 2.04 at the 1%, 5% and 10% level of significance, respectively. Superscripts a, b and c denote significance at the 1%, 5% and 10% level.

Each of the six equations passes all the standard diagnostic tests for residual serial correlation, functional form, normality and heteroscedasticity. Beginning with the result for the long-run, in all of the equations the coefficients on the lagged error-correction terms are significant with the expected signs at 1% significance level with the expected sign and plausible magnitude. This confirms the result of the bounds test for cointegration. In the long run there is a bi-directional Granger causality among the variables. This indicates that causality runs interactively through the error-correction term among the variables. Hence, economic growth drives the education and *vice versa* in the long run in Turkey. The coefficients on the lagged error correction terms in per capita income and higher education equations are larger than those of other equations. ECT_{t-1} measures the speed of adjustment to obtain equilibrium in the event of shock(s) to the system. The result suggests that changes in per capita enrolments in high school are a function of disequilibrium in the cointegrating relationship and implies that the series is non-explosive and that long-run equilibrium is attainable. For example, the coefficient of -0.9345 in the per capita real income equation indicates that a deviation from the equilibrium level of per capita real income during the current period will be corrected by 93 per cent in the next period. As for the short-run causality results, a uni-directional Granger causality running from per capita enrolments in secondary school, high school and technical high school to per capita real income because the *F*-statistics on the lagged differences of these explanatory variables are statistically significant. This emphasizes technical and vocational training as an important aspect of human capital and its important impact on economic growth as suggested by Temple (1999). There is evidence of uni-directional short-run Granger causality running from per capita enrolments in primary and high school to per capita enrolments in secondary school. Also, per capita enrolments in high school Granger-cause per capita enrolments in higher education but not *vice versa*. This implicitly indicates individuals' expectations of holding a university degree leading to a higher future monetary income.

The strong relationship between economic growth and education reflects the effects of increased schooling on economic growth or *vice versa*. Conceptually, schooling involves sacrificing current earnings for higher future earnings and economic growth, even when skill neutral, increases the wage gains from schooling. This follows that increases in productivity of schooling as a result of decreases in the opportunity cost of schooling. The strong long-run relationship between education and economic growth may also be due to the fact that education in Turkey is perceived as a productivity stimulant. In theory, the education provides monetary benefit as those who hold a higher level of education can expect higher income (Kim, 2002). It is generally acknowledged that in the early stages of the economic development, the quantity of schooling is a more important policy concern than that of quality. It might be due to the nature of education as a public good, so the government is responsible to ensure all people have access to education. Our results and the data indicate that resource allocation in schooling in Turkey seems to be based on output-maximising principle as proposed by a positive theory of human capital (Pritchett and Filmer, 1997). Hence, expansion in quantity of education by implementing eight-year mandatory schooling policy and increasing the number of universities and colleges in Turkey has been accomplished by improving the education quality. As a result, education is indeed a significant income determinant as well as a productivity determinant in Turkey.

3.4. Forecast Error Variance Decompositions and Impulse Response Functions

Granger causality test is constrained to the sample period, which is conveniently useful in detecting the possibility Granger exogeneity or endogeneity of the dependent variable within the sample period. Analyzing the degree of exogeneity of the variables beyond the sample period requires implementing other techniques, such as impulse responses and decomposition of variance methods, which measures the percentage of a variable's forecast error variance that occurs as a result of a shock from a variable in the system. Forecast error variance decompositions can be regarded as an out-of-sample causality test. An individual variable, which is truly exogenous with respect to the other variables in the system, will explain forecast error variance of each of the variable (Sims, 1980). A shock to an individual variable affects the variable itself and other variables in the system, generating variations both in it and in other variables. Forecast error variance decompositions show the relative importance of these affects, and impulse responses exhibit the dynamic responses of the variables to the shocks. We employ the generalized forecast error variance decomposition and generalized impulse response techniques of Koop et al. (1996) and Pesaran and Shin (1998). The generalized forecast error variance decomposition results are summarized in Table 4 over a 10-year period. For the brevity of presentation, we report the first 10-year period. Consistent with the findings from the Granger causality tests, the variance decomposition analysis indicates that enrolments in primary school, technical high school and higher education are the most exogenous variables, because a high proportion of its shocks are explained by its own innovations. Between 2.34 and 21.95% of the variation in per capita real income seems to be due to the innovations in school enrolments variables at the end of 10 years; whereas shocks to the per capita real income seem to account for about 1.09, 4.63, 12.95, 4.81 and 3.32% changes in per capita primary, secondary, high school, technical high school and higher education enrolments, respectively. Note that at the end of 10 years very little of the forecast error in per capita real income is explained by per capita enrolments in primary school. Also, per capita enrolments in technical high school explain only 1.21% of the forecast error in per capita enrolments in higher education.

Table 4: Results of Generalized Forecast Error Variance Decomposition (percentage of forecast variance explained by innovations)

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Variance Decomposition of $\Delta \ln y$										
$\Delta \ln y$	100.00	88.45	71.96	68.90	63.73	61.22	60.99	60.66	59.79	58.71
$\Delta \ln pri$	0.00	2.21	3.43	3.64	5.98	5.80	5.78	6.17	6.14	7.15
$\Delta \ln sec$	0.00	1.17	1.09	1.44	2.46	2.43	2.43	2.43	2.39	2.34
$\Delta \ln high$	0.00	6.71	17.14	19.44	20.31	22.68	22.69	22.68	22.35	21.95
$\Delta \ln thigh$	0.00	1.09	4.07	4.05	5.18	5.14	5.28	5.25	5.95	6.05
$\Delta \ln uni$	0.00	0.32	1.98	2.50	2.31	2.70	2.80	2.78	3.35	3.76

Variance Decomposition of Δln *pri*										
Δln *y*	0.00	0.07	0.66	0.67	0.63	0.78	0.89	0.94	1.08	1.09
Δln *pri*	99.99	99.53	97.85	95.62	89.93	75.80	75.44	74.78	73.85	73.08
Δln *sec*	0.00	0.02	0.24	0.33	0.40	1.22	1.22	1.40	1.41	1.68
Δln *high*	0.00	0.10	0.49	0.95	1.06	2.89	2.96	2.94	3.14	3.11
Δln *thigh*	0.00	0.09	0.59	1.31	6.29	16.94	16.77	17.24	17.10	17.08
Δln *uni*	0.00	0.15	0.15	1.08	1.66	2.34	2.69	2.67	3.39	3.93
Variance Decomposition of Δln *sec*										
Δln *y*	4.35	3.94	5.28	5.18	4.90	4.83	4.77	4.70	4.63	4.63
Δln *pri*	3.75	7.49	8.40	9.36	8.86	9.17	8.87	9.30	9.13	9.32
Δln *sec*	91.88	84.05	81.44	79.15	76.42	73.42	71.35	70.62	69.40	69.16
Δln *high*	0.00	0.87	1.25	1.28	1.27	1.64	1.76	1.82	2.36	2.41
Δln *thigh*	0.00	1.22	1.18	1.30	1.23	2.48	4.09	4.25	4.91	4.94
Δln *uni*	0.00	2.40	2.42	3.70	7.28	8.43	9.03	9.23	9.54	9.51
Variance Decomposition of Δln *high*										
Δln *y*	0.06	2.72	8.17	9.98	12.24	12.49	12.62	13.00	13.01	12.95
Δln *pri*	1.62	2.32	2.41	3.06	2.91	3.22	4.79	5.02	5.01	5.15
Δln *sec*	29.48	26.42	24.32	22.85	21.69	21.15	20.70	20.55	20.50	20.47
Δln *high*	68.83	67.12	62.33	61.38	57.64	56.75	54.63	54.05	54.06	53.85
Δln *thigh*	0.00	1.14	1.26	1.27	1.20	1.92	2.74	2.71	2.73	2.91
Δln *uni*	0.00	0.25	1.49	1.42	4.28	4.44	4.49	4.64	4.67	4.65
Variance Decomposition of Δln *thigh*										
Δln *y*	0.66	4.00	4.35	4.29	4.70	4.92	4.87	4.85	4.82	4.81
Δln *pri*	0.27	1.81	3.67	3.55	3.54	3.71	3.76	3.87	4.16	4.30
Δln *sec*	8.77	9.86	9.52	9.83	10.11	10.52	10.73	10.60	10.57	10.60
Δln *high*	0.03	0.92	1.02	1.21	1.18	1.19	1.34	1.35	1.47	1.49
Δln *thigh*	90.24	79.70	77.07	76.16	74.50	73.54	73.02	72.23	71.90	71.73
Δln *uni*	0.00	3.67	4.35	4.93	5.94	6.09	6.26	7.07	7.05	7.05
Variance Decomposition of Δln *uni*										
Δln *y*	2.87	3.78	3.45	3.41	3.39	3.37	3.33	3.32	3.33	3.32
Δln *pri*	0.01	0.65	2.84	2.78	3.24	3.42	4.10	4.34	4.36	4.37
Δln *sec*	3.01	3.70	4.63	5.87	5.93	5.87	5.98	5.97	5.96	5.96
Δln *high*	0.03	1.79	3.77	3.70	3.87	3.88	3.91	3.94	3.93	3.97
Δln *thigh*	0.16	0.15	0.14	0.49	0.58	0.63	0.86	0.91	1.04	1.21
Δln *uni*	93.88	89.89	85.14	83.72	82.96	82.81	81.79	81.50	81.36	81.15

Impulse response functions are plotted in Figures 1-2. For brevity of presentation, the impulse responses of the education variables to a shock to an education variable are not reported here. As can be seen from Figure 1, the initial responses of per capita real income to unanticipated changes in secondary, high school, technical high school and higher education enrolments tend to be positive. For the cases of the primary school enrolments, the initial impact on real GDP is negative and responses start to increase in the first period. It appears that shocks to primary school and high school enrolments tend to have a relatively more persistent impact on real income. Figures 2 exhibit the responses of school enrolments to unanticipated changes in per capita real income. The initial responses of school enrolments, except for high school, are positive, whereas the responses of the high school enrolments start to increase in the second period. Shocks to real income have a relatively small impact on higher education enrolment compared to that of other school enrolment variables. The initial decreasing response of higher education to a shock to real income is reversed starting from the second period.

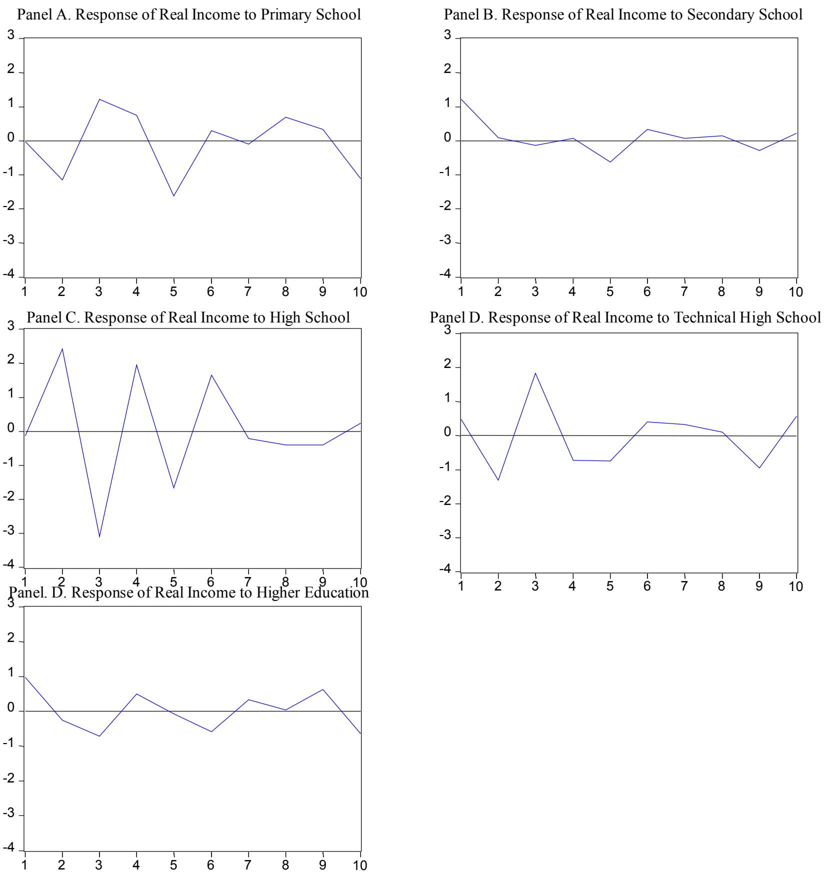

Figure 1: Impulse Responses to Innovations in Education

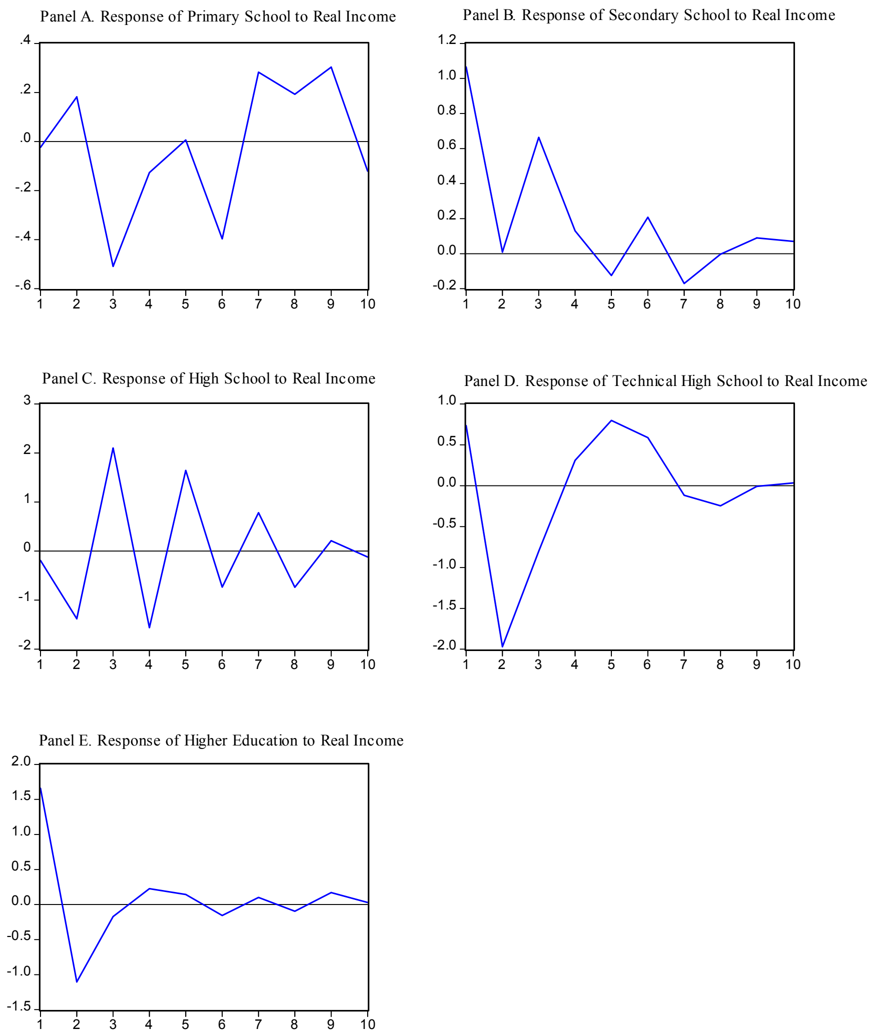

Figure 2. Impulse Responses to Innovations in Real Income

4. CONCLUSIONS

This paper has investigated the nature of the relationship between per capita economic growth and per capita school enrolment variables. We find evidence of long-run relationships amongst per capita real income and school enrolment variables and provide support for the hypothesis that economic growth is driving per capita high school enrolment in the long run in Turkey or *vice versa*. This suggests that per capita real income has been important in explaining per capita high school enrolments in the long run, while there is evidence of bi-directional long-run Granger causality between per capita real income and per capita enrolments in all level of schooling, implying that increases in school enrolments have significant affects on real income in the long run and *vice versa*. We find evidence of a uni-directional short-run Granger causality running from per capita enrolments in secondary school, high school and technical high school to per capita real income. We find a uni-directional short-run Granger causality running from per capita enrolments in primary and high school to per capita secondary school enrolments. Enrolments in high school Granger-cause enrolments in higher education in the short run. The variance decomposition and impulse response analyses also seem to support the Granger causality results. Overall, similar to the findings of Sari and Soytas (2006), our results suggest a rather strong relationship between education and economic growth in Turkey.

The possible policy implications of our findings are clear. The strong relationship between education and economic growth in Turkey may be due to the fact that education in Turkey is fully recognised both as productivity and income stimulant, and hence schooling has been conducted to expand the quantity as well as to improve the quality. The implementation of eight-year mandatory primary education and recently establishing new universities in every single province in Turkey may positively contribute to the country's long-run economic growth. One of the limitations of this paper is that we use per capita school enrolments as a proxy for human capital. Future research may analyse the relationship between human capital and real income in Turkey by using alternative indicators of human capital, such as school graduates as suggested by (Wang and Yao, 2003) or the average level of cognitive skills as a measurement of quality of education (Hanushek and Wößmann, 2007). Another limitation of this paper is that we only consider the relationship between school enrolments and real income. Future research may analyse the relationship among human capital, investment, and real income for Turkey. An alternative is to examine the relationship among economic growth, exports, and human capital because endogenous growth theory postulates that either human capital or trade is the primary engine of growth.

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