Economics Bulletin

Volume 32, Issue 1

Education, growth and technology diffusion

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Abstract

This paper tests the Nelson-Phelps hypothesis with recently developed panel cointegration tests and new cross-cou datasets. The empirical results give evidence that all types of education are important for TFP growth and that ther an interaction between education and the distance to the technology frontier. However, the analysis of sub samples the data indicates that the evidence of the Nelson-Phelps hypothesis is only convincing for developing countries whereas the evidence for developed countries is rather weak.

I would like to thank Philippe Aghion, Jess Benhabib, Christoph Hanck, John Hassler, Jonathan Temple and Fabrizio Zilibotti for their help comments.

Citation: Tobias Heinrich, (2012) "Education, growth and technology diffusion", *Economics Bulletin*, Vol. 32 No. 1 pp. 866-870.
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Submitted: January 14, 2012. **Published:** March 13, 2012.

1. INTRODUCTION

This paper investigates empirically the hypothesis of Nelson and Phelps (1966) that backward countries with an educated labor force have an advantage in using technologies developed abroad. It states that there is an interaction between education and the distance to the technological frontier. Inspired by endogenous growth theory Benhabib and Spiegel (1994) extend the hypothesis by an innovation effect of education and Vandenbussche et al. (2006) decompose education to investigate which type of education matters for TFP growth.

This paper uses cointegration analysis to test the Nelson-Phelps hypothesis for developing and developed countries and for different types of education. We apply new panel cointegration tests by Kao (1999) and Pedroni (1999, 2004), which allow for heterogeneous intercepts and trend coefficients across cross-sections, to recently extended cross-country datasets by Heston et al. (2009), Barro and Lee (2010) and Barseghyan and DiCecio (2010). The empirical results give support for the Nelson-Phelps hypothesis specified with total education and also for primary, secondary and tertiary education. However, the analysis of sub-samples of the data shows that the Nelson-Phelps hypothesis is only supported for developing countries whereas the evidence for developed countries is rather weak.

Our paper differs from previous empirical studies, such as those by Benhabib and Spiegel (1994), Engelbrecht (2003), Benhabib and Spiegel (2005) and Vandenbussche et al. (2006), which also find support for the Nelson-Phelps hypothesis, in two respects. First, we use cointegration analysis in contrast to regression analysis. Second, we take advantage of recently extended cross-country data sets which include most countries of the world. The new issues that we address is to test the Nelson-Phelps hypothesis with cointegration analysis separately for developed and developing countries and to provide a first study testing the hypothesis of Vandenbussche et al. (2006) for developing countries. We view our new country type specific results as important for policy issues.

This paper is structured as follows. Section 2 reviews the long-run equilibrium relationships implied by the Nelson-Phelps approach and tests it with panel cointegration tests. Section 3 offers some conclusions.

2. EMPIRICAL ANALYSIS

2.1. Long-Run Equilibrium Relationships

This section specifies the long-run equilibrium relationships with respect to education and technology growth implied by the models above. The models by Nelson and Phelps (1966), Benhabib and Spiegel (1994) and Benhabib and Spiegel (2005) assume that the technology of country i, a_{it}, is an increasing function of the interaction between the education level, h_{it}, and the gap between the technology, a_{it}, and the technology frontier, a_{mt}. It bases on the idea that education increases the capacity to adopt technologies and that technology adoption is easier if the country is far behind the technology frontier. These models imply an equilibrium relationship between a_{it}, h_{it} and a_{mt} such that ϱ_{it} given by

$$\varrho_{it} = a_{it} - \theta_1 h_{it} - \theta_2 a_{mt}, \tag{1}$$

is weakly stationary, where $\theta_1, \theta_2 > 0$. Equation 1 characterizes the cointegration relationship. Vandenbussche et al. (2006) modify equation 1 by using primary-secondary and tertiary education instead of total education.

2.2. Data and Measurement Issues

Equation 1 is tested with the following data. Heston et al. (2009) record income and population for up to 189 countries from 1950 to 2007. Barseghyan and DiCecio (2010) record physical capital, labor and TFP-estimates for up to 123 countries for the years 1950-2007; 50 countries have data available for the entire sample, 98 since 1960, and 123 since 1970. Human capital is from Barro and Lee (2010). This new improved data set records average years of education for 146 countries, at five-year intervals from 1950 to 2010 among other measures of human capital as average years of primary, secondary and tertiary education. Technology a_{it} is approximated by the logarithm of TFP of country i, and a_{mt} is approximated by the logarithm of TFP of the United States, which is standard in being used as the world's technologically leading country. For robustness reasons a_{it} is also approximated by output per capita of country i, and a_{mt} by output per capita of the United States, respectively.

2.3. Methodology and Empirical Results

To test the cointegration relationship characterized by equation 1 we apply the panel cointegration tests by Kao (1999) and Pedroni (1999, 2004) which extend the Engle-Granger framework to tests involving panel data that allow for heterogeneous intercepts and trend coefficients across cross-sections. Kao (1999) consists of a panel ADF-statistic and Pedroni (1999, 2004) constructs seven statistics of panel cointegration: panel v, panel rho, panel pp, panel adf, group rho, group pp and group adf. Pedroni refers to the first four, the "within dimension" statistics, as panel cointegration statistics, and the last three, the "between dimension" statistics, as group mean panel cointegration statistics. The first three statistics are versions for a panel of nonparametric statistics analogous to the non-parametric corrections of the Phillips-Perron test. The fourth one is a parametric statistic analogous to the t-statistic of the Augmented Dickey-Fuller test. The fifth and sixth statistics are analogous to the rho and t-statistics of Phillips-Perron. The seventh is analogous to the t-statistic of the Augmented Dickey-Fuller test. The panel statistic by Kao (1999) with deterministic intercept and the seven panel statistics in Pedroni (1999, 2004), with deterministic intercept and trend, are presented in Table 1. The tests are done for the whole sample (M1), for high income countries[1] (M2), and for low and middle income countries (M3) to investigate the appropriateness of the models for different types of countries. The tests are done without data points of the United States since the TFP-values of the United States are used to approximate the technology of the technological leader, a_{mt}.

The results are weak for yearly data for all models. However, they become much better for data in 5 year intervals which suggests that equation 1 describes a long-run relationship and that the short-term effects may be blurred by cyclical influences and transitional dynamics. Therefore, only the results with data in 5 year intervals are reported. Unfortunately, the results from the cointegration tests are not unanimous. Table 1 shows that for the specification with total education four of the tests reject the null hypothesis of non-cointegration for M1, two for M2 and five for M3. For the specification with primary education four of the tests reject the null hypothesis of non-cointegration for M1, two for M2 and five for M3. For the specification with secondary education four of the tests reject the null hypothesis of non-cointegration for M1, three for M2 and five for M3. For the specification with tertiary education four of the tests

[1] These are Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United States and United Kingdom.

	Total education			Primary education		
Test statistic	M1	M2	M3	M1	M2	M3
Kao's test	0.89	4.89**	2.64**	0.68	5.00**	2.58**
Pedroni's tests						
Panel v	-5.35	0.49	-5.22	-5.12	-0.31	-4.88
Panel rho	8.46	3.14	7.82	7.86	2.96	7.25
Panel PP	-4.36**	0.10	-4.32**	-6.20**	-1.01	-5.91**
Panel ADF	-3.20**	0.98	-3.29**	-4.85**	0.06	-4.73**
Group rho	11.78	3.89	11.14	11.63	3.81	11.01
Group PP	-12.34**	-2.76**	-12.23**	-14.38**	-3.27**	-14.24**
Group ADF	-3.87**	-0.52	-3.98**	-4.53**	-1.41	-4.32**
	Secondary education			Tertiary education		
	M1	M2	M3	M1	M2	M3
Kao's test	1.16	4.50**	2.68**	0.10	4.09**	2.58**
Pedroni's tests						
Panel v	-6.63	-1.75	-6.22	-4.92	0.23	-4.80
Panel rho	8.75	3.58	8.02	8.77	3.17	8.12
Panel PP	-2.65**	1.51	-2.99**	-5.68**	0.13	-5.71**
Panel ADF	-1.62*	1.66	-1.97*	-3.71**	1.11	-3.85**
Group rho	12.10	4.11	11.40	12.09	4.19	11.35
Group PP	-9.67**	-2.27**	-9.54**	-11.91**	-0.92	-12.55**
Group ADF	-2.86**	-1.62*	-2.42**	-4.31**	-0.12	-4.63**

TABLE 1
Results from panel cointegration tests by Kao and Pedroni with deterministic intercept and trend, with 5 year interval data. * Denotes null hypothesis of no cointegration rejected at 5 percent and ** at 1 percent.

reject the null hypothesis of non-cointegration for M1, one for M2 and five for M3. The results are similar with output per capita as a measure for a_{it}.

In summary, we conclude that there is evidence of the Nelson-Phelps hypothesis for the whole sample. However, the sub sample results show that the Nelson-Phelps hypothesis is only convincing for developing countries, with the majority of the tests always rejecting non-cointegration, whereas the support for developed countries is rather weak. Further, the results indicate that all types of education are important for TFP growth in developing countries and that there is an interaction between education level and the distance to the technology frontier. An explanation for the weak results for developed countries could be that TFP growth in these countries is better described by R&D based models (Ha and Howitt 2007; Madsen 2008).

3. CONCLUSIONS

By applying new panel cointegration tests to recently enlarged cross-country data sets this paper provides new evidence of the Nelson-Phelps hypothesis. However, the analysis of sub-samples of the data gives evidence in favor of the Nelson-Phelps models only for developing countries. The results also show that primary, secondary and tertiary education is important for TFP growth in developing countries. The evidence of an interaction between education and the distance to the technology frontier indicates that

growth in developing countries is driven by imitation especially if the country is distant from the world technology frontier and that all types of education foster technological catch-up.

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