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Human Capital, Exports, and Economic Growth: A Causality Analysis for Taiwan, 1952–1995

*Yih-chyi Chuang**

Abstract

By using cointegration and error-correction representation methodology, this paper tested the causal relationship among human capital accumulation, exports, and economic growth using data pertaining to Taiwan's real GDP, real exports, and higher education attainment over the period 1952–95. The main findings of the paper are that human capital accumulation fosters growth and stimulates exports, while exports promote long-run growth by accelerating the process of human capital accumulation. Taiwan's case study thus supports the human capital-based endogenous growth theory and the export-led growth hypothesis.

1. Introduction

Endogenous growth theory has argued that either human capital or trade is the primary engine of growth (e.g., Lucas, 1988; Romer, 1990; Stokey, 1991; Grossman and Helpman, 1991; Young, 1991). In empirical studies, Barro (1991), Barro and Lee (1993), and Benhabid and Spiegel (1995) found evidence that human capital fostered countries' long-run growth rates. Studies by Harrison (1996) and Dollar (1992) supported the trade effects on growth and export-led growth hypothesis.[1]

However, a close relationship may exist between trade and human capital accumulation. Opening up trade creates opportunities and increases the return on human capital, and hence stimulates the accumulation of human capital. There are several possible channels through which exports can promote the accumulation of human capital. First, export growth promotes learning (Chuang, 1998) and the diffusion of technical knowledge (Grossman and Helpman, 1991), which includes management, marketing, and production skills. Second, despite the low skill content of their exports, trade increases technology transfer from industrial to developing countries, and the technology transfer is biased in favor of skilled labor and hence stimulates human capital accumulation (Pissarides, 1997). By considering the substitutability between physical capital and unskilled labor, and the complementarity between physical capital and skilled labor, Stokey (1996) showed that, for a developing economy that is open to capital flows, trade may result in a sharp rise in wage rates and a dramatic increase in skill premium, and thus accelerates investment in human capital. Hanson and Harrison's (1995) study of Mexico supported this hypothesis. Conversely, the accumulation of human capital persistently enhances the quality (embodied and disembodied) of labor and in turn increases factor productivity and creates comparative advantage on further exports.

Nevertheless, feedback effects from economic growth to trade and human capital accumulation are also possible. Verdoorn's law suggests that there is a positive relationship between productivity growth and output growth. This accordingly creates a

* Chuang: National Chengchi University, Taipei, Taiwan, ROC. Tel: 886-2-29387630; Fax: 886-2-29390344; E-mail: ycchuang@nccu.edu.tw. The author thanks Chien-fu Lin and one anonymous referee for helpful suggestions. The usual disclaimers apply.

comparative advantage for exports. Moreover, Mincer (1996) considered the sources of growth of human capital in the course of economic development. Thus, human capital works not only as a cause of economic growth but also grows as a result. Based on the above discussion from different theoretical perspectives, a better understanding of the real sources of growth is thus required to examine the human capital–trade–growth nexus. Very few empirical works have emphasized this line of research.[2]

The main purpose of this paper is to apply a recently developed econometrics technique by considering the relationship between cointegration and causality in estimating the behavioral relationship among human capital accumulation, exports, and economic growth for Taiwan during the period 1952–95. Once cointegration between the variables is confirmed, the Granger causality test has to be augmented with an error-correction mechanism (ECM) term. This approach also enables us to evaluate the short-run dynamics and long-run equilibrium relationship at the same time.

The reason for picking Taiwan for a country-specific study is that during the four decades under scrutiny the Taiwanese economy experienced rapid growth in economic development, export performance, and educational enhancement. Since the end of World War II, Taiwan's economy has grown by leaps and bounds. The achievement of Taiwan's economic development has been well acknowledged by its successful industrialization, heavy dependence on international trade, and persistent accumulation of capital and improvement in human resources. For example, from 1952 to 1995 the average annual growth rate of real GDP in Taiwan rose as high as 8.18%. In the late 1950s, government policy changed from import substitution to export promotion, and then to the promotion of trade liberalization in the 1980s. During this period, Taiwan's dependence on foreign trade increased tremendously. From 1952 to 1995, the average annual growth rate of real exports was 13.15%. Investment in human capital accumulation was also remarkable. The distribution of employed workers having primary school, secondary school, and higher education attainments were 54.95%, 14.87%, and 3.93% in 1964. However, the corresponding figures in 1993 were 26.09%, 51.8%, and 18.04%, indicating a better quality of labor force engaged in production. Therefore, Taiwan is indeed an excellent candidate for investigation of the human capital–trade–growth nexus.

The main findings of the paper are that human capital accumulation of higher education fosters growth and stimulates exports, and exports promote long-run growth by accelerating the process of human capital accumulation. Taiwan's case study thus supports both the human capital-based endogenous growth theory and the export-led growth hypothesis.

2. Methodology, the Data, and the Estimation Procedures

Cointegration and Granger Causality

Granger (1988) showed that if time series are cointegrated, then standard Granger and Sims tests are invalid and conclusions drawn from estimates are misleading. As a result, error-correction modeling should be used to test for causality. Therefore, the proper procedure for a causality test should first involve tests of stationarity and cointegration. Engle and Granger (1987) defined a nonstationary time series to be integrated of order d if it achieves stationarity after being differentiated d times, which is usually denoted by $X_t \sim I(d)$. This can be done by using the augmented Dickey–Fuller (ADF) test for the presence of unit roots under the alternative hypothesis that the time series in question is stationary around a fixed time trend. The ADF test for one unit root is based on the following regression:

$$(1-L)x_t = \alpha + \beta x_{t-1} + \gamma t + \sum_{i=1}^{k} \theta_i (1-L)x_{t-i} + \varepsilon_t, \tag{1}$$

where L is the lag operator, t denotes time trend, and ε_t is a white noise. I use Akaike's information criterion (AIC) to choose the number of optimal lags (k). The null hypothesis is based on a test of $\beta = 0$; i.e. the variable has a unit root. In addition, the estimated results of a Phillips–Perron (PP) unit-root test are included.[3]

If two series, X_t and Y_t, are integrated of order one, Engle and Granger (1987) have shown that if a linear combination $Z_t = X_t - \delta Y_t$ exists such that it yields an outcome where $Z_t \sim I(0)$, then X_t and Y_t are said to be cointegrated. Their linear combination can be interpreted as a long-run equilibrium relationship. However, in testing for cointegration in a vector autoregressive (VAR) model we utilize the maximum-likelihood estimation procedure developed by Johansen (1991) and Johansen and Juselius (1990) based on the VAR model in vector autoregressive error-correction form with Gaussian errors:

$$(1-L)Z_t = \sigma + \sum_{i=1}^{k-1} \omega_i (1-L)Z_{t-i} + \Pi Z_{t-k} + \nu_t, \tag{2}$$

where Z is an $m \times 1$ vector of $I(1)$ variables, Π is a $m \times m$ matrix of unknown parameters, and $\nu \sim N(0,\Sigma)$. The null hypothesis is that Π has a reduced rank of r ($r < m$), where r is the number of common roots. In testing the lag length for the VAR structure, Sims' (1980) likelihood ratio test was adopted,[4] and in determining the cointegration rank, the trace test and maximum eigenvalue test are performed for the reduced rank test of cointegration. Note that there are five different models[5] that arise when deterministic components are restricted and, moreover, the choice of deterministic components in the model has consequences for the asymptotic distribution of the rank test statistics. Hence, according to Johanson (1992) we use the Pantula (1989) principle to jointly select the model for deterministic components and the determination of the cointegration rank.[6]

Granger's Causality Test under Error-Correction Modeling

When series are cointergrated, the simple Granger's causality test becomes inappropriate. According to the Granger representation theorem, the model needs to be modified with ECM by augmenting an error-correction term, as follows:[7]

$$(1-L)X_t = \theta\mu_{t-1} + \sum_{i=1}^{I} \gamma_i (1-L)X_{t-i} + \sum_{j=1}^{J} \phi_j (1-L)Y_{t-j} + \sum_{k=1}^{K} \eta_j (1-L)Z_{t-j} + \varepsilon_t, \tag{3}$$

$$(1-L)Y_t = \rho\tau_{t-1} + \sum_{i=1}^{M} \lambda_i (1-L)Y_{t-i} + \sum_{j=1}^{N} \delta_j (1-L)X_{t-j} + \sum_{k=1}^{P} \chi_j (1-L)Z_{t-j} + \upsilon_t, \tag{4}$$

$$(1-L)Z_t = \sigma\xi_{t-1} + \sum_{i=1}^{R} \nu_i (1-L)Z_{t-i} + \sum_{j=1}^{S} \pi_j (1-L)X_{t-j} + \sum_{k=1}^{T} \vartheta_j (1-L)Y_{t-j} + \omega_t, \tag{5}$$

where I, J, K, M, N, P, R, S, and T are optimal lags, and ε_t, υ_t, and ω_t are nonserially correlated error terms. The terms μ_{t-1}, τ_{t-1}, and ξ_{t-1}, which must be stationary, are the first lagged value of the error terms from the cointegration regressions:

$$X_t = a + bY_t + cZ_t + \mu_t, \tag{6}$$

$$Y_t = d + eX_t + fZ_t + \tau_t, \tag{7}$$

$$Z_t = g + hX_t + kY_t + \xi_t. \tag{8}$$

Note that ECM representation has the important advantage of explicitly modeling the short-run dynamics jointly with the long-run relationships. In fact, γ, ϕ, λ, δ, η, χ, ν, π, and ϑ capture short-run dynamics, and b, c, e, f, h, and k represent long-run equilibrium relationships. Note also that for the stability of the system, the parameters θ, ρ, and σ should be negative, which implies that after any external shock the system will converge to its long-run equilibrium. To verify the presence of any causal relationships, one needs to test for the joint significance of the lagged variables (i.e. lagged X_t, Y_t, and Z_t) in equations (3)–(5) by means of classical F-test. For example, if the joint test of lagged variable Y_t in equation (3) is significantly different from zero, then it implies that Y_t Granger causes X_t. As the results from Granger's causality test are sensitive to selection of lag length, the minimum final prediction error (FPE) criterion proposed by Akaike (1971) was adopted to determine the optimal lags of the model.

As for the data, I use the share of people who have attained an education level above higher education to the population of people with ages over 15 to measure the stock of human capital.[8] Data of real GDP and real exports in 1991 price for the period 1952–95 were collected from *National Income of Taiwan*, Republic of China, 1996. Data for higher education are taken from various issues of the *Monthly Bulletin of Manpower Statistics*, Taiwan, Republic of China. Both data sources are provided by the Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China. During 1952–95, the average annual growth rates of GDP and exports for Taiwan were 8.18% and 13.15%, respectively. The share of population having a higher education degree was 1.43% in 1952 and increased steadily to 18.02% in 1995, with an average annual growth rate of 5.89%.

3. Empirical Results

We first test for unit roots. Table 1 presents the ADF and PP test statistics for the levels and first differences of the log of real GDP (LnY), the log of real exports ($LnEX$), and higher education attainment ratio (HE), respectively.[9] The results show that all the variables are nonstationary in their level data; i.e. the series are $I(1)$. However, the stationarity property is found in the first-differencing level of all the variables.

Next, we perform cointegration analysis for these three variables. Sims' LR test identifies that maximum lag length for VAR is 4. Using Johanson's maximum-likelihood approach with the Pantula principle, we find $r = 2$ and the appropriate model is model 2; i.e. two significant cointegrating vectors and a model with an intercept in the cointegration space were identified using either the maximum eigenvalue or trace statistic. Table 2 presents the trace statistics, and Table 3 shows the results of choosing the deterministic components. As shown, we are able to reject null hypotheses of non-cointegration, where $r = 0$, and one cointegration vector, where $r \leq 1$, at the 5% significance level. The proper estimated cointegrated vector is[10]

Table 1. Results of the Unit-Root Tests

	Augmented Dickey–Fuller	Phillips–Perron	*AIC lags*
Levels			
LnY	–1.7673	–0.1466	2
LnEX	–0.3448	–1.6885	2
HE	–0.7074	–0.7397	2
First differences			
LnY	–3.2312*	–27.8083**	2
LnEX	–3.6994**	–42.9520**	2
HE	–3.8311*	–45.8842**	2

Notes: *LnY* and *LnEX* are real GDP and real exports in logarithmic form, respectively. *HE* is the share of people who have attained level of education above higher education with ages over 15. * and ** indicate significance at the 5% and 1% levels, respectively.

Table 2. Results of Johansen's Cointegration Test

Null	*Alternative*	*Statistic*	*95% critical value*	*Eigenvalue*
$r = 0$	$r \geq 1$	52.66*	34.795	0.5173
$r \leq 1$	$r = 2$	24.56*	19.993	0.3379
$r \leq 2$	$r = 3$	8.18	9.133	0.1891

Notes: Maximum lag in VAR is 4. * indicates significance at the 5% level.

Table 3. Determination of the Cointegration Rank and the Model for the Deterministic Components: Trace Test

$H_o: r$	$p - r$	*Model 2*	*Model 3*	*Model 4*
0	3	52.663**	34.174**	45.4603**
1	2	24.260**	17.721**	25.9131**
2	1	8.1768	5.856	10.7383

Notes: Pantula's (1989) principle for model selection of the deterministic components is used. Model 2: intercepts in the cointegration relations; model 3: deterministic trend in the levels; model 4: trends in the cointegration relations.

$$LnGDP = 8.548 + 0.0831 * \mathrm{HE} + 0.3631 * LnEX.$$
$$(t\text{-value}) \quad (112.606) \quad (65.261) \qquad (22.671) \tag{9}$$

Residual analysis for the tests of autocorrelation and normality all satisfy the basic assumptions of the model. See Tables 4 and 5 for the results of residual analysis and estimation of the multivariate cointegration model. Based on these results, I conclude that real GDP, real exports, and higher education are cointegrated; i.e. they exist in a long-run equilibrium relationship, and are therefore causally related.

Table 4. Residual Analysis

	Statistic	*p-value*
Test for autocorrelation		
Ljung–Box(9)	54.4656	0.38
LM(1), *CHISQ*(9)	4.314	0.89
LM(4), *CHISQ*(9)	10.766	0.29
Test for normality		
CHISQ(6)	5.646	0.46

Notes: Ljung–Box test based on the estimated auto- and crosscorrelations of the first [*T*/4] lags. The *LM*(1) and *LM*(4) are LM-type tests for first- and fourth-order autocorrelation.

Table 5. Estimation Results of the Multivariate Cointegration Model

$$
\begin{bmatrix} dLnY \\ dLnEX \\ dHE \end{bmatrix}_t = \begin{bmatrix} -0.177 & 0.084 & 0.008 \\ -1.233 & 0.376 & 0.084 \\ 6.412^{*} & -2.633^{**} & -0.330^{*} \end{bmatrix} \begin{bmatrix} dLnY \\ dLnEX \\ dHE \end{bmatrix}_{t-1} + \begin{bmatrix} -0.356 & 0.009 & -0.013 \\ -1.880^{**} & 0.331 & -0.014 \\ 0.730 & -1.043 & -0.299^{*} \end{bmatrix} \begin{bmatrix} dLnY \\ dLnEX \\ dHE \end{bmatrix}_{t-2}
$$

$$
+ \begin{bmatrix} -0.011 & -0.043 & -0.003 \\ -0.551 & -0.075 & 0.059 \\ 3.193 & -1.027^{**} & -0.237 \end{bmatrix} \begin{bmatrix} dLnY \\ dLnEX \\ dHE \end{bmatrix}_{t-3} + \begin{bmatrix} -0.471^{***} & 0.002 & 0.004 \\ -1.661^{***} & 0.237^{**} & 0.022 \\ 2.085 & -0.667 & -0.221 \end{bmatrix} \begin{bmatrix} dLnY \\ dLnEX \\ dHE \end{bmatrix}_{t-4}
$$

$$
+ \begin{bmatrix} 0.413^{**} & -0.141^{*} & -0.036^{***} & -3.160^{**} \\ 2.068^{***} & -0.790^{***} & -0.157^{***} & -17.563^{***} \\ 1.972 & -0.506 & -0.164 & -19.570 \end{bmatrix} \begin{bmatrix} LnY \\ LnEX \\ HE \\ \text{const.} \end{bmatrix}_{t-1}
$$

Note: *, **, and *** represent statistically significant at 10%, 5%, and 1% levels, respectively.

Table 6. Results of the Causality Tests for the Error-Correction Model

Dependent variable	*t-statistic for* EC_{t-1}	*F-statistic for* $\Sigma(1-L)LnY_{t-i}$	*F-statistic for* $\Sigma(1-L)LnEX_{t-j}$	*F-statistic for* $\Sigma(1-L)HE_{t-k}$	*FPE lags*
$(1-L)LnY$	1.720	0.326	2.267	4.519**	(1,1,2)
$(1-L)LnEX$	–15.134**	0.142	10.886**	10.352**	(1,4,1)
$(1-L)HE$	–3.426**	1.171	4.603*	0.710	(1,1,1)

Notes: *EC* denotes the error-correction terms. * and ** indicate significance at the 5% and 1% levels, respectively. The order of FPE lags is: GDP, exports, higher education.

Engle and Granger (1987) and Granger (1988) have shown that if two series are integrated of order 1, $I(1)$, then either unidirectional or bidirectional Granger causality must exist in at least the $I(0)$ variables. The results of the Granger causality test with ECM correction for equations (3) and (5) are presented in Table 6. The *t*-statistics for the error-correction terms are significantly negative for equations (4) and (5), implying that, without correcting for the long-run relationship among variables, the traditional Granger's causality test will be inappropriate.[11] The *F*-statistics from the

Granger causality test suggests bidirectional causality between export and higher education, and unidirectional causality running from higher education to real GDP.

The results from Taiwan's developmental experience thus support the thesis that human capital accumulation of skilled labor stimulates economic growth and sharpens the country's dynamic comparative advantage in exporting more skill-intensive goods. Moreover, it is through the indirect channel of accelerating of skilled labor accumulation that exports promote growth.

4. Concluding Remarks

This paper has tested the causal relationship among human capital accumulation, exports, and economic growth using data pertaining to Taiwan's real GDP, real exports, and higher education attainment ratio over the period 1952–95. It considers the relationship between cointegration and causality. The results of the tests suggest that (1) a positive long-run equilibrium relationship exists among human capital, exports, and economic growth; (2) there has been a significant bidirectional relationship between export growth and higher education accumulation and a significant positive Granger-causal relationship running from higher education accumulation to economic growth for Taiwan during the period. The findings of causal relationship among export growth, human capital accumulation, and economic growth from Taiwan's postwar experience support the human capital-based growth theory and the export-led hypothesis.

The accumulation of skilled labor is an important source for a country's long-run growth and for being able to consistently export refined goods in the competitive international market. However, no direct effect of exports on growth was found, although there was a channel, namely through human capital accumulation of skilled labor, by which exports affect economic growth. That is, opening trade creates opportunities and raises the rate of return on human capital investment. This, in turn, encourages local accumulation of skilled labor which reinforces the competitiveness in the international market and fuels the country's long-run growth. Therefore, it should be clear from Taiwan's case that human capital accumulation of skilled labor sustains the country's long-run growth, while opening trade accelerates the process of human capital accumulation.

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Notes

1. See also Xu (1996) for discussion of possible channels in which exports contribute positively to economic growth.

2. In their cross-country study, Gould and Ruffin (1995) noted that in addition to its role as an input in production, the stock of human capital is most responsible for higher growth in open economies.

3. The standard ADF test made the strict assumption of the error process being independently and identically distributed Gaussian processes. However, PP test is robust to autocorrelated errors. For more details see Phillips and Perron (1988).
4. The test statistic is $(T - C)$ $(\log|\Sigma_r| - \log|\Sigma_u|)$, where Σ_r and Σ_u are the restricted and unrestricted covariance matrices, T is the number of observations, and C denotes the number of variables in each unrestricted equation. The test started from $T = 8$ and compared likelihood ratio between T and $T - 1$ accordingly until the optimum lag length was found.
5. The five different models are—model 1: no deterministic components; model 2: intercepts in the cointegration relations; model 3: deterministic trends in the levels; model 4: trends in the cointegration relations; and model 5: quadratic trends in the level. However, as model alternatives 1 and 5 are not likely to produce sensible models for standard economic time-series data, they are excluded in advance.
6. See Johanson (1992) for the detailed description of the test procedure.
7. Note that here the deterministic components are assumed to have intercepts in the cointegration relations; see also equations (6)–(8).
8. Of course, there are other proxies to measure human capital; for example, school enrollment rates and the average years of educational attainments. For Taiwan's data, the correlation coefficients between these different human capital measures are rather high: from 0.76 to 0.99. However, by considering the data availability and the sample size property required for cointegration estimation, the data that we used here have the longest series that is available for the purpose of this current study. See also Wang and Yip (1995) and De-Meulemeester and Rochat (1995) for use of the same variable as a proxy for human capital.
9. The use of *LnHE* or *HE* does not change the main findings of the paper. However, *HE* is measured as education attainment ratio, for easier interpretation of the long-run relationship; for example, $dLnY/dHE$ represents the growth of GDP with respect to a one percentage increase in the education attainment ratio. The estimation results of *HE* are reported in this paper.
10. Wickens (1996) pointed out that, without prior information, cointegrating vectors derived from the maximum-likelihood estimation of unrestricted vector correction model are not identified to get a satisfactory economic interpretation. Among the two cointegration vectors, I choose the one with the higher corresponding eigenvalue, which also coincides with the economic theory that education and economic growth are positively correlated. The null hypotheses of zero restriction on each element of the cointegration vector were all rejected at the 5% level.
11. The coefficient of ECM term for the equation (3) is positive but insignificant. This may happen in empirical practice of ECM modeling which is mainly because the strong short-run dynamics partly offset the effect of ECM term. See, for example, Dutt and Ghosh (1996).