E C O N O M I C S   B U L L E T I N

An Empirical Analysis about Population, Technological Progress, and Economic Growth in Taiwan

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Abstract

This paper empirically analyzed the relationship between population, technological progress, and economic growth in Taiwan from 1954 to 2005, using the LA-VAR (lag-augmented vector autoregression) model. The empirical results reveal that a major conformational change in the economic development of Taiwan after 2000.

We are grateful to the Japan Society for the Promotion of Science for financial support provided to the 21st Century Center of Excellence Project.
Citation: Yao, Wan-Jun, Yu-Ching Hsieh, and Shigeyuki Hamori, (2007) "An Empirical Analysis about Population, Technological Progress, and Economic Growth in Taiwan." *Economics Bulletin,* Vol. 15, No. 23 pp. 1-13
Submitted: October 23, 2007. **Accepted:** November 30, 2007.
URL: http://economicsbulletin.vanderbilt.edu/2007/volume15/EB-07O00008A.pdf

1. Introduction

In 1949, the Kuomintang assumed control of the Taiwanese government and proposed a series of economic policies to promote economic growth. These policies included agrarian reform, substitution of imported goods by domestic ones, export promotion, 10 items construction, and 12 items construction. The Kuomintang government led Taiwan to industrialization and helped it achieve a steady growth in agricultural production. Subsequently, industrial development was linked with improvement in exports. In 1979, the Xinzhu Science Park was constructed. “The Fundamental Law on Technology” was enacted in 1999. These policies effectively promoted Taiwan’s research and development and led to technological progress. As a result, the Taiwanese economy witnessed long-term growth until 1999.

According to the Statistical Yearbook of the Republic of China 2006, the average growth rate of Taiwan’s GDP between 1954 and 1999 was 7.92%. In addition, the number of patent applications admitted per year increased at an average rate of 16.08% from 135 cases in 1954 to 29,707 cases in 1999 (Table 1). However, following 2000, after the Democratic Progressive Party assumed control of Taiwan’s administration, political instability and disputes within the government put an end to the high economic growth. After 2000, the growth rate of Taiwan’s per capita GDP (PGDP) decreased to 0.85%, as shown in Table 1. Furthermore, the population growth rate decreased from a yearly average of 2.09% during 1954 to 1999 to 0.5% between 2000 and 2005. In this paper, we will clarify the long-term relationship between population, technical progress, and economic growth and try to interpret this problem.

Taiwan achieved high economic growth from the 1950s until the end of the twentieth century and was known as one of the four “tigers” of Asia. Young (1994) insisted that the economic growth of Taiwan cannot be sustained merely by to technological progress and that a fall in the production capacity would eventually lead to the decline of economic growth because it was driven mainly by capital injection. Meanwhile, Lin (2003) conducted a growth accounting analysis using a production function that included human capital. He found that the contribution made by technological progress, physical capital, labor, and human capital to the Taiwan’s economic growth was 37.27%, 15.66%, 22.30%, and 24.77%, respectively. Further, he concluded that technological progress and human capital greatly contributed to Taiwan’s economy from 1965 to 2000. Furthermore, Lin (2004) showed that a rise in the education level greatly contributed to Taiwan’s economic growth.

However, the growth rate of the Taiwanese economy fell after 2000. Chow (2002) estimated the value of Taiwanese capital stocks from 1951 to 1999. In his growth accounting analysis, he used working hours as a substitute for the annual number of the workers . As a result, the contribution made by both capital stock and TFP (total factor productivity) was 40% each, but he found that the contribution made by labor was only that of 20%. Therefore, he concluded that the reduction in the number of working hours was the main cause for the economic slowdown from 1987 to 1999.

Bloom and Williamson (1998) analyzed the phenomenal economic growth in East Asia and pointed out that there was no particular difference between Taiwan and other East Asian countries. In a period of high economic development, the infant population increases first because of an increase in the birthrate and a decrease in the mortality rate; thus, the per capita income decreases. However, over a period of time, the labor force participation rate increases along with lower birthrates, and the per capita income increases. Thus, it could be said that the effect of the population bonus supported the economic growth in East Asia.

Figure 1 shows the demographic structure in Taiwan. The ratio of labor force has continuously increased since the 1950s. On the other hand, it is clear that the percentage of the young population is decreasing and that the percentage of the elderly population is increasing. The ratio of the aging population was 7.1% in 1993, and it increased to more than 8% in 1997. Subsequently, it exceeded 9% in 2002 and almost reached 10% in 2006. At this point, the increasing population growth in Taiwan and the changes in the demographic structure began to pose a serious problem for the country's economic growth.

The growth accounting analysis method is often used to analyze the relationship between population, technological progress, and economic growth. According to the growth theory, when an economy remains in a stationary state for a long period, the capital effect created by economic reforms gradually disappears. It is generally believed that economic growth essentially dependent upon increase in the population and rate of technological progress.

Technological progress can be measured by macro data such as TFP and micro data about research and development. Connolly (2003) claimed that the annual number of patent applications is a critical indicator of the extent of research and development in a country. On the other hand, the growth theory assumes the population-manpower ratio to be constant.

Bloom and Williamson (1998) defined $Y/N = (Y/L)(L/N)$ as a substitute for the production function. Thus, we obtain the equation $\Delta(Y/N) = \Delta(Y/L) + \Delta L - \Delta N$. In other words, the growth of PGDP is determined by the per capita capital stock, which in turn, depends on technological progress partition, $\Delta(Y/L)$; further, the balance between growth rates of manpower and population.

It can then be stated that not only the population growth rate but also the structure of the population has a significant influence on the economic growth of a country. Moreover, Bloom and Williamson (1998) analyzed the influence of the changing structure of the population on the labor force participation. In other words, an increase in the birthrate and decrease in the mortality rate tends to increase population and decrease the per capita income at the first stage. However, with time, the per capita income tends to increase as the manpower ratio increases. Moreover, the per capita income tends to decrease again when the percentage of the elderly population increases. Matthew and Williamson (1997) explained that the changing demographic structure affected not only labor force participation but also national savings and investment demand. It influenced capital stock through current balance and eventually influenced economic growth.

The endogenous growth theory corrects the assumption that technological progress is exogenous variable and handles it as an endogenous variable. According to Romer (1990), Grossman and Helpman (1991), and Barro and Sala-i-Martin (1995), innovation tended to increase the number of resources that could be used in an economy, and it was referred to as product innovation in real economy. There are several different points of view in these previous works on the original production elements. For example, Romer (1990) and Grossman and Helpman (1991) considered labor as part of the formulation of the original production element in their respective works. This formulation attaches importance to the existence of the researcher and the engineer who receives education in the academic activity. On the other hand, Barro and Sala-i-Martin (1995) assumed the final goods in the research department to be the original production element. This assumption lays emphasis on a large amount of equipment-related investment in the research department. The changes in the human capital are determined by the long-term demographic changes, and the final goods are determined by economic growth in the long term. Therefore, long-term innovation is promoted by the economic and population growth.

Thus far, the relation between economic growth and the birthrate has been discussed in great detail. Leibenstein 1957） pointed out the phenomenon in which the per capita income rises and the birthrate decreases. Further, he argues that based on data about children, we can obtain the three utilities, namely, the Consumption Utility, the Work or Income Utility, and the Security Utility. However, at the same time, the cost of raising children will accrue. With economic development, the necessity for a child to engage in work decreases. Moreover, social security is enhanced with economic development. Since the cost of raising children increases, the growth of PGDP tends to decrease the birthrate. Moreover, Because of the rise of the income is flexible to the quality. Becker (1960) used the Quality-Quantity Model to explain the rise of prices of children will improve the quality but the quantity will decrease.

On the other hand, Malthus (1798) summarized that due to the rise income in the eighteenth century, the living standard improved, expenditure involved in raising a child was understood, the hygiene improved, mortality rate decreased, and population increased. Easterlin (1966) proposed a relative income hypothesis in that the expansion period of business accompanied the rise in the birth rate, whereas the birth rate decreased during the recession period. Therefore, the order circulation proposition of the birthrate and business was led. Barro and Sala-i-Martin (1995) summarized and empirically clarified the proposition and demonstrated that there was a relation of the decrease in the advanced country during a population increase and economic growth.

As clarified above, there is a complex relationship between population, innovation, and economic growth. Population influences innovation and economic growth in various respects, and economy too influences population in an opposite manner. In this paper, we empirically analyze the relationship between population, innovation, and economic growth in Taiwan. This paper in has the following two features. First, we use the LA-VAR model to analyze the long-term economic development in Taiwan. In the standard time-series analysis, researchers conducted a causality analysis using the VAR or VEC (vector error correction) model after the pretest of unit root and cointegration tests. However, errors caused during the testing process might have a considerable influence on the analysis using VAR or VEC. Toda and Yamamoto (1995) developed the LA-VAR method to efficiently avoid these problems.[1] Second, two types of data (macro data such as TFP and micro data such as number of patent licenses) are used as variables representative of technological progress, which is a source of economic growth. Further, we will discuss the differences between the two cases.

2. LA-VAR model

The LA-VAR model was developed by Toda and Yamamoto in 1995. The model is as follows. First, we can express the n dimension vector $\{y_t\}$ as follows.

(1) $$y_t = \gamma_0 + \gamma_1 TR_t + J_1 y_{t-1} + J_2 y_{t-2} + ... + J_k y_{t-k} + \varepsilon_t , \qquad t = 1, 2, ...T ,$$

where TR is the trend, k is the number of lags, ε is the vector of error terms with

[1] Hamori (2000) analyzes the causal relationship between Germany, Japan, the UK, and the USA using LA-VAR.

mean zero and variance-covariance matrix Σ, and $\gamma_0, \gamma_1, J_1, J_2, ...J_k$ are the matrices of the parameters.

Let the null hypothesis be

(2) $H_0 : f(\phi) = 0$,

where ϕ is a subset of $(\gamma_0, \gamma_1, J_1, J_2, ...J_k)$. To test this hypothesis, we consider estimating a VAR formulated in levels using the ordinary least squares (OLS) method as follows:

(3) $y_t = \hat{\gamma}_0 + \hat{\gamma}_1 t + \hat{J}_1 y_{t-1} + \hat{J}_2 y_{t-2} + ... + \hat{J}_p y_{t-p} + \hat{\varepsilon}_t$,

where p is equal to the true lag length (k) plus the possible maximum integration order considered in the process ($d_{\max}$), and $\hat{\gamma}_0, \hat{\gamma}_1, \hat{J}_1, \hat{J}_2, ...\hat{J}_p$ are vectors (matrices) of the parameter estimates. Note that $d_{\max}$ must not exceed the true lag length (k). Since the true coefficient value of $\hat{J}_{k+1}, \hat{J}_{k+2}, ...\hat{J}_p$ is zero, it should be noted that the restriction ϕ does not include them. We can rewrite equation (3) as follows:

(4) $y_t = \hat{\Gamma}\tau_t + \hat{\Phi}x_t + \hat{\Psi}z_t + \hat{\varepsilon}_t$,

where

$$\hat{\Gamma} = (\gamma_0, \gamma_1), \quad \tau_t = (1, t)', \quad \hat{\Phi} = (\hat{J}_1, \hat{J}_2, ...\hat{J}_k),$$
$$x_t = (y'_{t-1}, ...y'_{t-k})', \quad \hat{\Psi} = (\hat{J}_{k+1}, ...\hat{J}_p), \quad z_t = (y'_{t-k-1}, ...y'_{t-p})'.$$

We can also write it in the vector form as the follows:

(5) $Y' = \hat{\Gamma}T' + \hat{\Phi}X' + \hat{\Psi}Z' + \hat{E}$,

where

$$Y = (y_1, ...y_T)', \quad T = (\tau_1, ...\tau_T)', \quad X = (x_1, ...x_T)', \quad Z = (z_1, ...z_T)'.$$

The Wald statistic W can be calculated as follows:

$$W = f(\hat{\phi})' \left[\left(\frac{\partial f(\phi)}{\partial \phi'} \right) \left(\hat{\Sigma}_\varepsilon (X'QX)^{-1} \right) \left(\frac{\partial f(\phi)}{\partial \phi'} \right)' \right]^{-1} f(\hat{\phi}),$$

where

$$\hat{\Sigma}_\varepsilon = \frac{1}{T} \hat{E}'\hat{E}, \quad Q = Q_\tau - Q_\tau Z(Z'Q_\tau Z)^{-1} Z'Q_\tau,$$
$$Q_\tau = I_T - T(T'T)^{-1} T,$$

and I_T is an identity matrix.

We can test the causal relationship using this test statistic W. In this approach, it is neither necessary to know the order of integration nor the existence of cointegration; thus, a pretest bias can be prevented.

3. Empirical Analysis

3.1 Data

In this paper, the variables used to in the analysis are the PGDP, an overall population (POP), and the technological progress of Taiwan. Data on PGDP and the population from 1954 to 2005 were taken from *Statistical Yearbook of the Republic of China* (2006). In order to represent the difference between the macro and the micro levels of technological progress, two data are used. The TFP is used as the proxy for the macro technological progress, which Chow (2002) calculated from 1954 to 1999. The number of patent license applications (PL) is used as the proxy of the micro-level technological progress, which, according to Connolly (2003), is a result of the research and development. The data on the number of patents applied for is taken from the *Annual Patent Report* (2001, 2006) which covers the period from 1954 to 2005. The logarithmic values of these data are used for the empirical analysis.

In order to demonstrate the robustness of empirical results, we analyze the following three cases:

Case 1: (Sample Period, Technological Progress) = (1954–1999, TFP)
Case 2: (Sample Period, Technological Progress) = (1954–1999, PL)
Case 3: (Sample Period, Technological Progress) = (1954–2005, PL)

Since the TFP data developed by Chow (2002) covers from 1954 to 1999, we can carry out the empirical analysis for the corresponding sample period (Case 1). The sample period of Case 2 is the same as that of Case 1, but we use PL to replace the TFP data. Case 3 extends the sample period up to 2005.

3.2 Empirical Results

In order to carry out statistical inference using LA-VAR, we need to choose the true lag order (k) of the model. We selected the true lag order based on the residual diagnosing by LM test. As is evident from Table 2, the null hypothesis of no serial correlation for all lags up to 10 is accepted for $k = 5$ in all cases. Thus, we decided the true lag to be five for all three cases and estimate a ($k + d_{\max}$)th order LA-VAR formulated in levels, where $d_{\max}$ is the maximum order of integration suspected in the process. We conducted some unit root tests on each variable and found that all variables are stationary in the first difference. So we determined the maximum order of integration to be one, and the lag length for the estimation of the LA-VAR model becomes six.

The results of the causality tests are shown in Table 3. Case 1 employs TFP for the period of 1954 to 1999 as the proxy for technological progress. As is evident from the table, TFP and the overall population influence PGDP, while PGDP influences neither TFP nor the overall population. Furthermore, there is no causal relationship between population and TFP. These results are consistent with classical growth theory. In other words, technology and population are exogenous and are the mainstays of economic growth. Technological progress shifts the production frontier up and has supported Taiwanese economy in the long term. The research and development promotion policy was intended to promote technological progress in Taiwan and boosted economic growth. In addition, an increase in the overall population has significantly influenced economic growth.

Case 2 uses the number of patent license applications from 1954 to 1999 as the proxy for technological progress. In this case, the number of patent licenses and the overall population may influence PGDP. At the same time, PGDP and the overall population also influence the number of patent licenses. However, there is no causality running from PGDP and the number of patent licenses to the overall population. These results are consistent with the endogenous growth theory. In other words, economic growth is promoted by technological progress and the overall population. At the same, technological progress depends on PGDP and the overall population. From 1954 to 1999, there was a synergistic relationship between technological progress and economic growth in Taiwan. The overall population directly influences economic growth. In addition, it indirectly influenced economic growth through technological progress.

Case 3 also uses the number of patent licenses as the proxy for technological progress and extends the sample period up to 2005. Compared with case 2, the sample period is extended for only six years, but the result changed significantly. Neither the number of patent licenses nor the overall population influenced PGDP, while PGDP and the overall population have an influence on the number of patent licenses. (If the significance level is lowered to 15%, the number of patent licenses also influences the overall population.)

It seems that a substantial change has occurred in the process of Taiwan's economic development after 2000. The political power alternated between the Kuomintang and the Democratic Progressive Party in 2000. Moreover, the struggle for political power between the two parties also greatly influenced Taiwan's economic development. Therefore, in 2000, neither the number of patent licenses nor the overall population influences economic growth. It is believed that in addition to the political factor, the structural change in the population may be a factor that influences economic growth. Until 1999, the proportion of the Taiwanese population participating in the workforce rose through the population transition. However, in the middle of the 1990s, the aging of the population started accelerating and continues to accelerate after 2000. This has also had a considerable influence on the economic growth of Taiwan. Bloom and Williamson (1998) argued that an increase in the young population and an increase in the elderly population have reciprocal influences on the economic growth of a country. It is believed that the causal relationship between the overall population and economic growth was weakened from 1954 to 2005 because the overall population from 1954 to 1999 and from 2000 to 2005 has had reciprocal effects on the economic growth.

4. Conclusion

This paper empirically analyzed the long-term economic development in Taiwan from 1954 to 2005, using the LA-VAR model. To the best of our knowledge, this is the first attempt to apply the LA-VAR model for analyzing the long-term relationship between population, technological progress, and economic growth. Moreover, we used two types of data: TFP and the number of patent license applications as the proxies for technological progress.

First, we use TFP as the proxy for technological progress from 1954 to 1999. The empirical results showed that the technological progress on the macro level and the overall population are exogenous and are the mainstays of economic growth. This result is consistent with the classical growth theory.

Second, we use the number of patent license applications as the proxy for technological progress over the same sample period. Empirical results showed that the number of patent licenses influenced economic growth; at the same time, the overall population and economic growth greatly increases the number of patent licenses. These results are consistent with the endogenous growth theory unlike those in the first case.

Finally, we extend the sample period of case 2 up to 2005 and find that the empirical results have greatly changed in comparison with the second case. Thus, there is a major conformational change in the economic development of Taiwan after 2000.

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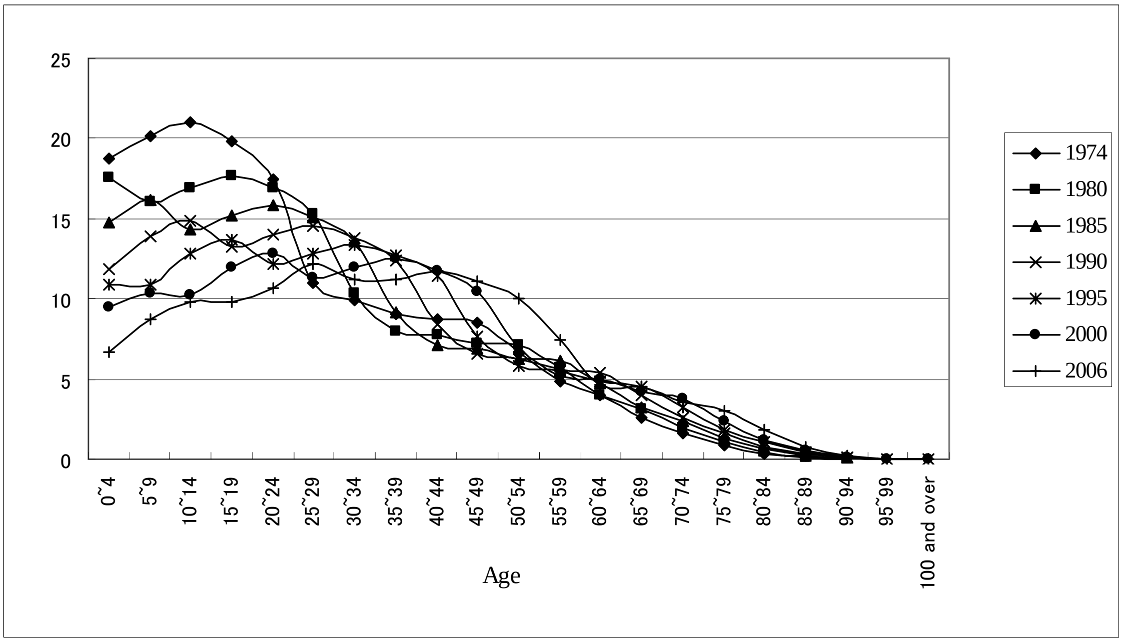
Figure 1. Demographic Structural Change in Taiwan



Source: Dept. of Household Registration Affairs, MOI.

Table 1. Growth Rates

Year	Variable	Growth Rates
1954–1999	PGDP	7.92%
	PL	16.08%
	POP	2.09%
	TFP	2.95%
1954–2005	PGDP	0.85%
	PL	13.70%
	POP	0.50%

Source: Republic of China Statistics Yearbook 2006
Note:
PGDP: Per capita GDPPOP: Population
TFP: Total factor productivity
PL: Number of property license

Table 2. Residual Diagnostics: LM Test

	Case 1 ($k = 5$)		Case 2 ($k = 5$)		Case 3 ($k = 5$)	
Lags	LM-Stat	*p*-value	LM-Stat	*p*-value	LM-Stat	*p*-value
1	11.54	0.24	7.54	0.58	13.93	0.12
2	9.40	0.40	13.07	0.16	9.76	0.37
3	6.13	0.73	8.12	0.52	4.68	0.86
4	9.13	0.43	11.97	0.22	6.81	0.66
5	19.24	0.02	6.30	0.71	14.49	0.11
6	13.51	0.14	11.81	0.22	9.76	0.37
7	12.54	0.18	9.51	0.39	13.27	0.15
8	12.15	0.20	3.43	0.94	11.83	0.22
9	3.87	0.92	15.16	0.09	3.15	0.96
10	11.57	0.24	14.55	0.10	14.44	0.11
11	4.06	0.91	5.10	0.83	5.37	0.80
12	4.91	0.84	3.11	0.96	5.55	0.78

Table 3. Result of Causal Relation of LA-VAR Model

	Dependent Variable			
	lnPGDP	lnPL	lnPOP	lnTFP
Case 1: 1954–1999 (p = 6, k = 5, d_{max} = 1)				
lnPGDP			0.91 (0.494)	1.43 (0 .256)
lnPOP	4.41 (0 .007)			1.77 (0 .165)
lnTFP	3.80 (0 .014)		0.64 (0.671)	
Case 2: 1954–1999 (p = 6, k = 5, d_{max} = 1)				
lnPGDP		4.08 (0 .010)	1.20 (0 .343)	
lnPL	2.19 (0 .096)		0.66 (0.657)	
lnPOP	6.01 (0 .001)	3.66 (0 .016)		
Case 3: 1954–2005 (p = 6, k = 5, d_{max} = 1)				
lnPGDP		4.83 (0 .003)	2.04 (0 .106)	
lnPL	0.31 (0 .904)		1.14 (0 .363)	
lnPOP	1.83 (0 .142)	3.18 (0 .023)		

Note: The numbers in parentheses are p-values.