Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (12): 2346-2350, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2346-2350

Re-estimation the Contribution Rate of Technological Progress to Economic Growth Accounting for Energy Consumption Factors Based on Time Series Data of China (1991-2011)

[1]Hu Junyan and [2]Gao Zijun
[1]School of Economics and Commerce, South China University of Technology, 510006, Guangzhou, Guangdong, China
[2]Faculty of Engineering, The University of Hong Kong, 999077, Hong Kong, China

Abstract: A lot of studies on technological progress ignore energy consumption in economic growth, so technological progress is overrated. Based on Tinbergen's improved Cobb-Douglas production function and Solow Economic Growth Model, this study uses China's 1991-2011 time series data to estimate the contribution rate of technological progress to economic growth and compare with the rate when energy consumption is taken into account. The results show that contribution rate of energy consumption to economic growth has an upward trend, so it must take energy consumption into account in order to reflect the real contribution rate of technological progress to economic growth the upward trend on contribution rate of technological progress to economic growth changes gently after accounting for energy consumption. The above findings illustrate China's recent economic growth relies more on energy consumption and it's urgent for Chinese economy to transform from "extensive growth" to "intensive development".

Key words: Economic growth, technological progress, energy consumption

INTRODUCTION

In recent years it remains a problem that what is the source of sustained and rapid economic growth in China? Some studies showed that technological progress played an important role in economic growth (George and Drakopoulos, 2009). While in Solow Economic Growth Model (Solow, 1956), Solow considered the unexplainable parts of economic growth, except for labor and capital input, as the contribution of technological progress to economic growth. Thus, how to accurately measure and evaluate the contribution of technological progress to economic growth becomes very necessary.

Many scholars used different models to estimate contribution rate of economic growth, such as Solow Model, Romer model and Lucas model. Li (2012) used Solow Model to estimate the total factor productivity from 1978 to 2010 in China and found that the contribution rate of technological progress to economic growth is lower than the rate of capital but higher than the rate of labor. (Wang and Xiang, 2005), respectively used expanding Solow Model and endogenous model to calculate the contribution rate of technology progress and found that there is just a slight difference when using two methods to calculate the rate. Wan *et al.* (2012) made use of Cobb-Douglas production function and Solow Model to study the contribution of technological progress to the economic growth with provincial or regional data. In order to overcome the disadvantages of Romer and Lucas model. Yang and Wang (2004) built a R and D and human capital endogenous model to explain the technological progress and human capital promote the economic growth jointly.

But more scholars pointed out that the general contribution rate of technological progress should be further refined. For example Mao *et al.* (2011) had isolated human capital factor from the general contribution rate of technological progress in Solow Model and found that the trend of this narrow contribution rate was similar with total factor productivity. Liu and Li (2013) estimate the role of the IT-derived human capital played in economic growth with data from China based on Lucas' Economic Growth Model Correction and found that the years 2004 to 2009 witness growth attributed mainly by physical capital and labor capital without technological advance, while the role played by IT-derived human capital, as well as organizational capital and social capital is comparatively less.

In fact, China's economic maintains an extensive growth in recent years. And China's economic growth will

Corresponding Author: Hu Junyan, School of Economics and Commerce, South China University of Technology, Guangzhou, Guangdong, China

depend on energy consumption for a long time. Many scholars also found there exist long term cointegration between energy consumption and economy growth (Warr and Ayres, 2010; Tang *et al*., 2012; Yu *et al*., 2012). Therefore it will overestimate the contribution rate of technological progress to economic growth if not stripping energy consumption. Thus it is necessary to strip energy consumption factor when analyzing the contribution rate. Based on these, this study uses the (Tinbergen, 1942) improved Cobb-Douglas production function and Solow Model to re-estimate the main contribution factors to economic growth with the data from 1991 to 2011 in China and further discusses changes on the contribution rate of technological progress to economic growth after considering energy consumption factor. The goal is to accurately measure the contribution rate of technological progress and to put forward some suggestions for the development of China's economic growth.

MODEL CONSTRUCTION AND DATA SOURCES

Model construction: Since this paper mainly studies how extract of energy consumption affects contribution rate of technological progress to economic growth, without considering other motives of technological progress and the internal mechanisms of economic growth. So, this study assumes that technological progress is an exogenous variable of economic growth and ignores the endogenous effect. Therefore, based on Solow model, this paper considers energy consumption variable, estimates the contribution rate of technological progress to economic growth under considering and without considering energy consumption and then analyzes the effect of energy consumption on contribution rate of technological progress to economic growth. Specific model is as follows.

Considering it is based on time series data to calculate the contribution rate of technological progress, the model construction is based on Solow Model and the improved Cobb-Douglas production function which introduces time variable by Tinbergen (1942). The function expression is as follows:

$$Y_t=A_tK_t^{\alpha}L_t^{\beta}=A_0e^{rt}K_t^{\alpha}L_t^{\beta} \quad (1)$$

Y for economic growth, A for technological progress, A_0 for initial technological progress, A_0e^{rt} for comprehensive technological progress, K for capital input, L for labor input, subscript t for period (t = 0,1,...,n), r for coefficient of technological progress, α and β are the marginal output elasticity coefficients of capital and labor inputs respectively. Equation 1 takes natural logarithm of both sides, then gets:

$$\ln(Y_t)=\ln(A_0)+rt+\alpha\ln(K_t)+\beta\ln(L_t)+\varepsilon \quad (2)$$

ε for the error term of Eq. 2. Assuming the same economies of scale, that is α+β= 1. Transpose and merge the variables, then gets:

$$\ln(Y_t/L_t)=\ln(A_0)+rt+\alpha\ln(K_t/L_t)+\varepsilon \quad (3)$$

By regression analysis, we get the elasticity coefficient (α, β) of capital and labor input. Supposing y, k and l respectively represent the growth rates of economic output, capital and labor input, the growth rate of technological progress (represented by total factor productivity, TFP) and contribution rate of technological progress (σ) are as follows:

$$FP = y-\alpha k-\beta l \quad (4)$$

$$\sigma=\frac{TFP}{y} \quad (5)$$

In order to further consider the regulation effect of energy consumption on the technological progress contribution rate, we add the energy consumption variable E in Eq. 1. The elastic coefficient of E is γ and growth rate of E is e. Assuming the same economies of scale, that is α+β+γ = 1. Finally we get a production function, the growth rate and contribution rate (σ) of technological progress considering effect of energy consumption. They are as follows:

$$\ln(Y_t/L_t)=\ln(A_0)+rt+\alpha\ln(K_t/L_t)+\gamma\ln(E_t/L_t)+\sigma \quad (6)$$

$$TFP' = y-\alpha k-\beta l-\gamma e \quad (7)$$

$$\sigma=\frac{TFP'}{y} \quad (8)$$

Growth rates of each variable are obtained through the geometric average method. And the equation is as follows:

$$x = (-1)*100\% \quad (x = y, k, l, e) \quad (9)$$

The equation calculating the contribution rate of other factors to economic growth is as follows:

$$Q_x = ix/y \quad (x = k, l, e,\ i = \alpha, \beta, \gamma) \quad (10)$$

Data sources: Data is derived from "China Statistical Yearbook" (1992-2012). Economic growth (Y) is measured by GDP. In order to eliminate the effect of price changes, we calculate the real GDP based on GDP in 1991 as the

Table 1: Descriptive statistics of variable indicators

Variable	Indicator (Unit)	Minimum	Maximum	Mean	Standard deviation
Y	GDP (100 million yuan)	21781.5	159369.0	71124.4	41597.5
K	Total fixed capital investment (100 million yuan)	5594.5	13857.1	10358.9	2003.1
L	No. of employees (10.000 people)	65491.0	76420.0	71895.1	3583.2
E	Total energy consumption (million tons of standard coal)	103783.0	348002.0	191883.1	79305.4

base period price and the GDP index of each year. Capital input (K) is represented by the total social fixed capital investment and the data of each year is adjusted by the total investment in 1991 as the base period price accordingly. Labor input (L) is represented by the number of employees at the end of each year. Energy consumption (E) is represented by the total amount of energy consumption in each year which is calculated through coal consumption calculation method. Descriptive statistics of variable indicators are shown in Table 1.

ESTIMATION OF TECHNOLOGICAL PROGRESS CONTRIBUTION RATE

Empirical analysis and test of model: According to equation 3-6, we carry on least squares regressions (OLS) under considering and without considering energy consumption respectively. The regression results are shown in Table 2. In these two regression results, the original DW values were 0.234 and 0.743, less than the dL value under 5% level of significance. In order to further eliminate the autocorrelation of each variable, we use Cochrane-Orcutt iterative method and obtain two acceptable DW values (DW∈(dU, 4-dU)). So there is not autocorrelation. From the results of R^2, two R^2 are higher than 0.9 which means the fitting degree of model is high and has passed F-test. The regression effect is nice. Meanwhile, the constant terms and coefficients of the explanatory variables in equation 3-6 all pass T-test.

From the contrast between coefficients of variables, we find that if without considering energy consumption, an increase of 1% in capital input leads to 0.259% economic growth and an increase of 1% in labor input leads to 0.741% economic growth. When considering energy consumption, an increase of 1% in capital input leads to 0.190% economic growth which means a decrease of 0.069% compared with the growth without considering energy consumption. And an increase of 1% in labor input leads to 0.586% economic growth which means a decrease of 0.155% compared with the growth without considering energy consumption. Besides, 1% growth of energy consumption causes 0.224% economic growth. Thus, energy consumption has an important role in promoting China's economic growth and also weakens the influence of capital and labor inputs to economic growth.

Table 2: Regression results of solow model

Variable	Equation 3: Without considering E	Equation 6: Considering E
t	0.089(0.005)*	0.071(0.006)*
ln(Kt/Lt)	0.259(0.072)*	0.190(0.088)*
ln(Et/Lt)	--	0.224(0.091)*
Intercept	-0.611(0.142)*	-0.709(0.182)*
R^2	0.9419	0.9909
F	137.80*	565.21*
DW	1.623	1.742

*Indicates significant at the 5% level, values in parentheses represent the standard deviation

Estimation the contribution rates to economic growth: According to the regressions, we get coefficients of variables. Then using equation 4-5 and 7-10, we estimate the growth rate and contribution rate to economic growth of each variable over years. The estimated results are shown in Table 3. From above Table 3:

- The contribution rate of capital input to economic growth is high but presents a downward trend which indicates that during the process of rapid economic development in China, capital has played a prominent role, especially in the 1990s and that also reflects the long-term situation that China dependent on capital to develop has been improved
- The contribution rate of labor input to economic growth is lowest and its trend is relatively stable. This result reflects that the institutional barriers and structural imbalances in education are the main reason for the relatively low contribution rate of labor input. It also reflects that the promotion of labor-intensive industries to China's economic growth is always limited. Therefore it is necessary to push labor-intensive industries to transfer to technology-intensive industries
- The contribution rate of technological progress shows an increasing trend, indicating that China's economy begins to gradually get rid of dependence on foreign capital and the positive effect of technological progress on economic development gradually increases. But the contribution rate of technological progress to economic growth is over 50% which is inconsistent with conclusions of some scholars' studies, for example, Wang and Zhang (2010) found that the rate was 30.8%. Such a difference is mainly due to the measure method. The contribution rate of technological progress is calculated through Solow model, in which

Table 3: Estimated results of contribution rates to economic growth

Year	Equation 1: Without considering E			Equation 2: Considering E			
	Capital	Labor	Technological progress	Capital	Labor	Technological progress	Energy consumption
1992	27.79	5.25	66.96	20.39	4.15	67.30	8.16
1993	38.22	5.26	56.53	28.04	4.16	58.72	9.08
1994	32.44	5.33	62.23	23.80	4.21	62.63	9.36
1995	28.37	5.50	66.12	20.82	4.35	64.48	10.36
1996	25.32	6.17	68.51	18.58	4.88	66.76	9.78
1997	22.50	6.68	70.82	16.51	5.28	69.56	8.65
1998	20.08	7.12	72.80	14.73	5.63	71.80	7.84
1999	18.10	7.41	74.49	13.28	5.86	72.87	7.98
2000	16.75	7.51	75.74	12.29	5.94	73.66	8.11
2001	15.47	7.62	76.91	11.35	6.02	74.44	8.19
2002	14.23	7.44	78.33	10.44	5.88	74.96	8.72
2003	13.52	7.21	79.27	9.92	5.70	73.68	10.70
2004	13.58	7.06	79.36	9.97	5.58	71.93	12.52
2005	12.79	6.77	80.44	9.39	5.35	72.09	13.17
2006	12.00	6.43	81.57	8.80	5.09	72.64	13.47
2007	11.60	6.10	82.30	8.51	4.82	73.21	13.46
2008	12.25	5.90	81.85	8.98	4.67	73.12	13.22
2009	11.29	5.75	82.96	8.28	4.55	73.97	13.20
2010	11.16	5.59	83.25	8.19	4.42	74.21	13.18
2011	11.48	5.49	83.03	8.42	4.34	73.89	13.35
Mean	18.45	6.38	75.17	13.53	5.04	70.80	10.63

technological progress measured by TFP represents many factors, including technology, knowledge and so on but except for capital and labor input. So it cannot exclude the non-technological progress factors effectively, so that the result magnifies the effect of technological progress on promoting economic growth which proves the necessity to extract other key factors, such as energy consumption, to do further analysis

- Although, the contribution rate of energy consumption is only 10.63% in average but its trend is increasing year by year and it reached 13.35% in 2011 which exceeded the rate of capital and labor input. Besides, the extract of energy consumption has decreased the contribution rates of capital, labor and technological progress. What's more, after stripping energy consumption, the contribution rate of technological progress shows a gently upward trend. It means that energy consumption plays a role in China's economic growth in nearly two decades. Previously, many scholars did not effectively remove these key factors when estimating contribution rate of technological progress to economic growth, so they had overvalued the rate. And, the result also reflects the fact that China's economic growth has depended on energy consumption excessively in recent years. Relevant data show that GPD of secondary sector (including industry and construction) was about 23.5 trillion Yuan in 2012, accounting for 45.3% in the national economy which shows that labor-intensive industries with high energy consumption is still the support of China's rapid economic growth. However, such a long-term highly dependence makes industrial decision radical, weakens the intrinsic motivation of technological innovation and reduces investment in innovation and thus directly or indirectly constrains the contribution effect of technological progress to economic growth

CONCLUSION AND POLICY IMPLICATIONS

Based on Solow Model, this study estimates the contribution rate of each factor to economic growth from 1991 to 2011 in China, with considering energy consumption factor. The results show that contribution rate of capital presents a downward trend while contribution rate of labor is lowest but has a stable trend which means that the dependence of economics on capital and labor is weakened a lot. And contribution rate of energy consumption is still rising, stripping energy consumption can reflect the contribution rate of technological progress to economic growth effectively and makes the upward trend on contribution rate of technological progress to economic growth change gently.

Hence, it is necessary to promote transformation from labor-intensive and energy consumption-based industry to technology-intensive industry and technological progress plays a key role in it. So for one thing, the government should adjust science and technology policy and research system and support the innovative enterprise and high-tech industry more strongly. At the same time, the government purchase system should lead the direction of consumption, make independent innovative products and low-energy consumption products become the real leaders in the domestic market, raise awareness of independent innovation and energy conservation and improve the overall independent innovation capability and comprehensive technological level. For another thing it is a good way to achieve the goal of saving energy consumption by technological progress and adjusting industrial structure. For example, government should give some policy priorities to innovative techniques and processes which are helpful to energy exploitation and utilization, such as, encouraging enterprises to do independent R and D, apply energy saving technologies and improve energy efficiency through technological innovation. Besides, government should use macroeconomic control to increase the proportion of energy-saving and high-tech industries, promote the adjustment and upgrading of inherent industrial structure and consider energy efficiency as an important technical indicator, in order to effectively promote China's economic transformation from the "extensive growth" to "intensive growth".

This study just extracts energy consumption and in fact there are many other factors influencing China's economic growth in addition to capital, labor and energy consumption. Thus, we should further refine to get the more accurate contribution rate of technological progress to economic growth. In addition, to discuss the relationship among energy consumption, technological progress and economic growth is helpful to clarify the key factors of the future economic growth, therefore, the empirical econometric method is worthy of further study in the future.

ACKNOWLEDGMENT

The authors are grateful to "the Fundamental Research Funds for the Central Universities, SCUT" (Project No. 2013ZM0116), "Soft Science Foundation of Guangdong Province" (Project No. 2012B070300028), "National Natural Science Foundation of China" (Project No. 71233003) and Humanities and Social Sciences Project (Project No. 70973038) from Ministry of Education of the People's Republic of China for providing financial support for this research project. Additional support from SRP of SCUT (Project No. 1989, 3346) is also gratefully acknowledged.

REFERENCES

George, M.K. and S. Drakopoulos, 2009. Economics of innovation: A review in theory and models. Eur. Res. Stud., 3: 25-38.

Li, X.N., 2012. Study on technology advancement efficiency of economic growth: 1978-2010. Sci. Technol. Prog. Policy, 29: 88-97.

Liu, X.T. and L.T. Li, 2013. The effect of IT-derived human capital-based on Lucas? economic growth model correction and its thinking. JCIT, 8: 869-878.

Mao, H.T., Z.S. Lv and J. Zhao, 2011. Resolution and measurement of the contribution rate of technical progress to economic growth-based on the time series data from 1987 to 2009. Manage, 8: 30-41.

Solow, R., 1956. A contribution to the theory of economic growth. Q. J. Econ., 70: 65-94.

Tang, J., L. Wang, L.L. Zhang and Z.Y. Qi, 2012. CO_2 emissions, energy consumption and regional economic growth: Base on panel VAR. JDCTA, 6: 401-409.

Tinbergen, J.Z., 1942. Theorie Der Langfristigen Wirtschaftsentwicklung: Weltwirtschaftliches Archiv. In: On the Theory of Trend Movements, Klaasen, L.H., L.M. Koyck and H.J. Witteveen (Eds.). North-Holland, Amsterdam, pp: 182-221.

Wan, P., L.Z. He and W. Zhao, 2012. Contribution analysis on technological progress to economic growth. Sci. Technol. Manage. Res., 6: 30-34.

Wang, D.J. and R.M. Xiang, 2005. Imput factors technology progress and economic growth. J. Yunnan Univ. Finances Econ., 21: 31-35.

Wang, X. and Y. Zhang, 2010. The empirical estimation of Chinese technological change level. China Soft Sci., 4: 155-163.

Warr, B.S. and R.U. Ayres, 2010. Evidence of causality between the quantity and quality of energy consumption and economic growth. Energy, 35: 1688-1693.

Yang, L.Y. and X.L. Wang, 2004. Human capital technological change and endogenous economic growth. China Econ., 4: 905-918.

Yu, Z.F., L. Yi and H. Zhang, 2012. Empirical analysis of the relationship between energy consumption and economic growth in China. JCIT, 7: 594-601.