Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2019.vol6.no2.63

Effects of Technology and Innovation Management and Total Factor Productivity on the Economic Growth of China

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Received: November 19, 2018 Revised: December 21, 2018 Accepted: March 30, 2019

Abstract

The paper aims to investigate relationships between technology and innovation management, total factor productivity and economic growth in China. By comparing the trends in total factor productivity growth of industrialized economies (i.e. OECD), this study intends to showcase the importance of total factor productivity progress in the Chinese economy. The study employs time series data of an annual basis for the period from 1977 to 2016 retrieved from the World Development Indicator. The study employs unit root test, cointegration test, fully modified least squares estimation method, canonical cointegrating regression and dynamic least squares estimation method to test the hypotheses. The results of the cointegrating regression analysis show that manufacturing growth leads to an increase of total factor productivity in the short-run in China. The findings of the study suggest that manufacturing (i.e. technology and product innovation) is positively related to the increase of total factor productivity in the short-run and total output growth in the long-run. The findings suggest that promoting technology and innovation management and supporting R&D subsidies may reduce the marginal cost of conducting R&D and increase the rate of technology and innovation management and R&D activity and therefore, the total factor productivity growth rate.

Keywords: Technological Progress, Innovation Management, R&D, Product Innovation, Total Factor Productivity, Manufacturing, China.

JEL Classification Code: L60, O14, O30, O47, O53.

1. Introduction

Nowadays, due to the trend of globalization and fierce competition around the world, governments of each country have realized the importance of making technological progress and promoting innovation management and therefore increasing total factor productivity growth rates. However, only a few governments, in particular, from developing countries spare their efforts on fostering various types of technological progress and innovation management. For developed countries, the common ways to evaluate technological innovation benefits have largely developed and the discussions about total factor productivity growth rates have widely spread. On the other hand, developing countries pay much more attention to traditional production factors of labor, capital and natural resources rather than technological progress and innovation management and total factor productivity growth rates.

After 2001 when China became a member of WTO, the manufacturing industry in the country has experienced an era of fast growing and substantial development. With its huge labor force and other factor conditions, China has been widely recognized as the largest workshop for manufacturing around the world and the manufacturing industry at the same time creates millions of jobs for people there. It is largely agreed that the manufacturing industry has played an extremely vital role in the recent rapid economic growth of China. However, as one of the important emerging markets, China also faces great challenges brought by the global competition. This is especially true for the manufacturing industry, and therefore organizations of various levels increasingly count on technological progress, new product development and product innovation to keep up with dynamic markets and response to the endless changes of needs of the markets

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(Ernst, 2002; Lovelace, Shapiro, & Weingart, 2001; West, 2002; Li & Atuahene-Gima, 2001).

In the process of making technological progress and product innovation, both governments and private sectors play important roles in actively searching new innovation tools with high efficiency. Within the cooperation between public and private sectors, innovation is often assumed to be with an inherent and undisputable feature since the purpose is to work for a specific period of time to innovate products while sharing risks and information (van Ham & Koppenjan, 2002). There are some unique features of each system of innovation and therefore different input factors result in different outputs. Instead of emphasizing different input factors within a specific system of innovation, this study intends to investigate dynamic relationships between several important input factors which might affect the level of innovation performance and therefore the levels of the total output in the Chinese economy.

2. Literature Review

2.1. Overview of Technological Progress and Product Innovation in China

Currently, China is experiencing a very important turning point with its increasing attention on innovation performance of all levels. Organizations have realized that the success of innovation outcomes would be their competitive advantages to win the market and meanwhile generate both economic and social benefits (Wind & Mahajan, 1997; Kerin, Varadarajan, & Peterson, 1992; Lieberman & Montgomery, 1988). Debates and discussions about innovation performance and related productivity factors have never stopped in recent decades since the remarkable benefits brought to enterprises and nations (Damanpour, 1991; Hult, Hurley, & Knight, 2004; Porter, 1990) and some enterprises made ambitious moves with their increased value from profitable growth brought by innovation. Since China has been attractive for many multinational enterprises to invest and compete in its market, in order to maintain its competitive advantages, improving technological progress and innovation performance has become one of the most important strategies for those companies. Also, many industries especially the manufacturing in the country, are experiencing revolutionary upgrade (Boisot & Child, 1996) and, with increasing attention on technological progress and product innovation, the adoption of such innovation management could result in positive outcomes of their product success (Ozer, 2004).

Schroeder, Bates, and Junttila (2002) highlighted the role of in-house manufacturing capabilities for productivity, in particular, the capabilities to build competitive advantages. Production capabilities as well as research and development (R&D) capabilities are vital for companies' innovation progress (Bell & Pavitt, 1993). Product innovation as a strategy, not only enables companies to make new products much more meaningful to employees within the organizations, but also facilitates them to take actively and deliberately participation in the whole innovation process (Dougherty & Hardy, 1996; Ozer, 2005). Zhou (2006) indicated that an innovation strategy may be a better choice for companies who intend to compete in and win the Chinese market since it improves positive outcomes of new product development. And Zahra and Covin (1994) demonstrated that the better the company is good at its product development, the much more positive results it would obtain on its whole firm performance.

2.2. Drivers for Technological Progress and Product Innovation in Private Sectors

For private sectors, there is one vital factor which might positively affect the new product development process and innovation performance is cross-functional interface (Griffin, 1997). Such importance is also confirmed by some other researchers. For instance, Song and Noh (2006) showed that for those high-tech companies in Korea, cross-functional interface is extremely vital to their success in product innovation. Moreover, during the research of companies in China, Song and Thieme (2006) found that creating the more harmonious atmosphere among functional departments and actively encouraging participation of employees in the whole process of decision-making are of great importance. In addition, the factor also deals with the proficiency of the product innovation process, in-house testing of new products, trial production, production startup, and obtaining necessary technology (Ozer, 2004). What's more, the proficiency of technology not only result in improved performance of innovation, but also support enterprises more resource and give them more advantages to be competitive in other innovation activities (Cooper, 1999; Montoya-Weiss & Calantone, 1994; Ozer, 2004; Song & Parry, 1997). Similarly, Jeong, Pae, and Zhou (2006) found that companies' technological progress and innovation activities would be positively affected by technology orientation and their proficiency of technology from some manufacturing companies in China.

Besides, with respect to the impact of private investment on companies' innovation moves, Lerner, Sorensen, and Strömberg (2011) examined changes around the time of innovation activities of some companies brought by private sectors' long-term investments. After examining the number and contexts of innovative patents of chosen companies which received private investments in the past two decades, Lerner et al. (2011) found that after receiving private investment, companies are more likely to file innovative patents frequently without sacrificing any originality and generality. Those companies not only maintain their patents of high levels, but also become more focused with the support of private investment. Meanwhile, with the concentration of patents, companies tend to develop and strengthen their competitive advantages and constantly, to contribute more patents and innovation activities with great impact.

Moreover, Roumboutsos and Saussier (2014) found that within the partnerships between private and public sectors, the private party has great impacts on innovation activities and could provide potential incentives for innovation. Within such partnership, the longer the periods of contracts are, the greater levels of investments are expected. And with renegotiation clauses included in such partnerships, transfer fees attached to asset value and concessions also provide further incentives for innovation. However, Roumboutsos and Saussier (2014) argued that private investments are more likely to go to those innovation activities which might have more direct impacts on those private parties such as reducing costs of operation and maintenance. Additionally, most of private parties unlikely have big interests in supporting innovation activities which aim to improve social benefits, therefore, they usually focus on their investment incrementally in innovation activities of relatively low risks regarding to their own competence.

2.3. Impact of Public Support on Product Innovation and Innovation Performance

Besides of vital factors of private sectors, obtaining external financing, for example, loans provided by public sectors, is very important for firms to finance its fixed investments (Mueller & Reize, 2013). Unlike private investments which are more incremental, such kinds of investments usually require much more capital during irregular intervals in order to make internal financing from cash flow accrue more continuously. It is widely believed that state support and various kinds of loans are often in favor of young companies, and the actual factor which makes contributions to positive outcomes is the structure of existing support mechanism (Simachev, Kuzyk, & Feygina, 2015). Among these support mechanisms, the more widespread use the invested new equipment has, the worthier the investment is, in other words, it depends on the bonus depreciation. Therefore, for those startup and young firms, such an incentive is very important if those companies have the ability to build their fixed assets intensively.

Currently in the manufacturing industry of China, there are some industrial policies which provide companies financial support including loans, tax allowances as well as grants, there are also special organizations such as national technology and productivity centers providing information, education, training and other help to companies with needs (Storey & Techer, 1998). Previous literature (i.e. Storey & Techer, 1998) mentioned that there are direct and indirect public measures to intervene and support the whole competitive environment for companies. Among those direct measures, on the supply side, there are always financial support and technical assistance, and on the demand side, there are government purchases and contracts. Meanwhile, among the indirect measures, public sectors intend to improve the innovation environment by providing taxation policy and improving patent systems.

When companies intend to enhance its R&D capabilities and innovation performance, capital would be one of the most essential factors, and under which condition the financial assistance is becoming more important than ever. In the past decades, innovation is widely considered as a vital stimulus to the country's economy and industrialization (Pavitt & Walker, 1976; Kim, 1980; Archibugi, Cesaratto, & Sirilli, 1991; Ernst & Kim, 2002; Guan & Chen, 2012). Even though different from other countries, China is operated under a different social and economic system, innovation performance of organizations still plays an essential role (Guan, Yam, & Mok, 2005). In China, companies enjoy various kinds of loans such as the Special Loans scheme, the Direct Earmarks scheme and the Tax Credits scheme. Each scheme provides companies different incentives. The Direct Earmarks scheme mainly focus on innovation projects while providing partial or full financial support, and companies are not required to pay back. Different from such a scheme, the Special Loans scheme asks firms to pay back the loans. Generally, it is difficult for Chinese companies, especially those startups and relatively young firms to obtain loans from the banks, therefore, the interest rate of the Special Loan could be attractive and acceptable.

2.4. Total Factor Productivity, Innovation and Economic Growth

Total factor productivity is a synonym for multi-factor productivity. The OECD (2001) productivity manual uses the multi-factor productivity to signal certain modesty with respect to the capacity of capturing all factors contribution to output growth. Total factor productivity is the portion of output not explained by traditionally measured inputs of labor and capital used in production (Comin, 2006). As such, its level is determined by how efficiently and intensely the inputs are utilized in production. If all inputs are accounted for, then total factor productivity can be taken as a measure of an economy's long-term technological change or technological dynamism (Ayres, Ayres, & Warr, 2002; Comin, 2006; Gordon, 2017; Natividad, 2014; OECD, 2001). Technology growth and production efficiency are regarded as two of the biggest sub-sections of total factor productivity, which enhance its position as a driver of economic growth. Total factor productivity is often posited as the real driver of growth within an economy, while labor and investment are still important contributors.

The equation below (in Cobb–Douglas form) represents total output (Y) as a function of total factor productivity (A), capital input (K), labor input (L), and the two inputs' respective shares of output (α and β are the share of contribution for K and L respectively). An increase in either A, K or L will lead to an increase in output.

$$Y = A \times K^{\alpha} \times L^{\beta}$$

Total factor productivity growth is usually measured by the Solow residual, as shown in the landmark article by Robert Solow (1956). Let Y denote the growth rate of aggregate output, K denote the growth rate of aggregate capital, L denote the growth rate of aggregate labor, and α and β are the share of contribution for K and L respectively. The Solow residual measures total factor productivity growth if the growth rates of the inputs are measured accurately. Total factor productivity plays a critical role on economic fluctuations, economic growth and cross-country per capita income differences. At business cycle frequencies, total factor productivity is strongly correlated with output and hours worked (Burnside, Eichenbaum, & Rebelo, 1995; King & Rebelo, 1999; Kydland & Prescott, 1982).

The long-run growth in an economy with an aggregate neoclassical production function must be driven by growth in total factor productivity. For over 30 years, the conceptual difficulty when trying to endogenize total factor productivity growth was how to pay for the fixed costs of innovation in a perfectly competitive economy with constant returns to scale in capital and labor (Comin, 2006). In this context, all output is exhausted by paying capital and labor their marginal products, and therefore, no resources are left to pay for the innovation costs. Romer (1990) and Aghion and Howitt (1992) solved this problem by granting the innovator monopolistic rights over his innovation, which are sustainable through the patent system. In this way, innovators can recoup the initial fixed costs of innovation through the profit margin they make from commercializing their patent. By linking the total factor productivity growth rate to innovation, endogenous growth models shed light on the determinants of total factor productivity growth. R&D subsidies and an abundance of skilled labor reduce the marginal cost of conducting R&D and increase the rate of innovation and new product development and therefore, the total factor productivity growth rate. Increments in the size of markets increase the innovators' revenues, leading to more innovation and higher total factor productivity growth.

2.5. Hypotheses

The aforementioned innovation capacities are determined by the same set of conditions that are closely linked to the state of total factor productivity development. Comparing the trends in total factor productivity growth of industrialized economies (i.e. high-income countries or OECD), this study aims to demonstrate the importance of total factor productivity progress in the Chinese economy. Accordingly, the following hypotheses are considered:

Hypothesis 1: There is a long-run equilibrium relationship between total factor productivity growth and economic growth

Hypothesis 2: Manufacturing growth is related to total factor productivity growth in the short-run.

Hypothesis 3: High-technology export growth is related to total factor productivity growth in the short-run.

Hypothesis 4: Innovation and patent growth is related to total factor productivity growth in the short-run.

3. Research Methodology

3.1. Data and Indicators

The sample is restricted to the period of time in which annual data is available and comparable among variables from 1977 to 2016. All of the time series data was collected and retrieved from the World Development Indicator database published by the World Bank.

Economic Growth – GDP growth (annual %): Annual percentage growth rate of GDP at market prices based on constant local currency is used a proxy of economic growth. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

Total Output – Merchandise exports (current US$): Merchandise exports are used as the proxy of total output. Merchandise exports show the f.o.b. value of goods provided to the rest of the world. Data are in current U.S. dollars.

Capital Input - Domestic credit to private sector (% of GDP): Domestic credit to private is used as the proxy of capital input. Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable, that establish a claim for repayment. The financial corporations include monetary authorities and deposit money banks, as well as other financial corporations where data are available. Examples of other financial corporations are finance and leasing companies, money lenders, insurance corporations, pension funds, and foreign exchange companies.

Labor Input - Employment to population ratio (15+, total (%), national estimate): Employment to population ratio is used as the proxy of labor input. Employment to population ratio is the proportion of a country's population that is employed. Employment is defined as persons of working age who, during a short reference period, were engaged in any activity to produce goods or provide services for pay or profit, whether at work during the reference period or not at work due to temporary absence from a job, or to working-time arrangements. Ages 15 and older are generally considered the working-age population.

Total Factor Productivity Growth:

Manufacturing value added, high-technology exports *and* ***patent applications:*** Manufacturing value added, high-technology exports and patent applications are used as the main drivers of total factor productivity growth.

Manufacturing, value added (current US$): Manufacturing refers to industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Data are in current U.S. dollars.

High-technology exports (% of manufactured exports): High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

Patent applications (by residents and nonresidents): Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention - a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years.

3.2. Descriptive Statistics of Data

All these time series data have been collected and retrieved from the World Development Indicator database published by the World Bank. For all these time series data are reported on an annual basis and employed for the period from 1977 to 2016 (40 observations for each group). Table 1 displays descriptive statistics along with various summary statistics for the time series. Table 2 displays the results of Pearson correlation analysis between the time series.

Table 1: Descriptive Statistics of Total Factor Productivity of China (1977-2016)

	Unit	Minimum	Maximum	Mean	Std. Deviation
GDP	%	3.91	15.13	9.61	2.67
Exports	%	4.29	37.17	18.69	8.85
Merchandise exports	%	.02	15.85	2.93	4.37
Capital	%	49.74	156.70	95.79	29.47
Employment	%	68.40	75.30	73.60	2.58
Manufacturing	%	29.37	40.10	33.38	2.75
High-tech exports	%	6.43	30.84	15.78	9.55
Patent	Number	8009	1101864	188570	310976

Table 2: Pearson Correlations

	GDP	Capital	Employ-ment	Manu-facturing	High-tech exports
Capital	.803***				
Employment	-.990***	-.779***			
Manufacturing	.623***	.861***	-.585***		
High-tech exports	.771***	.853***	-.765***	.795***	
Patent	.946***	.768***	-.931***	.514***	.630***

Correlation is significant at the 5% significance level (***, p-value < 0.001).

3.3. Unit Root Test

It is well known in the literature that the data generating process for many economic variables are characterized by stochastic trends that might result in spurious inference if the time series properties are not carefully investigated. A time series is said to be stationary if the mean and autocovariances of the series do not depend on time. Any series that is not stationary is said to be non-stationary (i.e. it has a unit root). The formal method to test the stationarity of a series is the unit root test. There are several well-known tests for this purpose based on individual time series: the augmented Dickey-Fuller (ADF) unit root test (Dickey & Fuller, 1979, 1981), the Phillips-Perron (PP) unit root test (Phillips & Perron, 1988), and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) unit root test (Kwiatkowski, Phillips, Schmidt, & Shin, 1992), among others.

Table 3 reports the results of unit root tests. All test equations were tested by the method of least squares, including an intercept but no time trend in the model. Probabilities for all tests assume asymptotic normality. In the ADF and PP tests, an optimal lag in the tests is automatically selected based on Schwarz Info Criterion and the lag length (bandwidth) in the tests is automatically selected based on the Newey-West estimator (Newey & West, 1994) using the Bartlett kernel function. In ADF and PP tests, probability values for rejection of the null hypothesis of a unit root are employed at the 0.05 level based on MacKinnon (1996) one-sided p-values. KPSS tests the null hypothesis: a series has no unit root (stationary), while the alternative hypothesis assumes that the series has a unit root (non-stationary). In KPSS test, probability values for rejection of the null hypothesis are based on Kwiatkowski et al. (1992) LM statistic p-values.

Table 3: Results of Unit Root Tests

Tests	ADF(0)	ADF(1)	PP(0)	PP(1)	KPSS(0)	KPSS(1)
GDP	-1.719	-4.409***	-1.496	-4.323***	0.772***	0.191
Capital	-0.748	-5.764***	-0.661	-5.881***	0.753***	0.093
Labor	-0.560	-3.529**	1.185	-3.463**	0.594**	0.348
Manufacturing	1.270	-8.904***	1.299	-4.532***	0.751***	0.342
High-tech	-1.090	-6.145***	-0.653	-7.088***	0.683**	0.116
Patent	2.377	-4.599***	2.377	-4.591***	0.734**	0.341

The numeric values in cells are t-statistic. Probability values for rejection of the null hypothesis are employed at the 5% significance level (**, p-value < 0.05 and***, p-value < 0.01).

4. Empirical Results

4.1. Cointegration Test

Engle and Granger (1987) point out that a linear combination of two or more non-stationary series may be stationary. If such a stationary linear combination exists, the non-stationary time series are said to be cointegrated. If these variables are cointegrated, then there exists long-run equilibrium among the variables. In other words, if the variables are cointegrated, there is a long-run relationship, and there exists a force to converge into long-run equilibrium. There are two test methods to identify whether there is a long-run relationship among variables: the Engle-Granger single equation test method (Engle & Granger, 1987) and the Johansen conintegration test (Johansen, 1988). Cheung and Lai (1993) report that the Johansen approach is more efficient than the Engle-Granger single equation test method because the maximum likelihood procedure has useful large and finite sample properties. The Johansen cointegration test models each variable as a function of all the lagged endogenous variables in the system. The Johansen procedure uses two ratio tests: a trace test and a maximum eigenvalue test, to test the number of cointegration relationships. Both tests can be used to determine the number of cointegrating vectors present, although they do not always indicate the same number of cointegrating vectors.

Table 4 reports the results of the Johansen cointegration test. The test equation was tested by the method of least squares. The regression model allows for a linear deterministic trend in data and includes intercept but no trend in vector autoregressive models. For the two likelihood ratio test statistics, the probability value for rejection of the null hypothesis of no cointegration is based on the MacKinnon, Haug, and Michelis (1999) p-values. The null hypothesis of no cointegration is rejected at the 5 % significance level. The trace test indicates at least three cointegrating equations exist at the 0.05 level, while the maximum eigenvalue test indicates at least one cointegrating equation exists at the 0.05 level. Therefore, the null hypothesis of no cointegration can be rejected at the 0.05 level. The results of the Johansen cointegration test in Table 4 suggest hypothesis 1 that there is a long-run equilibrium relationship between total factor productivity growth and economic growth in China is supported.

Table 4: Results of Johansen Cointegration Test

Number of cointegration (r)	Trace statistic	Maximum eigenvalue statistic
$r = 0$	120.051***	42.335**
$r \leq 1$	80.716***	26.875
$r \leq 2$	53.841**	25.686
$r \leq 3$	26.897	14.204
$r \leq 4$	13.494	11.033
$r \leq 5$	1.915	1.915

Regression model: Output = Capital + Labor + TFP (Manufacturing + High-tech + Patent)

Cointegrating equations are significant at the 0.05 level (**, p-value < 0.05 and ***, p-value < 0.01).

4.2. Cointegrating Regression Analysis

Considering the results of the Johansen cointegration test in Table 4, it is evident that there is a long-run equilibrium relationship between total factor productivity growth and economic growth in China. In this case, an unrestricted vector autoregressive model would not be an effective option for testing causal relationships in the short-run. Engle and Granger (1987) noted that if two or more time series variables are cointegrated, there is always a corresponding error correction representation in which the short-run dynamics of the variables in the system are influenced by the deviation from equilibrium. The cointegrated variables must have an error correction representation in which an error correction term is incorporated into the model. In this case, a vector error correction model is formulated to reintroduce the information lost in the differencing process, thereby allowing for long-run equilibrium as well as short-run dynamics. There are several estimation methods for testing a single cointegrating vector, an error correction term. These are fully modified OLS (Phillips & Hansen, 1990), canonical cointegrating regression (Park, 1992), and dynamic OLS (Saikkonen, 1992; Stock & Watson, 1993).

Phillips and Hansen (1990) propose an estimator that employs a semi-parametric correction to eliminate the problems caused by the long-run correlation between the cointegrating equation and stochastic regressor innovations. The Fully Modified OLS (FMOLS) estimator is asymptotically unbiased and has fully efficient mixture normal asymptotics allowing for standard Wald tests using asymptotic Chi-square statistical inference (Hansen, 1992). The FMOLS estimator employs preliminary estimates of the symmetric and one sided long-run covariance matrices of the residuals. The canonical cointegrating regression (Park, 1992) is closely related to FMOLS, but instead employs stationary transformations of the data to obtain least squares estimates to remove the long-run dependence between the cointegrating equation and stochastic regressor innovations. Like FMOLS, the canonical cointegrating regression (CCR) estimates follow a mixture normal distribution, which is free of non-scalar nuisance parameters and permits asymptotic Chi-square testing. The CCR transformations asymptotically eliminate the endogeneity caused by the long-run correlation of the cointegrating equation errors and the stochastic regressor innovations, and simultaneously correct for asymptotic bias resulting from the contemporaneous correlation between the regression and stochastic regressor errors (Park, 1992). Estimates based on CCR are therefore fully efficient and have the same unbiased, mixture normal asymptotics as FMOLS (Park, 1992).

Saikkonen (1992) and Stock and Watson (1993) propose a simple approach to constructing an asymptotically efficient estimator that eliminates the feedback in the cointegrating system. The Dynamic OLS (DOLS) method involves augmenting the cointegrating regression with lags and leads of ΔX_t so that the resulting cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovations. The model employs an intercept-trend specification for the cointegrating equation, with no additional deterministics in the regressor equations, and four lags and leads of the differenced cointegrating regressor to eliminate long-run correlation between the innovations. Under the assumption that adding lags and leads of the differenced regressors soaks up all of the long-run correlation between long-run variances, least-squares estimates of the equation have the same asymptotic distribution as those obtained from FMOLS and CCR (Saikkonen, 1992; Stock & Watson, 1993).

Table 5: Results of Cointegrating Regression Analysis

Country	China	China	China	OECD	OECD
Estimation method	FMOLS	CCR	DOLS	FMOLS	DOLS
Capital	1.282(0.350)**	1.216(0.374)**	1.118(0.309)**	0.814(0.341)*	1.042(0.425)*
Labor	4.041(5.569)	4.949(5.932)	14.192(7.962)	-3.757(3.801)	-6.629(5.046)
Manufacturing	1.351(0.246)**	1.384(0.261)**	1.205(0.265)**	3.300(0.485)**	2.903(0.558)**
High-tech	0.233(0.260)	0.234(0.280)	0.520(0.341)	2.184(0.449)**	1.974(0.567)**
Patent	0.284(0.225)	0.285(0.241)	0.245(0.242)	0.864(0.188)**	0.942(0.199)**
Cointegrating equation deterministics	-30.687(26.697)	-35.160(28.396)	-73.522(33.671)*	-74.407(19.942)**	-52.655(23.465)*
R-squared	0.980	0.979	0.998	0.940	0.990
Adjusted R-squared	0.977	0.976	0.995	0.931	0.979
Long-run variance	0.051	0.051	0.009	0.032	0.011
Cointegration coefficient diagnostic[1]	-1.149 DF = 33	-1.239 DF = 33	-2.183* DF = 33	-3.768** DF = 33	-2.243* DF = 33
Cointegration test[2]	0.653	0.556	0.086	1.817**	0.072

Regression model: Output = Capital + Labor + TFP (Manufacturing + High-tech + Patent)

Probability values for rejection of the null hypothesis are employed at the 5% significant level (*, p-value < 0.05 and **, p-value < 0.01).

The numeric values in cells are coefficients of regressors and standard errors follow in parenthesis.

[1] Cointegration coefficient diagnostic test has been conducted by Wald test (null hypothesis: the cointegration coefficient is zero (0)).

[2] Cointegration test has been conducted by Hansen parameter instability test for the null hypothesis (null hypothesis: series are cointegrated).

Table 5 reports the results of cointegrating regression analysis using FMOLS, CCR and DOLS. Table 5 shows that capital growth is related to an increase of total output in the short-run both in China and in OECD. The results confirm that capital input is positively related to the increase of total output in China and OECD countries. That is, when the economy is getting industrialized, it shows that the share of contribution of capital tends to diminish gradually in value in the model, eventually disappearing.

In testing hypothesis 2 that manufacturing growth is related to total factor productivity growth in the short-run, Table 5 shows that manufacturing (i.e. product innovation) is significant at the 0.01 level in China and OECD. The results confirm that manufacturing growth is positively related to the increase of total factor productivity and economic growth both in China and in OECD. That is, when the economy is getting industrialized (i.e. OECD), it shows that the share of contribution of manufacturing increases greatly to such an extent in value in the system.

In testing hypotheses 3 and 4 that high-technology exports and innovation and patent application growth are related to total factor productivity growth in the short-run, Table 5 shows that high-technology exports and innovation (i.e. R&D) and patent applications are not significant at the 0.05 level for China, but significant at the 0.01 level for OECD. The results suggest that total factor productivity from high-technology exports and innovation and patent applications is positively related to the increase of total output and economic growth for OECD countries. That is, when the economy is getting industrialized, it shows that the share of contribution of total factor productivity growth increases greatly to such an extent in value in the system.

5. Discussion and Policy Implication

According to the analysis of the data above, this study yields some important findings. The study has some theoretical implications on relevant literature and has also put forward with several managerial recommendations. This study examined the causal relationships between technological progress and innovation management, total factor productivity growth and economic growth in China and discussed the relationships between total factor productivity growth and economic growth. The results suggest that there exists a long-run equilibrium relationship between total factor productivity growth and economic growth in China. Moreover, the results suggest that the capital input is positively and strongly related to economic growth both in China and in OECD until now. The results suggest that manufacturing growth is positively related to the increase of total factor productivity and total output both in China and in OECD. The results also suggest that the total factor productivity from high-technology exports and innovation and patent applications is positively related to the increase of total output in OECD countries while that of China is insignificant. On the contrary, data shows that when the economy is getting industrialized, the share of contribution of labor productivity diminishes greatly in value in the model, eventually negative while the share of contribution of manufacturing still increases greatly in value in the model, with positive.

This study benefits the literature of technology and innovation management, total factor productivity growth and economic growth in several ways. For policy makers, firstly, the findings could empirically support the government decisions of industrialized economies to further facilitate their industrial policies that promote technological progress and innovation management for their total factor productivity growth. Secondly, governments of developing countries like China should give their policy priority to facilitate/promote technological innovation, product innovation, and R&D intensity and therefore lead to total factor productivity growth.

Some managerial implications are clear based on the empirical results. Firstly, both public and private sectors should pay attention on how to facilitate/promote technological progress and product innovation, and how to increase R&D intensity from manufacturing firms. Secondly, governments and organizations may encourage innovation and patents through several ways to yield total factor productivity growth in their organizations and economies. For example, policies and incentives should help technology and innovation-oriented companies by providing more technical and financial support and by facilitating the whole process of patent registration and protection. What's more, companies need to develop their R&D network, production-collaboration, and R&D investment capabilities.

6. Conclusions and Research Limitations

This study examined the causal relationships between technological progress and innovation management, total factor productivity growth and economic growth in China and discussed the relationships between total factor productivity growth and economic growth. The results suggest that there exists a long-run equilibrium relationship between total factor productivity growth and economic growth in China. Moreover, the results suggest that manufacturing growth is positively related to the increase of total factor productivity and total output in China. The results also suggest that the total factor productivity from high-technology exports and innovation and patent applications is positively related to total factor productivity growth in OECD countries while that of China is insignificant.

This study has limitations that may offer significant opportunities for future research on this important topic. Perhaps, future research focuses more specifically on those factors that directly impact total factor productivity growth in specific economic contexts.

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