

The Spillover Effects of Technological Progress Based on Two-Sector Model : An Empirical Research from Chinese Manufacturing Sectors

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Abstract

As the technology has the nature of public goods, industrial technology innovation activities have positive externalities on related sectors. Two-sector Model is built to identify and calculate the spillover effects of technological progress. Specifically, the industry is divided into two sectors, and technological progress in one sector is added to the production function of the other sector to research the relationship between technological progress in one sector and output growth of the other. Panel data constituted by time-series from 2000 to 2007 and cross-section data of 31 provinces in Chinese manufacturing sectors is used for empirical test. The conclusion is drawn that there are very significant spillover effects from the technological progress in equipment manufacturing sector on non-equipment manufacturing sector. The estimated results of different divisions prove that the production efficiency of equipment manufacturing sector and equipment updating speed of non-equipment manufacturing sector influence the spillover effects.

Key words: technological progress, spillover effects, two-sector model

1. Introduction

According to industrial linkage theory, there are extensive and close economic relations between related industries in the process of economic activities. As the technology has the nature of public goods, industrial technology innovation activities have positive externalities. The technical progress in specific industry can not only bring its own economic growth, but also has a technological spillover effect on the related sectors. In terms of the theories, the technical progress in one sector has a spillover effect on the other sector, promoting the raising of the whole economy. But does this spillover effect really exist?

As far as the studies on spillover effects between sectors, there are two theoretical frameworks. One is the extended one-sector model, mainly used in the study of FDI spillover effect. Its core method is to add the foreign investment as an independent factor into the production function of domestically-funded enterprises. R.Findlay (1978) constructs a simple dynamic model inspecting the impact of steady-state characteristics on spillover effect, such as the technological gap and the proportion of foreign capital, under the assumption that FDI can increase the local technology through "contagion". Koizumi and Kopecky (1980) consider that the technology involved in the foreign investment has the public goods nature, which can bring the additional benefits to the society, and they inspect the impact of FDI on a nation's economic growth by constructing an international capital flow model in long-term. Romer (1990), Aghion(1992) and Barro (1997) analyzes decisive effects of the spillover effects on sustained economic growth from international technology. Rodriguez-Clare (1996) studies the spillover effects between industries of FDI. If the multinational companies' final goods use many intermediate products and there is a big difference between the two countries in the production of intermediate products, the local country will benefit from the spillover effects between industries of FDI. Markusen and Venables (1999) emphasize the dynamic effect on the local productivity generated by FDI through intermediate input and expansion of service requirements, including competitiveness effect and the linkage effect. And a conclusion is reached that multinational companies can boost the local firms producing intermediate product or the final goods. Another theoretical framework is the two-sector model. To inspect the contribution rate of exports to economic growth, Feder (1983) dichotomizes all productive activities into export and non-export sector and makes a function to evaluate externality on non-export sector from export sector.

By two samples of 19 countries (or regions) and 31 countries (or regions) and the empirical data of 1964-1973, it is verified that the export sector influences non-export sector through externality and productivity difference effect, and thus indirectly promotes economic growth. Feder's two-sector model is extended by subsequent researchers in different ways. Ram (1985) empirically tests the effects on economic growth from export, using 73 developing countries' data from 1960 to 1977. The effect is not obvious in 1960-1970 but apparent in 1970-1977. Ram (1987) then modifies the model to test the effects from export on the export promotion policy, using cross-section and time series data of 88 developing countries. Robert and Alexander (1994) expand the model into three-sector model of government, export sector and non-export sector. The empirical data of OECD countries shows a significantly positive correlation between government department and export sector, while the spillover effect from government and non-export sector is not obvious. Odedokun (1996) uses the two-sector model to examine the effect from financial department on the real economy and economic growth. Based on the findings of 71 developing countries, the effect is especially apparent in low-income countries. Wang (1999) (2000) adds the expected process of adaptability into the two-sector model and constructs a dynamic two-sector model considering supply and demand to test the causality between financial development and economic growth. The empirical result of Taiwan shows that the external effect from financial department on the real economy is greater than its reverse.

The main problem is whether the technical progress in one sector has positive externality and the degree it spreads into the other sector. This article intends to propose a dynamic framework, which is based on the production function theory and Feder's two-sector model. The intersectoral externalities or spillover effects can be derived and estimated. The framework is applied as a prototype to the case of China, a newly industrialized country in East Asia, using panel data constituted by time-series from 2000 to 2007 and cross-section data from 31 provinces. The rest of the article is structured as follows. Section 2 presents the framework of the dynamic two-sector model. Section 3 is the data resources and variable selection. Section 4 is the quantitative analysis and Robustness Test. Section 5 tests the spillover effect of different regions and makes the comparison. The last part summarizes concluding remarks.

2. The model

One production function is postulated for each sector. We assume that the whole industry is divided into one sector and the other sector. There exists an externality or spillover effect of one sector onto the production of the other sector. It infers that, while production of one sector is a function of only labor and capital, production of the other sector is a function not only of labor and capital but also of the technical progress in the first sector. In other words, externality arises if an expected technical progress in one sector promotes the output of the other sector. The system described above can now be specified in equations below.

$$Y_t = E_t + N_t \quad (1)$$

$$K_t = K_{Et} + K_{Nt} \quad (2)$$

$$L_t = L_{Et} + L_{Nt} \quad (3)$$

$$E_t = E(L_{Et}, K_{Et}) \quad (4)$$

$$N_t = N(L_{Nt}, K_{Nt}, T_{Et}) \quad (5)$$

Where,

Y_t = aggregate output of the whole industry in period t.

K_t and L_t = capital and labor input of the whole industry in period t.

E_t and N_t = aggregate output of one sector and the other sector in period t.

K_{Et} and K_{Nt} = physical capital used in the respective sector in period t.

T_{Et} = technical progress in one sector in period t

L_{Et} and L_{Nt} = labor force engaged in one sector and the other sector in period t.

By total differential,

$$dY = dE + dN \quad (6)$$

$$dK = dK_E + dK_N \quad (7)$$

$$dL = dL_E + dL_N \tag{8}$$

$$dE = E_{LE} * dL_E + E_{KE} * dK_E \tag{9}$$

$$dN = N_{LN} * dL_N + N_{KN} * dK_N + N_{TE} * dT_E \tag{10}$$

And,

$$dY = dE + dN = E_{LE} * dL_E + E_{KE} * dK_E + N_{LN} * dL_N + N_{KN} * dK_N + N_{TE} * dT_E \tag{11}$$

where, E_{LE} , E_{KE} , N_{TE} represent the marginal productivities of labor, capital and technical progress in one sector, and N_{LN} , N_{KN} stand for the marginal productivities of labor and capital in the other sector.

By recognizing the possible existence of a difference in marginal productivity between the two sectors, we define the following relationship as in Feder (1983):

θ is the productivity differential that makes the ratios deviated from unity.

$$E_{LE} / N_{LN} = E_{KE} / N_{KN} = 1 + \theta \tag{12}$$

By a simple manipulation, Eq. (11) can be derived as shown below:

$$dY = N_{LN} * dL + N_{KN} * dK + \frac{\theta}{1 + \theta} * dE + N_{TE} * dT_E \tag{13}$$

Assuming that the spillover elasticity on the other sector from the technical progress in one sector (T_E) is constant, so,

$$N_t = N(L_{Nt}, K_{Nt}, T_{Et}) = T_E^\lambda \varphi(L_{Nt}, K_{Nt}) \tag{14}$$

From Eq. (14),

$$N_{TE} = \lambda * \frac{N}{T_E} \tag{15}$$

By substituting Eq. (15) into Eq. (13), it can now be rewritten as,

$$dY = N_{LN} * dL + N_{KN} * dK + \frac{\theta}{1 + \theta} * dE + \lambda * \frac{N}{T_E} * dT_E \tag{16}$$

Divided by Y, it can further be written as,

$$\frac{dY}{Y} = N_{LN} * \frac{L}{Y} * \frac{dL}{L} + N_{KN} * \frac{K}{Y} * \frac{dK}{K} + \frac{\theta}{1 + \theta} * \frac{E}{Y} * \frac{dE}{E} + \lambda * \frac{N}{Y} * \frac{dT_E}{T_E} \tag{17}$$

Where, $\frac{dL}{L}$ and $\frac{dK}{K}$ indicate the growth rates of labor and capital respectively, $\frac{E}{Y} * \frac{dE}{E}$ indicates the direct

contribution to the whole industry from one sector. $\frac{N}{Y} * \frac{dT_E}{T_E}$ shows that the technical progress in one sector promotes the whole industrial economy through their elasticity.

The technical progress in one sector is measured in Cobb-Douglas production function, which is regarded as a basic method to measure the technical level or technical progress.

$$Y = AK^\alpha L^\beta \tag{18}$$

Where, Y indicates the output, K and L are the input of capital and labor, α and β indicate the output elasticity of capital and labor, A is the technical level, i.e. the Total Factor Productivity(TFP). Given that

$A = \frac{Y}{K^\alpha L^\beta}$, the formula of technical progress in one sector is

$$T_E = \frac{E}{K_E^\alpha L_E^\beta} \tag{19}$$

In general, there are two forms of the production function: constant returns to scale ($\alpha + \beta = 1$) and variable returns to scale ($\alpha + \beta \neq 1$). Under the assumption of constant returns to scale, i.e. $\alpha + \beta = 1$. Eq. (19) can be converted to

$$T_E = \frac{E/L_E}{(K_E/L_E)^\alpha} \tag{20}$$

So,

$$\frac{dT_E}{T_E} = \frac{d(E/L_E)}{E/L_E} - \alpha * \frac{d(K_E/L_E)}{K_E/L_E} \tag{21}$$

Substituting Eq. (21) into Eq. (17),

$$\frac{dY}{Y} = N_{LN} * \frac{L}{Y} * \frac{dL}{L} + N_{KN} * \frac{K}{Y} * \frac{dK}{K} + \frac{\theta}{1+\theta} * \frac{E}{Y} * \frac{dE}{E} + \lambda * \frac{N}{Y} * \left(\frac{d(E/L_E)}{E/L_E} - \alpha * \frac{d(K_E/L_E)}{K_E/L_E} \right) \tag{22}$$

To compute $\frac{N}{Y} * \left(\frac{d(E/L_E)}{E/L_E} - \alpha * \frac{d(K_E/L_E)}{K_E/L_E} \right)$, it needs to determine the output elasticity coefficient α . There are

mainly three methods: empirical estimation, ratio method and method of regression. This article uses ratio method to measure the output elasticity. As the capital and labor input may have the same tendency over time, so there is serious co-linearity between variables. To weaken this problem, the variables are usually processed in average form. So the formula is derived from Eq. (18),

$$\ln \frac{Y}{L} = \ln A + \alpha * \ln \frac{K}{L} \tag{23}$$

Thus, the formula of output elasticity of one sector is

$$\ln \frac{E}{L_E} = C + \alpha * \ln \frac{K_E}{L_E} + e \tag{24}$$

Decomposing $\frac{N}{Y} * \left(\frac{d(E/L_E)}{E/L_E} - \alpha * \frac{d(K_E/L_E)}{K_E/L_E} \right)$ of Eq. (22),

$$\frac{dY}{Y} = N_{LN} * \frac{L}{Y} * \frac{dL}{L} + N_{KN} * \frac{K}{Y} * \frac{dK}{K} + \frac{\theta}{1+\theta} * \frac{E}{Y} * \frac{dE}{E} + \lambda * \frac{N}{Y} * \frac{d(E/L_E)}{E/L_E} + (-\alpha) * \lambda * \frac{N}{Y} * \frac{d(K_E/L_E)}{K_E/L_E} \tag{25}$$

Replaced $N_{LN} * \frac{L}{Y}$, $N_{KN} * \frac{K}{Y}$, $\frac{\theta}{1+\theta}$, λ , $(-\alpha) * \lambda$ of Eq.(25) by C_1 , C_2 , C_3 , C_4 , C_5 and $\frac{dY}{Y}$,

$\frac{dL}{L}$, $\frac{dK}{K}$, $\frac{E}{Y} * \frac{dE}{E}$, $\frac{N}{Y} * \frac{d(E/L_E)}{E/L_E}$, $\frac{N}{Y} * \frac{d(K_E/L_E)}{K_E/L_E}$ by g_i , g_l , g_k , ce , $cetn1$, $ce^{k/l}n1$, Eq.(25) is

rewritten as:

$$g_i = C_1 * g_l + C_2 * g_k + C_3 * ce + C_4 * cetn1 + C_5 * ce^{k/l}n1 \tag{26}$$

So, Eq. (26) is the elasticity formula to measure the spillover effect of technical progress in one sector under the assumption of constant returns to scale.

As for the assumption of variable returns to scale, i.e. $\alpha + \beta \neq 1$, firstly, Eq. (19) is converted in the average form:

$$T_E = \frac{E/L_E}{(K_E/L_E)^\alpha * L_E^{(\alpha+\beta-1)}} \tag{27}$$

So,

$$\frac{dT_E}{T_E} = \frac{dE/L_E}{E/L_E} - \alpha * \frac{dK_E/L_E}{K_E/L_E} - (\alpha + \beta - 1) * \frac{dL_E}{L_E} \tag{28}$$

Substituting Eq. (28) into Eq.(17),

$$\frac{dY}{Y} = N_{LN} * \frac{L}{Y} * \frac{dL}{L} + N_{KN} * \frac{K}{Y} * \frac{dK}{K} + \frac{\theta}{1+\theta} * \frac{E}{Y} * \frac{dE}{E} + \lambda * \frac{N}{Y} * \left[\frac{dE/L_E}{E/L_E} - \alpha * \frac{dK_E/L_E}{K_E/L_E} - (\alpha + \beta - 1) * \frac{dL_E}{L_E} \right] \tag{29}$$

In the same way, to compute $\frac{N}{Y} * \left[\frac{dE/L_E}{E/L_E} - \alpha * \frac{dK_E/L_E}{K_E/L_E} - (\alpha + \beta - 1) * \frac{dL_E}{L_E} \right]$, it needs to determine α and $(\alpha + \beta - 1)$.

Derived from Eq. (18),

$$\ln E/L_E = C + \alpha * \ln K_E/L_E + (\alpha + \beta - 1) \ln L_E + e \tag{30}$$

Decomposing $\frac{dE/L_E}{E/L_E} - \alpha * \frac{dK_E/L_E}{K_E/L_E} - (\alpha + \beta - 1) * \frac{dL_E}{L_E}$ of Eq. (30),

$$\begin{aligned} \frac{dY}{Y} = N_{LN} * \frac{L}{Y} * \frac{dL}{L} + N_{KN} * \frac{K}{Y} * \frac{dK}{K} + \frac{\theta}{1+\theta} * \frac{E}{Y} * \frac{dE}{E} + \lambda * \frac{N}{Y} * \frac{dE/L_E}{E/L_E} + (-\alpha) * \lambda * \frac{N}{Y} * \frac{dK_E/L_E}{K_E/L_E} \\ + (1 - \alpha - \beta) * \lambda * \frac{N}{Y} * \frac{dL_E}{L_E} \end{aligned} \tag{31}$$

Replaced $\frac{N}{Y} * \frac{dE/L_E}{E/L_E}$, $\frac{N}{Y} * \frac{dK_E/L_E}{K_E/L_E}$, $\frac{N}{Y} * \frac{dL_E}{L_E}$ of Eq.(31) by $cetn2$, $ce^{k/l}n2$, $ce \ln$ and $(-\alpha) * \lambda$,

$(1 - \alpha - \beta) * \lambda$ by C_5 , C_6 , Eq.(31) is rewritten as:

$$gi = C_1 * gl + C_2 * gk + C_3 * ce + C_4 * cetn2 + C_5 * ce^{k/l}n2 + C_6 * ce \ln \tag{32}$$

So, Eq. (32) is the elasticity formula to measure the spillover effect of technical progress in one sector under the assumption of variable returns to scale.

By knowing the possibility of existence of simultaneity in generating externalities, the follow two equations will be treated as a system of equations in the estimation procedure, where μ is disturbance terms. So, Eq.(I) and Eq.(II) will be the basic model for empirical analysis.

$$gi = C_1 * gl + C_2 * gk + C_3 * ce + C_4 * cetn1 + C_5 * ce^{k/l}n1 + \mu \tag{I}$$

$$gi = C_1 * gl + C_2 * gk + C_3 * ce + C_4 * cetn2 + C_5 * ce^{k/l}n2 + C_6 * ce \ln + \mu \tag{II}$$

3. Data Construction and Resources

In empirical application of the two-sector model to the case of China, we confine our study to exam the relationship between the equipment manufacturing sector and non-equipment manufacturing sector.

Equipment manufacturing sector is to provide the technical equipments to other sectors for reproduction. All variables are annual observations from 2000 to 2007.

The data used are from above-designated-size enterprises in 31 provinces in China¹.

¹ The data are published by National Bureau of Statistics from China Statistical Yearbook, Sta. Almanac of Chinese Industrial Economy and China's Economic Census Yearbook.

The productions of equipment manufacturing sector defined in this article consist of steel products, electronics products and investment category products of weapon industry, which all belong to the seven categories and 185 sub-categories of Metal Product Industry, General Equipment Manufacturing Industry, Special Equipment Manufacturing Industry, Transport Equipment Manufacturing Industry, Electrical Equipment and Equipment Manufacturing Industry, Electronic and Telecommunication Equipment industry, Instruments and Office Stationeries Manufacturing Industry. The data used in this article is integrated from the above seven industries.

The output variables are deflated using the Producer's Price Index for Manufactured Products and expressed in constant prices as of the year 2000. As for the capital input, there are mainly five indicators in the existing literature.(1) Fixed Assets Investment in the statistical data;(2)Accumulated Amount;(3) Net Value of fixed assets and Average Balance of current assets of all the apartments;(4)Net Capital Stock and Net Fixed Capital Stock in National Economic Accounting;(5) capital services supplied. Since the Net Fixed Assets is frequently used to test the technical progress contribution ratio, the annual net value of net fixed assets is used to indicate the capital input. The input variables are deflated using the Price Indices of Investment in fixed assets and Perpetual Inventory Method (PIM) and also expressed in constant prices as of the year 2000.The formula is:

$$K_{E_t} = I_t + (1 - \delta)K_{E_{t-1}} \tag{33}$$

where, K_{E_t} and $K_{E_{t-1}}$ represent the capital stock of equipment manufacturing sector in period t and t-1, I_t is the capital input, δ is the rate of depreciation of equipments. From Eq. (33), the key to test the capital stock is to determine the rate of depreciation and the capital stock in base period 2000. Many Chinese scholars use different methods to measure the depreciation rate. Such as, Huang Yongfeng evaluated the rate of depreciation of equipments as 17%, assuming that the life span is 16 years, while ZhangJun assumed 20 years and computed the rate as 15%.This article chooses 17% as the rate of depreciation. As for the capital stock in base period, in the existing literature, the capital input of base period is divided by 10% (Huang Yongfeng, 2002), which is used in this article. As for the labor input, there are three indicators home and abroad.(1) laborer number, i.e. the employed number;(2)the whole work time, i.e. average labor time multiplies laborer number;(3) Compensation of Laborers. As the laborer number can simply indicate the labor input scale and it has no price-adjusting problem, this article uses average annual employed number to represent the labor input.

Table 1 Variable symbols and their descriptive statistics

symbol		mean	SD	Maximum	Minimum
Indicators of output elasticity	$E/L_{E_{i,t}}$	27.56151	17.86246	98.16090	1.821429
	$K/L_{E_{i,t}}$	61.13383	47.73957	446.4970	22.14120
	$E_{i,t}$	2297.335	4032.037	28535.92	0.510000
	$K_{E_{i,t}}$	2974.478	3074.644	13749.69	9.200000
	$L_{E_{i,t}}$	63.25300	91.12457	621.0000	0.280000
Indicators of technical spillover effect	$gi_{i,t}$	0.217539	0.087628	0.471560	0.002427
	$gl_{i,t}$	0.030439	0.079340	0.344415	-0.339350
	$gk_{i,t}$	-0.002052	0.043746	0.123465	-0.064552
	$ce_{i,t}$	0.063236	0.052927	0.244071	-0.018123
	$cetn1_{i,t-1}$	0.138109	0.145233	1.595893	-0.056381
	$cetn2_{i,t-1}$	0.134021	0.094487	0.813949	-0.174805
	$cek/ln_{i,t-1}$	0.029146	0.635357	7.982386	-0.386556
$ce ln_{i,t-1}$	0.004418	0.102905	0.704140	-0.470816	

In the two-sector model, to test the spillover elasticity, the main variables are gi 、 gl 、 gk 、 ce 、 $cetn_i$ (i.e.cetn1 and cetn2),standing for the growth rate of output value, labor input, capital input of enterprises above designated size, and the direct contribution from equipment manufacturing sector and technical spillover on non-equipment manufacturing sector from equipment manufacturing sector.

From the derivation in section 2, the direct contribution is each variable divided by total output multiplies its own growth rate.

The growth rate of labor input is these enterprises' average annual laborer number, while the growth rate of capital input is these enterprises' average annual net fixed assets.

Due to the time lag in technical spillover, the variables in empirical model which are related to $cetn_i$ all use lagged variables. In addition, the measurement of capital variable and capital stock in the above process is the same as that of capital stock in output elasticity of equipment manufacturing sector. Variable symbols and a detailed description of data are given in Table 1.

4. Empirical Analyses

This article uses panel data of 31 provinces in China (except for Hong Kong, Macao and Taiwan) from 2000 to 2007. The regression empirically tests the spillover effect of technical progress in equipment manufacturing sector on non-equipment manufacturing sector.

4.1 The estimation of spillover elasticity

Table 2 Results of output elasticity of equipment manufacturing sector

Assumptions	$\alpha + \beta = 1$	$\alpha + \beta \neq 1$	
Constant and output elasticity	α	α	$\alpha + \beta - 1$
Constant	0.755294 (0.992545)	-1.457048*** (-3.228586)	
Output elasticity	0.596300*** (3.093380)	0.896777*** (7.531433)	0.304896*** (43.13345)
Ad-R ²	0.356054	0.731690	
F-value	16.13634	67.35778	
Prob(F-statistic)	0.000000	0.000000	

T-values are in parentheses. *** indicates significance level of 1%; ** indicates significance level of 5%; * indicates significance level of 10%.

To estimate the spillover effect of technical progress, the output elasticity of capital and labor input in equipment manufacturing sector is not necessary. But to analyze the production characteristics of equipment manufacturing sector, this article calculates the output elasticity, and the results are tabulated in Table 2.

The results show that α , the output elasticity of capital input and β , the output elasticity of labor input are both very significant under the assumptions of constant returns to scale and variable returns to scale. And α is 0.596 and 0.897 while β is 0.404 and 0.408, which indicate that the contribution from capital to output is greater than that from labor.

As the elasticity coefficient difference of input factors is highly related to their utilization, some scholars have reached the conclusions that capital elasticity coefficient of heavy industry and capital-intensive industry is greater than that of light industry and labor-intensive industry (Wang Dewen, 2004). So Chinese equipment manufacturing sector is a typical capital-intensive industry, in which capital is usually combined with relevant technology, having a significant effect on economic growth of the industry.

In addition, under the assumption of variable returns to scale, $\alpha + \beta - 1 = 0.305 > 0$, so it belongs to increasing returns to scale.

Fixed Effects Model is used to estimate the spillover elasticity of equipment manufacturing sector.

Considering the possible Heteroskedasticity of cross section, consistent covariance matrix of White heteroskedasticity is used to modify the model so as to have the robust t-statistics results. The results of parameters are in Table 3.

Table 3 Empirical results of spillover effect of technical progress in equipment manufacturing sector

Variables		Assumptions	
		$\alpha + \beta = 1$	$\alpha + \beta \neq 1$
Constant		0.149459*** (18.06594)	0.151511*** (18.51031)
$g_{li,t}$		0.296611*** (4.148063)	0.296179*** (4.164246)
$g_{ki,t}$		0.620371*** (4.265687)	0.596612*** (3.740337)
$ce_{i,t}$		0.520703*** (5.393829)	0.512122*** (5.583881)
$cetn_{i,t-1}$	$cetn1_{i,t-1}$	0.158045*** (3.886001)	0.150723*** (3.840917)
	$cetn2_{i,t-1}$		
$cek/ln_{i,t-1}$	$cek/ln1_{i,t-1}$	-0.276398*** (-3.522674)	-0.237374** (-2.465686)
	$cek/ln2_{i,t-1}$		
$celn_{i,t-1}$			0.033156 (0.548783)
Ad-R ²		0.617931	0.615606
F-value		27.03900	24.44005
Prob(F-statistic)		0.000000	0.000000

T-values are in parentheses. *** indicates significance level of 1%;** indicates significance level of 5%;* indicates significance level of 10%.

4.2 Results analysis

The estimated results show that the signs of all variable coefficients are as expected. The Adjusted R-squared are all above 0.61 and the equation’s goodness-of-fit is comparatively high, passing the test of significance. Under the assumptions of constant returns to scale and variable returns to scale, the results are almost the same.

The estimated coefficient of *cetn*, the technical spillover effect from equipment manufacturing sector on non-equipment manufacturing sector, is positive at the level of 1% under the two assumptions, which proves the existence of the spillover effect. Meanwhile, the estimated coefficient of *ce* is significant at the level of 1%, indicating the direct contribution of equipment manufacturing sector to the whole industry is very apparent. The estimated values are 0.51 and 0.52, showing that the impetus function on the whole industry from equipment manufacturing sector is very great. $C_3 = \theta/(1+\theta) > 0$, $\theta > 0$ represents the marginal productivity of equipment manufacturing sector is higher than that of non-equipment manufacturing sector. Due to the two assumptions, the parameter estimations are different and the results have differences. The concrete explanation of the empirical results is as follows:

(1) Assuming constant returns to scale, the estimated results of the spillover effect of technical progress in equipment manufacturing sector is significant at the level of 1% and the spillover elasticity is 15.8%. The reasons that the spillover elasticity is not very great lie in two sides. One is the comparatively low technical level and production efficiency of Chinese equipment manufacturing sector. The other is the slow equipment updating speed of non-equipment manufacturing sector. The net value of fixed assets (including the production equipments) from 2001 to 2004 increases at the rate of -6.8%, -5.4%, -4.0%, -1.6%. After four years of negative growth, the growth rate becomes to be positive from 2005 to 2007, but only at the level of 0.2%, 2.8% and 4.4%. So the average growth rate between 2001 and 2007 is -1.5%. Even considering the depreciation, the equipment updating speed is still slow so that non-equipment manufacturing sector can not enjoy the spillover effect from equipment manufacturing sector, which is named “threshold effect” in the study of spillover effect of FDI by Borenztein(1998). The threshold effect means that only when the factors affecting the spillover effect are above the “threshold” can the effect be apparent. In the conditions of limited technical level of equipment manufacturing sector and the slow speed of equipment updating in non-equipment manufacturing sector, the factors do not reach the “threshold”, so the spillover effect is not apparent.

While the equipment manufacturing sector has a notable driving force on the whole industry and the direct contribution C_3 is 52%. $C_3 = \theta/(1 + \theta)$, $\theta=1.08$ shows that the marginal output in equipment manufacturing sector is 108% higher than that of non-equipment manufacturing sector. The contribution of labor to industrial economic growth is about 30% and the growth of investments in fixed assets to the industry is 62%. So Chinese industrial economic growth owes to the investments in fixed assets to a large extent, reflecting the current situation of investment-lead economic growth.

(2) Assuming variable returns to scale, the parameter estimation of technical spillover from equipment manufacturing sector is still significant at the level of 1% and the spillover elasticity is 15.1%, which is close to that of the variable returns to scale. And $C_3 = \theta/(1 + \theta)=51.2%$, $\theta=1.04$ indicates that the marginal output in equipment manufacturing sector is 104% higher than that of other industries. So the rapid development of equipment manufacturing sector will push Chinese economic growth. In addition, the contribution of labor to the growth of the whole industry is about 30% and the contribution of increasing investments in fixed assets is 60%, which also can prove Chinese situation of investment-lead economic growth.

4.3 Robustness Test

In the test of the capital stock of investments in fixed assets, the depreciation rate is still in discussion and different rates will influence the technical spillover elasticity. To get the robust results, this article not only uses 17% as the depreciation rate, which is usually used in the test of capital stock in manufacturing industries, but also 10% assumed by Gong Liutang (2004) and 5% assumed by Perkins (1998). The empirical results are tabulated in Table 4. From the empirical results, the spillover elasticity is apparently positive under different depreciation rates. If the depreciation rate is 10%, the elasticity is 15.3% and 13.3%, and if the rate is 5%, the elasticity is 8.6% and 10.1%. Additionally, both the equation and the variables are of great significance, passing robustness test. The results prove that the technical progress in equipment manufacturing sector can drive the output growth of non-equipment manufacturing sector.

Based on the results of parameter estimation and robustness test, no matter the depreciation rates and the assumptions of returns scale, there exists a positive relation between the technical progress in equipment manufacturing sector and the output of non-equipment manufacturing sector. The driving force from equipment manufacturing sector to the whole industrial economy is certain and great.

Table 4 Robustness test of technical spillover elasticity of equipment manufacturing sector under different depreciation rates

Depreciation rate of investment stock of fixed assets		Depreciation rate=10%		Depreciation rate=5%	
Assumptions		Constant returns to scale	Variable returns to scale	Constant returns to scale	Variable returns to scale
constant		0.135391*** (25.27097)	0.138728*** (24.48100)	0.156990*** (12.44104)	0.167870*** (14.38746)
	$g_{li,t}$	0.307312*** (4.431512)	0.305326*** (4.451815)	0.281415*** (3.597260)	0.270247*** (3.351775)
	$g_{ki,t}$	0.679423*** (3.851194)	0.622658*** (3.309138)	0.460283*** (4.341735)	0.398548*** (3.566382)
	$ce_{i,t}$	0.485646*** (4.897941)	0.478163*** (5.193663)	0.653020*** (7.485655)	0.575191*** (7.582181)
$cetn_{i,t-1}$	$cetn1_{i,t-1}$	0.153762*** (3.605653)		0.086172*** (3.060826)	
	$cetn2_{i,t-1}$		0.133004*** (3.168456)		0.100589*** (3.190092)
$cek/ln 2_{i,t-1}$		-0.241281*** (-3.272485)	-0.149677 (-1.547925)	-0.248939*** (-2.985657)	-0.151430** (-2.256009)
$ce ln_{i,t-1}$			0.080840 (1.238122)		0.113086** (2.133140)
Ad-R ²		0.611910	0.610486	0.620738	0.624425
F-value		26.38520	23.93960	27.35085	25.33413
Prob(F-statistic)		0.000000	0.000000	0.000000	0.000000

T-values are in parentheses. *** indicates significance level of 1%; ** indicates significance level of 5%; * indicates significance level of 10%.

5. Influences of production efficiency and equipment updating speed

In the empirical test, it assumes that the spillover effect is the same in all the areas. But actually, factors like the production efficiency of equipment manufacturing sector and the equipment updating speed of non-equipment manufacturing sector affect the spillover effect. To examine the above two factors' influence, the areas are divided into groups to test the elasticity under different constraint conditions. And the depreciation rate is assumed as 17% in consideration of space and error.

5.1 Divisions by production efficiency

This article uses per capita aggregate industrial output value to represent the production efficiency. If the value is above 25.88 billion Yuan per million people (25.88 is the average amount of all provinces in China from 2000 to 2007), the area belongs to the high production efficiency group, and the others belong to the low efficiency group. According to this standard, the high efficiency group includes Beijing, Tianjin, Liaoning, Jilin, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Shandong, Hubei, Guangdong, Guangxi, and Chongqing. To get more accurate results, four provinces (Henan, Hunan, Hainan and Xizang) of insufficient data are excluded. The results of this division are as follows:

Table 5 The results of spillover effect according to the division by production efficiency

Standard Assumptions Variables	Production efficiency of equipment manufacturing sector			
	Constant returns to scale		Variable returns to scale	
	High efficiency	Low efficiency	High efficiency	Low efficiency
Constant	0.118698*** (11.60585)	0.162099*** (17.92904)	0.108812*** (10.57209)	0.160187*** (18.09462)
$g_{li,t}$	0.305953*** (3.523704)	0.382321*** (7.058146)	0.283416*** (3.450943)	0.348141*** (4.063749)
$g_{ki,t}$	0.090900 (0.371820)	1.638597*** (7.968534)	0.550667* (1.774505)	1.594833*** (6.713383)
$ce_{i,t}$	0.593972*** (7.442753)	1.273574*** (4.128342)	0.682682*** (9.581417)	1.372924*** (5.384346)
$cetn_{i,t-1}$	0.263109*** (3.599043)	0.038168* (1.726999)	0.205603*** (3.904901)	0.096144* (1.764808)
$cek/\ln 2_{i,t-1}$	-0.343963*** (-5.513977)	-0.001186 (-0.494497)	-1.235567*** (-5.010599)	-0.065558 (-0.462209)
$ce \ln_{i,t-1}$			-0.746008*** (-4.546330)	0.113482 (1.305592)
Ad-R ²	0.747839	0.575531	0.775207	0.668561
F-value	25.61542	11.44033	27.02073	15.12004
Prob(F-statistic)	0.000000	0.000000	0.000000	0.000000

T-values are in parentheses.*** indicates significance level of 1%;** indicates significance level of 5%;* indicates significance level of 10%.

According to the empirical results, after the areas are divided by production efficiency, the spillover elasticity of technical progress changes apparently. Under the assumption of constant returns to scale, the elasticity is 26.31% in the areas of high production efficiency and 3.81% in the areas of low efficiency, making a difference of almost 23%. Under the assumption of variable returns to scale, the elasticity is 20.56% in the areas of high production efficiency and 9.61% in the areas of low efficiency, making a difference of almost 11%. These two conditions show that the production efficiency of equipment manufacturing sector has a great impact on the technical spillover effect and the higher the production efficiency, more apparent the effect.

5.2 Divisions by equipment updating speed

This article uses the growth rate of fixed assets investment (FAI) stock to represent the equipment updating speed in non-equipment manufacturing sector. If the average growth rate is above -0.01189(-0.01189 is the average value of the growth rate in all provinces in China from 2000 to 2007), the area belongs to high updating speed group, and the others all belong to the slow updating speed group. According to this standard, the high updating speed group includes Hebei, Shanxi, Inner Mongolia, Jiangsu, Zhejiang, Fujian, Shandong, Henan, Hubei, Hainan, Guizhou, Shaanxi, Ningxia. Similarly, and provinces of insufficient data like Henan, Hunan, Hainan, Xizang are excluded. Table 6 shows the empirical results.

According to this kind of division, the technical spillover elasticity of equipment manufacturing sector still has the difference. Under the assumption of constant returns to scale, the elasticity is about 23.47% in the areas of high equipment updating speed in non-equipment manufacturing sector, and 9.89% in the areas of low updating speed. Under the assumption of variable returns to scale, the elasticity is about 34% in the areas of high updating speed, and 12.88% in the areas of slow updating speed, making a difference of almost 21%. These two conditions both indicate that the equipment updating speed of non-equipment manufacturing sector has a great impact on the technical spillover effect of equipment manufacturing sector. And the effect is more apparent in the areas of high updating speed.

Table 6 The results of spillover effect according to the division of equipment updating speed in non-equipment manufacturing sector

Standard Assumptions Variables	Equipment updating speed in non-equipment manufacturing sector			
	Constant returns to scale		Variable returns to scale	
	High speed	Low speed	High speed	Low speed
Constant	0.151916*** (5.592464)	0.161357*** (12.42255)	0.155607*** (6.261152)	0.149129*** (20.04638)
$gl_{i,t}$	0.482262*** (5.629162)	0.162041 (1.077186)	0.409575*** (6.918856)	0.159338 (1.038501)
$gk_{i,t}$	0.375315 (1.087291)	1.136149** (2.052745)	0.015347 (0.049735)	1.346115* (2.301717)
$ce_{i,t}$	0.404295 (1.098040)	0.622331*** (6.878039)	0.285508 (1.231791)	0.715618*** (10.75322)
ce_{t-1}	0.234664*** (3.333032)	0.098921 (1.370826)	0.340030*** (4.498372)	0.128788* (1.784164)
ce_{t-2}	-0.001408 (-0.413879)	-0.177509 (-1.289086)	0.156025 (1.233496)	-0.408438** (-2.042333)
ce_{t-1}			0.306789*** (3.703813)	-0.269563 (-1.237027)
Ad-R ²	0.534044	0.619472	0.654710	0.623162
F-value	8.449828	16.46529	12.20433	15.28162
Prob(F-statistic)	0.000000	0.000000	0.000000	0.000000

T-values are in parentheses. *** indicates significance level of 1%; ** indicates significance level of 5%; * indicates significance level of 10%.

6. Conclusions

This article tests the spillover effect from technical progress in one sector on the other by constructing two-sector model and using panel data of Chinese equipment manufacturing sector and non-equipment manufacturing sector from 2000 to 2007. The conclusions are as follows:

(1) Expanding Feder's two-sector model, technological progress in equipment manufacturing sector is added to the production function of non-equipment manufacturing sector to study the spillover effect of technical progress in equipment manufacturing sector. Technical progress T has an impact on the whole industry by its elasticity relation ($\frac{N}{Y} * \frac{dT_E}{T_E}$) with N , the output of non-equipment manufacturing sector. Meanwhile, the direct contribution from equipment manufacturing sector to industrial economy is tested by analyzing the share of output value of equipment manufacturing sector divided by output in the whole industry and multiplies the growth rate of equipment manufacturing sector ($\frac{E}{Y} * \frac{dE}{E}$), indicating the difference of production capacity between equipment manufacturing sector and non-equipment manufacturing sector.

(2) The empirical tests show that the spillover elasticity is between 15.1% and 15.8%, indicating that technical progress in equipment manufacturing sector has an apparently positive impact on non-equipment manufacturing sector. The notable driving force of equipment manufacturing sector is about 52% and its marginal productivity is far more than that of non-equipment manufacturing sector. 17%, 10% and 5% are separately used as the depreciation rate to test the spillover elasticity and similar conclusions are reached, testifying the robustness of the results.

(3) In the test of output elasticity of equipment manufacturing sector, under the assumptions of constant returns to scale and variable returns to scale, the output elasticity of capital input is 0.596 and 0.897, higher than 0.404 and 0.408, which are the contributions of labor input. It shows that Chinese equipment manufacturing sector belongs to typical capital-intensive industries and capital input has an important effect on output growth. The growth rate of capital and labor both influence the industrial output apparently, and the contribution of investment is above 60% and labor, 30%. It indicates that Chinese industrial economy is a mode of investment-lead development.

(4) In different divisions, the results show that production efficiency of equipment manufacturing sector and equipment updating speed of non-equipment manufacturing sector both affect the technical spillover effect. The higher the production efficiency of equipment manufacturing sector and the equipment updating speed of non-equipment manufacturing sector, more apparent the spillover effect of technical progress. As for the policy, it indicates that investments in research and development of equipment manufacturing sector are needed and innovation abilities, production efficiencies and the equipment updating speed of other industrial sectors should be promoted, to develop the driving force of equipment manufacturing sector to the whole industrial economy.

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