Journal of Applied Sciences

ISSN 1812-5654

science alert

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Journal of Applied Sciences 13 (12): 2294-2299, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2294-2299

DSGE Model of American Internationalized National Innovation System and its Evolutionary Trends

[1]Liu Jian-Hua, [2]Li Xin and [2]Jiang Zhao-Hua
[1]School of Management Engineering, Zhengzhou University, Zhengzhou, 450001, China
[2]School of Management and Public and Law, Dalian University of Technology, Dalian, 116023, China

Abstract: DSGE (Dynamic Stochastic General Equilibrium model) can be applied to many areas of study and produces more realistic policy recommendations. American internationalized national innovation system includes business, colleges and universities, government and overseas departments and the four-sector DSGE model of national innovation systems are built. By using econometric methods, this study forecasts the evolutionary trends of the main indicators of the American internationalized national innovation system development in 2020.

Key words: American internationalized national innovation system, DSGE models, evolutionary prediction

INTRODUCTION

So far, there have been a large number of case studies and empirical researches on national innovation system, but the analyses using models to support relevant policies are still insufficient (Forni *et al*., 2009). In terms of quantitative study, models are built mainly on basis of the following three methods: Econometric methods, stochastic differential methods and Dynamic Stochastic General Equilibrium (DSGE) (Malley *et al*., 2009) which has started to develop recently. Different from the past, DSGE could be utilized for better assessment of innovation policies' effects in the case of economic fluctuation.

Internationalized national innovation system includes business, colleges and universities (including scientific research institutes that run independently), government and overseas departments (Jiang and Liu, 2012). This study learns from the way in which DSGE models are built and does empirical researches and models on American internationalized national innovation system.

AMERICAN COMPANIES' INNOVATION BEHAVIORAL MODEL

As to the effects that innovation input has on the increase of companies' productivity, Grilichesli evaluated the output elasticity of research input at the level of company by using production function model and discovered that American research input had positive correlation with productivity (Griliches, 1980a, b, 1986, 1988). Mairesse and Sessenou (1991) studied the relationship between research activities and companies' productivity which turned out to be the fact that researches could boost the increase of companies' productivity and brought companies high profits. But in the national innovation system, the effects of innovation input are mainly reflected in two aspects to companies which play the role of innovation agents: For one thing, to gain, maintain and promote intellectual property; for another thing, to improve the productivity. Based on such facts, the American companies' innovation behavioral model is built as is shown in Eq. 1. C_t means American companies' R and D input, A_{t-3} means the number of patents 3 years ago. For example, if t is 2001, then A_{t-3} is the number of patents in 1998, Y_t means American GDP.

$$C_t = C_1 + aY_t + bA_{t-3} + cA^2_{t-3} \quad (1)$$

The American data from 1997 to 2008 can be used to calculate American companies' R and D input which is based on the price in 2005 and American GDP which is based on the price in the same year. By parameter estimation of American companies' innovation behavioral model in Table 1, the empirical model can be achieved as is shown in Eq. 2:

$$C_t = -304063 + 24.1Y_t + 3.84A_{t-3} - 0.0000155A^2_{t-3} \quad (2)$$

It can be seen from Table 1 that the regression model passes the verification, the Adjusted R-squared is 92.6% which means the figure is relatively high and has a strong ability of explanation, as well as the fact that the

Corresponding Author: Liu Jian-Hua, School of Management Engineering, Zhengzhou University, Zhengzhou, 450001, China

Table 1: Estimation of American companies' innovation behavioral model

Variable	Coefficient	Std. Error	t-statistic	Prob.
C_1	-304063	82620.31	-3.68024	0.0062
A_{t-3}	3.837166	1.30137	2.948559	0.0185
Y_t	24.13604	3.078425	7.840389	0.0001
A^2_{t-3}	-1.55E-05	4.75E-06	-3.25713	0.0116
R-squared	0.946307	Mean dependent var		202516.1
Adjusted R-squared	0.926172	S.D. dependent var		22178.26
S.E. of regression	6026.135	Akaike info criterion		20.5068
Sum squared resid	2.91E+08	Schwarz criterion		20.66844
Log likelihood	-119.041	F-statistic		46.99814
Durbin-Watson stat	1.411841	Prob (F-statistic)		0.00002

Dependent variable: C_t, Method: Least squares, Sample: 1997 2008, Included observations: 12

regression equation fits the sample well enough; that the regression equation passes the F verification means the effects of linear regression are notable. In addition, both the independent variables and constants pass t verification.

AMERICAN KNOWLEDGE PRODUCTION AND COOPERATION MODEL

In American national innovation system, the internationalization degree of science (thesis) is highly concerned with that of technology (patent). Therefore, the American knowledge production and cooperation model is built as is shown in Eq. 3. n_t means the number of American internationally cooperated theses, N_t means the number of science and technology theses published in America, u_t means the number of foreign patents applied in America, G_t means the number of patents granted in America; X_3 means "companies' science and technology input/(companies' science and technology input + government's science and technology input)".

$$\frac{n_t}{N_t} = C_2 + aX_3\frac{u_t}{G_t} \quad (3)$$

According to Table 2, the American knowledge production and cooperation model can be achieved as is shown in Eq. 4:

$$\frac{n_t}{N_t} = 0.05 + 2.53X_3\frac{u_t}{G_t} \quad (4)$$

From model (2), it is clear that the regression model passes the verification, while the Eq. 4 indicates that the increase of internationalization of scientific research is higher than that of technological development (it is notable that X_3 is usually greater than 0.5, so the coefficient before u_t/G_t is greater than 1). This is because science is of greater openness than technology and has more inner demands of internationalization than technology does. In the same time, it demonstrates that America leads the way in science worldwide.

AMERICAN GOVERNMENT INDUCTION MODEL

Many scholars have studied how input of science and technology from government affected that from companies. Government funds played essential roles in science and technology activities (Guellec and de la Potterie, 2000; David *et al*., 2000). Garcia-Quevedo (2004) thought that the grants from US defense could facilitate the increase of companies' research expenditure. He introduced control variables so that he was able to gauge the effects government's research input had on companies' research behavior efficiently. David *et al*. (2000) discovered that the intensity of government funds facilitated that of companies obviously.

In the national innovation system, the behavioral pattern of government, who plays the role of coordinator, booster and judge is: Using financial policies (financial investment, tax tools) and monetary policies, industrial policies, international technology trade policies and so on to stimulate and induce companies to invest in innovation, so that the economic society can develop fast and harmoniously. Therefore, the dynamic model of American company R and D input is built as is shown in Eq. 5. S_{t-2} means the government's R and D funds 2 years ago, h_t means the subsidiaries' R and D funds, H_t means the foreign companies' R and D funds in America.

$$C_t = C_3 + aS_{t-2} + b(h_t + H_t)/S_{t-2} \quad (5)$$

According to the statistic data from 1997 to 2008 of Science and Engineering Indicators, the government's R and D input is based on the data two years ago, meaning the effects government's R and D input has on companies' R and D input after two years.

On the basis of the estimation in Table 3, the dynamic model of American company R and D input can be achieved as is shown in Eq. 6:

$$C_t = -74779 + 2.1S_{t-2} + 162968(h_t + H_t)/S_{t-2} \quad (6)$$

Model Eq. 6 indicates that one unit of government's R and D input can lead to over two units of companies' R and D input.

AMERICAN TECHNOLOGICAL INPUT-OUTPUT PROPORTION MODEL

In condition of internationalization, from the perspective of international technological competitiveness, the proportion of technological output and technological input depends on the independence of technology (it is measured by "the proportion of own technology and valid patents" in this study) and the proportion of high-tech production exports and total exports. Therefore, the American technological input-output proportion model can be built as is shown in Eq. 7:

$$Y, X_1, X_2, X_3 \quad (7)$$

mean respectively the proportion of technological output and technological input, the proportion of own technology and valid patents, the proportion of high-tech production exports and total exports and companies' science and technology input/(companies' science and technology input+government's science and technology input).

According to the results of estimation in Table 4, the American technological input-output proportion model can be achieved as is shown in Eq. 8:

$$\log y = -0.81 + 8.7X_1 * X_2 * X_3 \quad (8)$$

Equation 8 shows that the "competitiveness of international technological market" hinges on the

Table 2: Estimation of American knowledge production and cooperation model

Variable	Coefficient	Std. Error	t-statistic	Prob.
C_2	0.049628	0.043012	1.153811	0.281900
$X_3 \frac{u_t}{G_t}$	2.533332	0.392947	6.447003	0.000200
R-squared	0.838592	Mean dependent var.		0.324989
Adjusted R-squared	0.818416	S.D. dependent var.		0.037665
S.E. of regression	0.016050	Akaike info criterion		-5.249330
Sum squared resid	0.002061	Schwarz criterion		-5.188820
Log likelihood	28.246660	F-statistic		41.563840
Durbin-watson stat	1.544732	Prob(F-statistic)		0.000199

Dependent variable: n_t/N_t, Method: Least squares, Sample: 2001 2010, Included observations: 10

Table 3: Estimation of dynamic model of American company R and D input

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C_3	-74779	18994.8	-3.936810	0.00340
S_{t-2}	2.102383	0.248278	8.467860	0.00000
$(h_t+H_t)/S_{t-2}$	162967.9	33092	4.924692	0.00080
R-squared	0.970637	Mean dependent var.		193420.20000
Adjusted R-squared	0.964112	S.D. dependent var.		36811.35000
S.E. of regression	6973.621	Akaike info criterion		20.74997
Sum squared resid	4.38E+08	Schwarz criterion		20.87120
Log likelihood	-121.5	F-statistic		148.75320
Durbin-watson stat	1.193543	Prob (F-statistic)		0.00000

Dependent variable: Y, Method: Least squares, Sample: 1997 2008, Included observations: 12

Table 4: Estimation of American technological input-output proportion model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C_4	-0.814950	0.379453	-2.147700	0.0549
$aX_1*X_2*X_3$	8.709048	1.093139	7.967011	0
R-squared	0.852296	Mean dependent var		2.179615
Adjusted R-squared	0.838868	S.D. dependent var		0.467201
S.E. of regression	0.187540	Akaike info criterion		-0.36901
Sum squared resid	0.386885	Schwarz criterion		-0.28209
Log likelihood	4.398553	F-statistic		63.47326
Durbin-watson stat	1.231170	Prob (F-statistic)		0.000007

Dependent variable: log y, Method: Least squares, Sample (adjusted): 2000 2008, Included observations: 9 after adjusting endpoints, Convergence achieved after 7 iterations

combined efforts of "the independence of technology", "the proportion of high-tech production exports and total exports" and "companies" science and technology input/ (companies' science and technology input+government's science and technology input)".

FORECAST OF THE AMERICAN NATIONAL INNOVATION SYSTEM AND THE TREND OF ITS INTERNATIONALIZED DEVELOPMENT

Based on the empirical models above, now the forecast of the American national innovation system and the trend of its internationalized development in 2020 can be achieved.

American companies' innovation behavior: American technological development mainly relies on its companies, who offer and use most of the R and D funds. It can be seen from the American companies' innovation behavioral model that there is a growing trend in the American R and D input, number of valid patents and GDP. From 1997 to 2008, the R and D input of American companies grew stably which increased by about 48% during the 12 years. However, developing countries like China, India, Korea, etc have been developing so fast that the world pattern is changing all the time. In order to maintain its international status of science and technology power, America has to add its R and D input continuously to promote its scientific and technological innovation and achievements. According to model (2), we forecast the companies' R and D input, as is shown in Fig. 1 and come up with the trend of American R and D input which shows that American R and D input will keep increasing.

Trend of American knowledge production and cooperation: The trend of 2020 can be forecasted by using American knowledge production and cooperation model (3). The number of internationally cooperated theses in American colleges and universities increases slowly while the proportion of patents which are applied by foreign countries in America and total number of American patents is also on the rise which indicates that more and more achievements of theses are gained by cooperation of America and other countries and the academic communication is more frequent.

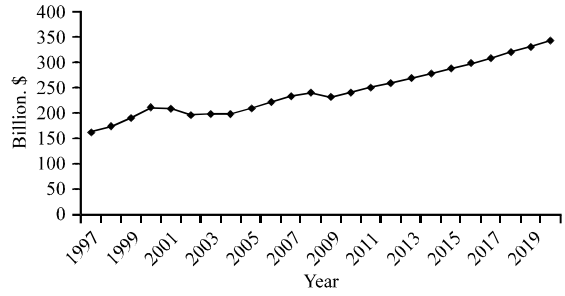

Fig. 1: 1997-2020 trend of R and D input of American companies

About 3 quarters of colleges which rank the top 40 in the world are in America, so are most of the Nobel laureates. There is no doubt that America leads the whole world in capacity of knowledge. But the amount of overseas students has been rising year by year and more than half of the students who receive a doctor's degree in engineering in America come from other countries. Among the theses published in America, there are more and more internationally cooperated ones, whose proportion grew from 20% in 2001 to over 30% in 2008. While the R and D investment of American overseas subsidiaries and the R and D investment of foreign companies in America go up annually, so does the proportion of number of patents applied by foreign countries in America and total number of patents. For one thing, it indicates that American ability of innovation has been strengthened and its production of innovation is increasing. For another thing, it shows the growing enhancement of American international cooperation. The reasons can be explained in two aspects. First of all, the demand of globalization forces research fields to collaborate internationally so that they can meet the requirements. In addition, the cooperation in research fields is of great help for all parties to play their respective advantages which enables them to complement with each other and is beneficial for the high productivity of scientific achievements. Secondly, internationalization can help a nation attract more excellent talents for its own

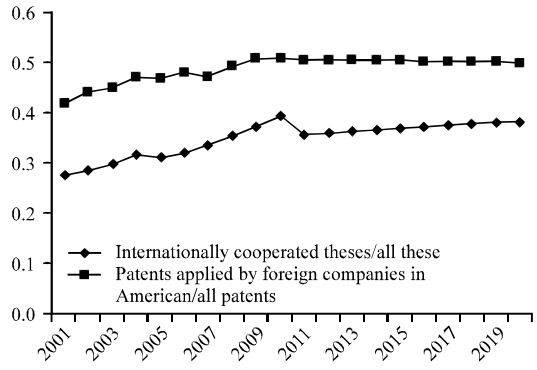

Fig. 2: Trend of number of American internationally cooperated theses and patents applied by foreign countries in America

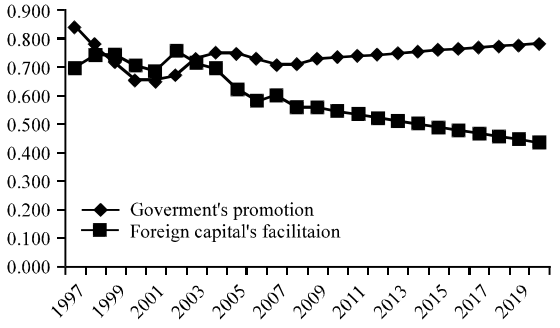

Fig. 3: 1997-2020 trend of impacts of American government's induction and foreign capital's facilitation

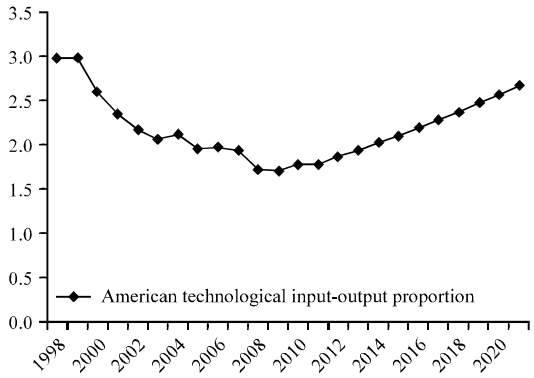

Fig. 4: 1998-2020 trend of American technological input-output proportion

scientific research, enabling the scientific achievements to be applied to its own economic and technological develop immediately.

Effects of american government induction: The effects of American government's promotion and foreign capital's facilitation can be forecasted by using model 6. Fig. 3 shows that the impacts of the government are relatively steady and rise slowly, while the ones of foreign capital decrease to some extent which is reverse to the trend in China.

American technological input-output proportion: American technological input-output proportion in 2020 can be forecasted by using model (8). Owning to the "reindustrialization", technological globalization and further knowledge densification of international trade, the proportion of input of American technology and output of technology went down before 2008 and it is foreseen that the proportion will go up since 2009 to 2020.

CONCLUSION

- American internationalized national innovation system includes business, colleges and universities, 0.99 government and overseas departments and the four-sector DSGE model of national innovation systems are built. To begin with, American companies' innovation behavioral model demonstrates that there are mainly two impacts of companies' innovation input: one is to gain, maintain and promote intellectual property, the other one is to increase the productivity. Secondly, American knowledge production and cooperation model shows that the increase of scientific research internationalization is higher than that of technological development internationalization. In addition, American government induction model indicates that one unit of government's R and D input can lead to over two units of companies' R and D input. Finally, American technological input-output proportion model illustrates that "competitiveness of international technological market" hinges on the combined efforts of "the independence of technology" and "the proportion of high-tech production exports and total exports"
- The forecast of development trend of American national innovation system in 2020 indicates that American internationalization will grow further, the R and D input of American companies will maintain an increasing trend, The proportion of number of internationally cooperated theses in American colleges and universities and total number of theses will rise year by year, so does the proportion of patents which are applied by foreign countries in America and total number of American patents. There will be more and more collaborated achievements of America with other countries, the international academic communication will be more frequent, the effects of the government's facilitation are relatively steady and rise slowly, while the ones of foreign capital decline which is reverse to the trend in China. It is forecasted that the proportion of high-tech production exports and total exports will increase, so will the one of American technological output and American technological input

ACKNOWLEDGMENT

Key project of National Natural Science Foundation of China (71033002, National Innovation Systems Theory and International Policy Research under the PORC Framework). Liu Jian-hua (1963), Henan Zhengzhou,

Zhengzhou University, Associate Professor, Ph.D., principal research areas are innovation and regional development strategies

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