Impacts of R&D Expenditure on Economic Growth and Structure Based on Beijing Dynamic CGE Model

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Abstract: Science and technology is an important source for economic development, and is a mainfactor of national, regional and enterprise core competitiveness. As a scientce and technological innovation center, Beijing is currently building a world city with Chinese characteristics. Technological innovation is an important driver of economic development, and science and technology investment is an important guarantee for technological development. So what is the impact of technological innovation on Beijing's future economic growth?
This article will add R&D investment forming knowledge capital factor (R&D capital) to the CGE model and consider technology spillover effect between industries, to study the impact of R&D investment policy on the macro-economy of Beijing. The simulation results of Beijing Dynamic CGE model show that: The future major driving force of economic development of Beijing is the technological progress. If Beijing can implement the scientific concept of development, deepen the reform of the science and technology system , implement the optimal allocation of science and technology investment , and promote the integration of science and technology and economy, then in next 5-10 years, Beijing will still be able to maintain a high growth rate, and the industrial structure and consumption structure will be more reasonable, which will also narrow the gap between urban and rural areas.

Keywords: science and technology investment; computable general equilibrium model; economic growth

0 Introduction

In 2010, the Beijing whole society development (R&D) spending reaches 82.18 billion yuan, which more than doubled 2005's, and the average annual growth rate is 16.7%. The ratio of R & D expenditure to GDP reaches 5.8 % , which is much higher than the national average, and R & D investment intensity is the highest in China.R&D expenditures as a source for economic and social development draw more and more people's attention. It plays an essential role in promoting economic development, especially in enterprise productivity. From the development point of economic growth theory, the main stream view is now about that: the main source of economic growth comes from science and technology progress, which is increased with the accumulation of physical and human capital. However, economists believe that only by capital accumulation, even including the broad concept of human capital, there exist the law of diminishing marginal return on capital, which is not enough to support long-term economic growth. Therefore, in order to avoid the law of diminishing capital return in long-term, we have to rely on technological progress ------the continuous progress in production methods and product categories, and quality. Therefore, the impact of R&D on economic growth has been a hot issue of widespread concern.

The basic framework of the CGE model is relatively mature, but how to bring R&D mechanism in the CGE model has been a difficulty. From the existing literatures on how to add R&D to CGE model ,in general there are two mechanisms: One way is that R & D investment increases, causing technological progress, thereby affecting the entire economy , in fact, it is an indirect mechanism through total factor productivity.Another mechanism is based on a new theory of economic growth,which thinks that besides physical capital and labor , Knowledge capital is alsofactor of production , that can be directly into the production function, but also thinks theknowledge capital has technology spillover effect , which will affect other businesses or industries production efficiency. Giesecke and Madden (2006), in dynamic CGE model empirical analysis, assumes that R & D spending will lead to personnel training, and improve labor productivity; Successful results of the technical research will improve factor productivity, and promote industrial development. The empirical results show that its R & D investment will gradually bring real consumption, real investment and economic growth, but government tax revenue growth is limited, and has no effects to employment and price changes. However, the R&D capital don’t include in the production function.

There are some CGE modelers introduce R & D capital, and considers the technology spillover effect. Garau and Lecca (2007) divided invested capital into physical capital and intellectual capital, and took into account the effectiveness of international technology spillovers. Intellectual capital embodied in the middle of the transaction matrix X, the authors isolated intellectual capital flow V from X, and used YTM (Yale Technology Matrix) to estimate V elements. In the dynamic CGE model, he analyzes the influence of regional R & D policies on regional economic growth and employment.

In short, the indirect mechanism in CGE model, has some flaws, and R&D capital datais more difficult to estimate. Therefore, thestudy of R & D investment policies analysis in the CGE literature is relatively less, so this article will expand the production function with R & D capital factor, to establish Beijing dynamic CGE model to study the Beijing R & D investment policies and the optimal allocation problem.

1 Beijing R&D investment

Over the past three decades, China's economy maintains a rapid development momentum, people's living standards are greatly improved, but economic growth is mainly driven by the expansion of the factors. Although the high-tech industry has been developing rapidly, but still is at the low end of the industrial value chain. The good news is that we have realized the importance of technological innovation for economic and social development, and Chinaisbuilding innovation-oriented country. Scientific and technological investment has been strengthened. Since 2000, China R & D expenditures has an annual growth rate of 23%, in 2009 that reached 580.21 billion yuan, which has also been among the toppestcountries with high R & D spending, But the R&D intensity is relatively low, R&D intensity of China reached 1.7%, but still does not meet target(2%) of the "Eleventh Five" Plan. As a national science and technology innovation center,

R & D spending of Beijing hasreached 82.18 billion yuan in 2010, two times of that in 2005, and the average annual growth rate is 16.7%. The R & D expenditure to GDP ratio reached 5.82%, much higher than the national average.level.

Table 1 China and Beijing R & D Intramural expenditures

Year	2005	2006	2007	2008	2009	2010	Average annual growth rate（%）
Beijing							
Beijing R & D expenditure (billion yuan)	379.5	433．0	527.1	620.1	668.6	821.8	16.7
Ration of R & D to GDP（%）	5.45	5.33	5.35	5.58	5.5	5.82	--
China							
National R&D expenditure (billion yuan)	2450	3003.1	3710.2	4616	5802.1	7062.6	23.58
Ration of R & D to GDP（%）（%）	1.32	1.39	1.4	1.47	1.7	1.76	

Source: Statistical Yearbook of Beijing, Statisticalyearbook of China Science and Technology

1.1 Sources of Beijing R&D funding

R&D intensity, i.e ratio of R&D expenditure to GDP ,is an important indicator to measure the extent of a country's efforts in technological innovation. R&D expenditure, by source of funds are grouped into:government funds, corporate funds, foreign funds, and other funds.Beijing R & D expenditure is 21.954 billion yuan in 2002 and 93.664 billion yuan in 2011, an average annual growth rate of 17.5 %, of which government funds and corporate funds almost keep the same pace with Beijing R & D investment growth, but foreign funds and other sources of funds have relatively few growth. over the past decade, Beijing R & D investment’s high growth is primarily from a substantial increase in government R & D funding and business R & D funding.

Specificly, from the sources of R & D funding growth rate, since 2006, the government funds are slightly higher than the increase rate of corporate funds, and far higher than the growth rate of foreign funds. From 2006 to 2011, the government R & D funds have an annual growth rate of 20.93%, corporate R & D funds with an average annual growth rate of 13.90%, other R & D funds an annual growth rate of 11.48%, foreign R & D funds an annual growth rate of 8.00%.

1.2 Compared with the other regions, theR&D investmentproportion of the governmentis higher and that of the enterprisesis lower

On the one hand, from the country's R & D investment structure, the corporates’ R & D investment grew thefastest, the government’s R & D investment increasing ratewaswith an average annual growth rate of 24.27% from 2003 to 2010 , this indicatorofcorporateswas32.74% which was significantly higher than the government’s.Thissituationis in opposite directions withthe R & D expenditure in Beijing.. It also led larger difference between the National R & D funds sources structure and the Beijing area. With respect to the country's R & D funding sources structure, in 2010 the government R & D expenditure accounted for 57.40% in Beijing area, beinghigher than the national government R & D expenditure (24.02%) which is 33.38%; while corporates’ R & D funding sources accounted for 32.90% in Beijing area, beinglower than national corporates’ R & D expenditure (71.69%) which is 38.97 percent.

On the other hand, compared with other provinces from the lateral view, such as Shanghai and Tianjin (see Figure 3) , Shanghai and Tianjin’s R & D funding sources have thesame structurewith the country's roughly , for example,Shanghai and Tianjin’s government R & D funding accounted for 29.64% and 19.23% respectivelyin 2010 , beingsignificantly lower than that of Beijing government R & D(57.40%), while the Shanghai and Tianjin enterprise R & D expenditure accounted for 74.14% and 66.07% respectively, being significantly higher than Beijing 's enterprise R & D expenditure which is 32.90% .
In short, the above analysis shows that the proportion of government R & D funding in the Beijing area is relatively higher, while the proportion of corporate R & D expenditure is relatively lower.

2 Dynamic CGE model settings

2.1 Principle explanation for SAM table with R & D capital and R & D workforce

In this paper, using the Beijing Municipal Science and Technology Statistics data, the capital element is divided into R & D and non-R & D capital (physical capital), and labor forceis divided into R & D and non-R & D labor force. Some literatures suggest that R & D capital gains rate is significantly higher than the non-R & D capital. Assuming that R & D capital is 15%, we separate R & D capital returnsfrom 2010 input-output tables. With 2009 R & D resources inventory data, the sub-sector structure data of personnel number and wages of R & D of Beijing, we isolates R & D labor remuneration from the 2010 input-output table about workers compensation. So we resolve how to split R & D capital and non-R & D capital, R & D and non-R & D labor force to prepare for the SAM table. As for the preparation methods of the SAM Table other specific account, we see reports "in Beijing SAM table prepared" of Beijing Science Research Center. So we worked out the data base SAM tables which are required for this article dynamic CGE model.

2.2 The characteristics set of dynamic CGE model

This model has a simple recursive dynamic structure. This part mainly gives a brief introduction to the dynamic characteristics of model..The dynamic characteristics of the model is mainly reflected in the following factors: (1) the number’s growth of the production factors (capital and labor); (2) the increases of TFP, the rate of technological progress in different sectors. In this model, the growth rate of the population, labor force and labor productivity is exogenous. Capital growth of savings / investment relationship in the model endogenously determined. The base year for the model is 2010, and the data is mainly from the 2010 Beijing Social Accounting Matrix (Social Accounting Matrix, SAM).

2.3 Key assumptions and scenarios design of the model

2.3.1 The assumption of the production function

In order to reflect technical progress in the CGE model, we introduce R & D capital to the production functionofaddedvalue, and reflect the substitution of R & D and physical capital. The paper will draw on the production function settings form in Los & Verspagen (1997) and Los (2000). The model assumes that capital and labor are the same, the new growth theory has knowledge as an important factor of production been added into the production function, but relatively difficult to measure knowledge. Now most studies generally regard R & D expenditures as knowledge inputs.The R & D investment forms R & D capital and theR & D capital like capital and labor as a factoris putinto the production function. Taking the form and type of technology spilloversinto account,theindustry R & D investment will not only increase the rate of technological progress of the departmentbutalso improvethe production technology. Scherer (1982) proposed to putthe R & D capital into the production function,and not only the department's own R & D investment, but alsothe spillover effects between industries with technology products as the carrierneed to be considered.
Model specific production function is:

$$Y = A(IRD)K^{\alpha}L^{\beta}H^{\gamma}$$

where Y represents output, and K, L, Hrepresentcapital, labor and R & D capitalrespectively. IRD is expressed as an indirect R & D indicator through inter-industry technology spillover for some industry, it is not a direct factor investment for this industry, but it will affect the technology progress of this industry, so it is necessary to characterize the technology spillover effect among the industries as a whole enlarging effect for the entire production function. This article assumes that, with the increase in R & D capital, technological throughout the economy will improve, which means that total factor productivity in different sectors will increase because the R & D capital is increased.

With the introduction of R & D capital and non-R & D capital (ordinary physical capital), R & D and non-R & D labor force, the model assumes that capital synthesis and labor synthetic, for which the elasticity of substitution in production function model is the key, so this paper will make sensitivity analysis for elasticity of substitution of R & D capital bundles and R & D labor bundles. The model’sspecific nested structure design is shown in Figure 4.

2.3.2 TFP Set under the baseline scenario

The productivity improvementin the model is mainly reflected by the change of total factor productivity (TFP). Through the research of Chinese TFP changes over the last 30 years, we found that there aremany factors affecting TFP change in Beijing , such as restructuring , human capital spillovers , technological development, market reforms , urbanization , foreign effect , foreign trade effect, infrastructure and administrative costs. Despite the different approacheswere used, there are manydifferentestimations of total factor productivity in Beijing, but the estimated results all indicated that Beijing 's growth rateof TFP is 5% (Table 2) . Taking the future developmentinto account , the agricultural sector hada lower proportion in Beijing and a relatively higher level of modernization than the national level.We conservatively assume that the agricultural sector's total factor productivity growth in Beijing is decreasedfrom 4% in 2011 to 2.5% .As for the non-agricultural sector , the model assumes the biased technical progress exists, and we think human capital will be greater than physical capital in the contribution of TFP productivity growth in Beijing. Non- agricultural sector’s (industry and tertiary industry) capital productivity increase remained at around 5% and the productivity of labor is on a 6% level.

Table2 Beijing estimates results of total factor productivity growth

year	Total factor productivity growth (the introduction of intangible capital)	Total factor productivity growth
1979	8.51	5.09
1980	10.27	8.54
1981	-2.73	-6.08
1982	5.12	2.38
1983	14.42	12.52
1984	14.88	14.28
1985	4.78	3.48
1986	0.49	-0.64
1987	3.46	2.31
1988	7.40	6.66
1989	0.30	-0.93
1990	0.58	-2.88
1991	5.84	4.94
1992	7.42	5.80
1993	8.72	10.33
1994	9.09	5.52
1995	7.27	6.86
1996	4.86	5.01
1997	7.22	7.40
1998	6.49	9.16
1999	7.36	7.44
2000	8.41	8.12
2001	8.36	7.26
2002	7.28	2.51
2003	7.27	5.02
2004	8.57	-3.84
2005	8.28	6.45
2006	9.09	6.15
2007	10.81	9.16
2008	6.54	4.09
2009	7.81	6.65
2010	8.25	6.24
2011	6.15	3.94
Average	6.93	5.12

2.3.3 The assumption of net exports of goods and services abroad and outside the province

Considering the conditions of Beijing area net exports of goods and services, the model assumes that the services will have a substantial increase in exports, but imports and exports of goods and services will maintain being balancedwhich means that the foreignsavingis assumed tokeepunchanged.

2.3.4 Scenario Design

Table3 Simulationscenario design

Scenario Category	Setting the scene
Baseline Scenario	1. Exogenous growth of the total urban and rural population 2. Exogenous growth in total labor supply exogenous changes in agricultural land 3. A variety of existing taxes and transfer payments remain unchanged, with the basic level is very 4. From 2010 to 2020 exports and imports of goods and services essential to maintain fiscal balance, foreign savings to maintain the level of the base year 2010. 5. Exogenous growth of government consumption. 6. Exogenous capital and labor productivity growth in the agricultural sector, that is exogenous TFP agricultural sector, exogenous factor productivity growth in the non-agricultural sector capital, exogenous productivity in labor, but there are biased technical progress . 7.Capital between departments partly flows. Between different types of capital does not exist mobility. Between different departments of labor exist partly flows, Between the different types of labor does not exist mobility.
"Innovation-driven" development scenarios	1. Endogenous GDP growth. 2. R & D activities in the fixed asset investment increased year by year, R & D capital stock in the economic system increase 3. With the R & D activities increasing investment in fixed assets, and R & D capital stock increasing, the whole economy to productivity in all sectors will be gradually increased, the contribution rate of scientific and technological progress than the baseline scenario is 0.1% per year. Technology spillover effect is stronger than the baseline scenario. 4. Since the reform of scientific management system, establishing independent innovation system, the scientific and technological achievements transformation with remarkable results, the model assumed that after 2014, productivity of R & D capital and R & D researchers than physical capital and non-R & D personnel more 1.5% per year. 5. Assuming other urban and rural population, taxes, transfer payments, government consumption growth and other variables and baseline scenario are similar.

3 Simulation results

Under the previous model's assumptionwith the 2010 Beijing SAM table, we make some exogenous parameter calibration and estimation in the model. Then, we use GAMS software to make simulation analysis for computable general equilibrium model. According to the simulation results of different scenarios, we carry out a comparative analysis of different scenarios.

3.1 Baseline Scenario

1 Analysis of source of economic growth

Table4 2011-2020 economic growth and source (% baseline scenario)

baseline	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

scenario										
GDP growth	8.10	7.70	7.90	7.50	7.20	6.80	7.00	6.50	6.30	6.00
In which										
Labor growth	3.68	2.70	2.66	1.77	1.72	0.86	0.86	0.43	0.21	0.13
Capital growth	4.74	4.53	4.25	3.93	3.58	3.16	2.65	2.09	1.41	0.63
TFP growth	3.99	4.30	4.67	4.99	4.87	5.23	5.61	5.61	5.77	5.75
Source of growth：										
Labor	2.21	1.68	1.70	1.16	1.16	0.59	0.61	0.31	0.16	0.10
Capital	1.89	1.73	1.54	1.35	1.17	0.98	0.78	0.58	0.37	0.16
TFP	3.99	4.30	4.67	4.99	4.87	5.23	5.61	5.61	5.77	5.75

Source: CGE model results

The simulation result of the baseline scenario is that economic growth rate showed a decreasing trend year by year. In the"Twelfth Five" period, the average economic growth rate of Beijing is about 7.68%, if the labor force continues to grow in the future, IT technical development rapidly, and total factor growth rate is more than 4.56%, the economic growth of Beijing in the " Twelve Five "will still maintain a rapid growth rate, and economic growth will be more than " Twelfth Five " plan target (7.5%). If future technological advances rapidly, and theTFP growth rate in 2016-2020 remains above 5.6%, economic growth rate of Beijing in the "thirteenth-five" period will be around 6.52%, lower 1% compared with " Twelfth Five ", while the 2020 economic growth rate will be 6%.

From the source of economic growth perspective, between" Twelfth Five" and 2020, the main driving force of economic growth in Beijing is from the technical progress (TFP growth). In " Twelfth Five" period, the average GDP growth is 7.68%, due to technical progress (TFP growth) 4.56%, accounting for 59.43% of GDP growth rate. In "Thirteen Five" period, the average growth pulled by technical progress (TFP growth) is 5.59%, accounting for 85.78% of GDP growth. The main driver of economic growth is technological progress.
For thecapital factor, the pull by the investment is only 1.54% accounting for 19.99% of GDP growth rate in "Twelfth Five" period. Investment pulled 0.57% to GDP growth in "Thirteen Five" period, accounting for 8.8% of the GDP growth.

For the labor factor, because of the Beijing region's higher economic development level and wages, a large number of outside workers will continue to flow into Beijing, even though Beijing itself faces an aging population trend, but labor in Beijing region in the next 10 years will still maintain a certain growth rate. Thus, the labor factor will stimulate economic growth in Beijing, but the driving effect decreases. In "Twelfth Five" period, the labor factor drives GDP growth 1.58 %, accounting for 20.58% of GDP growth. In "Thirteenth Five" period, the labor factor bring GDP growth 0.35%, accounting for 5.4% of the GDP growth rate.

In short, the speed of Beijing's economic growth rate tendstobegradually decrease in the future.. For Beijing the main driving force of economic growth in the future is from advances of technology, and the contribution share of capital and labor is lower.

2. Economic size and per capita income levels

Table52011-2020 economic size and per capita GDP (baseline scenario)

Index	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GDP (trillion yuan)	1.48	1.60	1.73	1.86	2.00	2.15	2.29	2.45	2.61	2.78	2.94
Per capita GDP (million yuan)	7.56	7.94	8.33	8.75	9.25	9.74	10.32	10.95	11.61	12.31	13.04
GDP (trillion U.S. dollars)	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.39	0.41	0.43
Per capita GDP (ten thousand U.S. dollars)	1.12	1.17	1.23	1.29	1.37	1.44	1.52	1.62	1.71	1.82	1.93

From the economic scale, the end of"Twelfth-Five" period (2015), according to 2010 pricesthe total output value of Beijing willreach 2.15 trillion yuan, approximately 0.32 trillion dollars. In2020 itwill reach 2.94 trillion yuan, about 0.43 trillion dollars. With the substantial growth of economies scale, theGDP of per capitain Beijing also increased sharply, In the end of "twelfth-five", the GDP of per capitawill reach 97,400 yuan in Beijingwithout considering the exchange rate factor, according to the average exchange rate in 2010 (1 dollar = 6.7695 yuan), the GDP of per capita is $ 14,400, the GDP of per capitain 2020 will be130,400 yuanwhich is about $ 19,530. According to the World Bank income group standards, even without considering the exchange rate factor, In "Twelfth Five" period, Beijing's per capita GDP levels also entered the ranks of high-income. But what must be noted is that the level of GDP per capita in Beijing relative to the United States and Japan is lower. In 2009 in the U.S. per capita GDP is about $ 46,381. In other words, without considering exchange rates, Beijing is less than per capita GDP of U.S 1/2 in 2020.

3 structure of consumption, investment and net outflows of goods and services

Table6 2011-2020 expenditure Act structure (baseline scenario)

GDP expenditure structure	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Resident consumption	31.35	31.28	31.28	31.29	31.35	31.47	31.64	31.84	32.11	32.43	32.82
Government consumption	21.33	21.02	20.75	20.50	20.27	20.06	19.88	19.71	19.56	19.42	19.30
Gross capital formation	41.11	38.86	36.52	34.05	31.64	29.12	26.47	23.68	20.77	17.69	14.45
The net outflow of goods and services	6.21	8.84	11.45	14.16	16.75	19.35	22.00	24.77	27.56	30.45	33.43

From consumption perspective, the consumption of residents tended tobe upward slightly in the baseline scenario..In"Eleventh Five" period, Beijing 's average consumption rate was 31.33% , the consumption in"Twelfth-Five " period is 32.17% ,and in 2020 consumption rate is 32.87% . Government consumption rate showed a gradually downward trend, this model which assumes growth rate of government consumption keep pace with GDPconsistently.

Under the baseline scenario, gross capital formation accounting for the overall the proportion of GDP declines. The rate of capital formation will decline from 41.11% in 2010 to 14.45% in 2020. This model assumes thatBeijing Foreign trade in services exports will rise sharply in the futureand thedomestic and international demand for services will increase which will result in a growth of net outflow of services trade, and partly result in the lower rate of investment ..On the other hand , because the model is a dynamic delivery push model driven by savings, when the economy reduces savings , investment will decrease , while investment in the past forms a higher capital stock , the depreciation rate is high , resulting in a smaller net investment in the current period.

As for a net outflow of goods and services, the model assumes demand for services will increase in future, and export services abroad and to other provinces will increase significantly..The huge outflow of service increases net outflow of goods and services and makes a net outflow goods and services accounting for of GDP larger in following years from 6.21% in 2010 to 33.43% in 2020.

4. The industrial structure

From the three industrials structures and under the baseline scenario, the proportion of primary industry continue to reduce, by 2015, the proportion of primary industry will be 0.73% and will declineto around 0.54% in 2020. Proportion of secondary industry also showed a downward trendwhich decreases from 23.79% in 2010 to 20.55% in 2015and will decrease again to 17.31% in 2020which is 6.48%lower than that in 2010. The proportion of the adder value of the tertiary industry is rising, up to 78.72% at the end of 2015, continuing to rise to 82.15% in 2020. Overall, firstly, the proportion of secondary industry is reducing and tertiary industry proportion is increasing. This is identical to the general law of development of countries around the world. By analyzing the European countries data of late 19th century to the 1950s, Kuznets concluded: either from time series or from the cross section analysis, the relative proportion of primary industry in national income is falling, the relative proportion of secondary industry are rising , while the tertiary industry from the time series analysis is uncertain, but the cross section analysis is up slightly , and edged up slightly . Later scholars Bo Hao supplemented the 1970s data, and in the " modern industrial economy ",he pointed out : In the first industrial ,the relative proportion of labor and national income in the 1960s of the Western developed countries remains downward trend, and fter entering the 1970s ,this trend is slightly weakened, labor and income proportion of secondary industry declined slightly, but both labor and income of the tertiary industry maintains an upward trend , which is a " service economy " phenomenon. Therefore, in the next 10 years, Beijing will stage into services economy. The main factors that increase the proportion of tertiary industry in Beijing, one is with the improvement of people's income level , changes in consumption structure of residents, increasing demand for services , as well as increasing future demand for services of intermediate inputs in various departments; Second is urbanization, which also increases the proportion of tertiary industry; Third is the trend of population aging in China, increasing demand for social services , thus stimulating the development of tertiary industry . Finally, the export of services increases, stimulating the development of service industry in Beijing.

Table7 2010-2020 industrial structure (% baseline scenario, price, calculated by value added)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Primary Industry	0.95	0.91	0.86	0.82	0.77	0.73	0.69	0.65	0.61	0.58	0.54
Secondary industry	23.79	23.15	22.54	21.91	21.23	20.55	19.88	19.22	18.57	17.93	17.31
Tertiary Industry	75.26	75.94	76.60	77.27	78.00	78.72	79.43	80.13	80.82	81.49	82.15
Total	100	100	100	100	100	100	100	100	100	100	100.

3.2 Comparison of "innovation-driven" development scenario

In order to analyze the impact of increase of Science and Technology investment in Beijingwhich leaded to the economic and social development of Beijing, we base on the baseline scenario, and design the "innovation-driven" development scenarios. With the increase of investment in the future of science and technology, gradual increase of R&D capital, and the reform of science and technology system, the ability of technology to promote economic development is stronger. Not only the productivity of R&D capital and R&D researchers improves, which increases the economic value of scientific research, but also because science and technology bring enhanced technology spillover effect, it will lead to the improvement of the contribution rate of scientific and technological of Beijing, a slight increase in total factor productivity than in the baseline scenario. Specifically in the model assumption, the model assumed that after 2014, the productivity of R & D capital and R & D researchers increase 1.5% per year more than physical capital and non-R & D personnel, In addition, the baseline productivity growth of all the elements is higher about 0.1% than scenario.

Relative to the baseline scenario, under "innovation-driven" scenario, economic growth rate of Beijing is higher than that of baseline scenario (see Table 8). During the "thirteenth five", the growth rate of the gross regional product of Beijing averaged 6.65%, with an average higher than the baseline scenario 0.13%. By 2020, under the "innovation-driven" development scenario, the growth rate of the gross regional product of Beijing reached 6.16%, higher than the baseline scenario 0.16 %, an increase of 2.6%.

Table8 Comparison of economic growth in 2011-2020

Year	GDP growth in the baseline scenario	Innovation-driven scenario	Percentage change relative to the baseline scenario
2011	8.10	8.10	-
2012	7.70	7.70	-
2013	7.90	7.90	-
2014	7.50	7.50	-
2015	7.20	7.28	1.11
2016	6.80	6.88	1.23
2017	7.00	7.09	1.26
2018	6.50	6.64	2.21
2019	6.30	6.45	2.40

2020	6.00	6.16	2.66

From the perspective of GDP, under the innovation-driven scenario, the total production in Beijing reached 2.1486 trillion yuan in 2015, higher than the baseline scenario 0.0016 trillion yuan , the total production in Beijing will reach 2.9638 trillion million in 2020, higher than the baseline scenario 0.0196 trillion (see Table 9). Under the "innovation-driven" development scenario, the cumulative GDP of Beijing will be more than the baseline scenario 54.4 billion yuan. That means that we need to increase investment in technology, deepen the science and technology system, promot the industrialization of scientific and technological achievements. In addition, from the specific simulation model, we also found that the role of science and technology development to Beijing's economic growth is mainly reflected by the technology spillover effect.That the spillover effects of technological development causes total factor productivity growth increased by 0.5% per year in Beijingwill make economic growth slightly increased by 1%.

Table9Beijing Gross Product Value(trillion yuan)

Year	baseline scenario	Innovation-driven scenario	GDP change in absolute terms
2010	1.4831	1.4831	0.0000
2011	1.6032	1.6032	0.0000
2012	1.7266	1.7266	0.0000
2013	1.8630	1.8630	0.0000
2014	2.0028	2.0028	0.0000
2015	2.1470	2.1486	0.0016
2016	2.2930	2.2965	0.0035
2017	2.4535	2.4592	0.0058
2018	2.6129	2.6226	0.0097
2019	2.7776	2.7918	0.0143
2020	2.9442	2.9638	0.0196

Under innovation-driven development scenarios, the income of rural residents and urban residents are significantly improved (see table 10, 11), the income of perrural residentwill be increasedfrom 23,300 yuan in 2010 to 49,100 yuan in 2020, havingan increase of 110.48%, and the income ofper urban resident is increasedfrom 46,600 yuan 2010 to 85,600 yuan in 2020, havingan increase of 83.86%. Comparedwith the baseline scenario, the growth rate of the income level of rural residents is higher than urban residents’, thus the income gap between urban and rural residents tends to be narrower

Table10Per capita income of rural residents

Year	Innovation-driven scenario	baseline scenario	Changes in magnitude
2010	2.33	2.33	0.00%
2011	2.50	2.50	0.00%
2012	2.68	2.68	0.00%
2013	2.88	2.88	0.00%

2014	3.10	3.10	0.00%
2015	3.35	3.35	0.07%
2016	3.62	3.61	0.14%
2017	3.91	3.90	0.21%
2018	4.22	4.21	0.33%
2019	4.55	4.53	0.45%
2020	4.91	4.88	0.57%

Table11Per capita income of urban residents

Income of urban residents	**Innovation-driven development scenarios**	**baseline scenario**	**Changes in magnitude**
2010	4.66	4.66	0.00%
2011	4.88	4.88	0.00%
2012	5.11	5.11	0.00%
2013	5.37	5.37	0.00%
2014	5.69	5.69	0.00%
2015	6.02	6.02	0.04%
2016	6.43	6.43	0.09%
2017	6.88	6.87	0.13%
2018	7.39	7.37	0.22%
2019	7.95	7.93	0.31%
2020	8.56	8.53	0.41%

From the changes of the structure for the three industries, the development of innovation-driven scenarios and the baseline scenario are similar in the three industrial structure evolution, but a smaller proportion of three industries difference (see Table 12). This meets the evolution of the economic industrial structure. When we subdivision the industry segments，such as the interior of some of the tertiary industry added value, some of the industry‘s proportion increase, however, some industry decreases. The proportion of comprehensive technical services, education, health, social security and social welfare increases; relatively lower in the proportion of real estate, public administration and social organization industry.

Table12Three industrial’s structure changes underinnovation-driven development scenarios

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Primary Industry	0.95	0.91	0.86	0.82	0.77	0.73	0.69	0.65	0.61	0.58	0.54
Secondary industry	23.79	23.15	22.54	21.91	21.23	20.55	19.88	19.22	18.57	17.93	17.31
Tertiary Industry	75.26	75.94	76.60	77.27	78.00	78.72	79.43	80.13	80.82	81.49	82.15
Total	100	100	100	100	100	100	100	100	100	100	100.

In conclusion, from the above simulation results, the main driving force of the future of Beijing's economic development is thetechnological progress. If Beijing can implement the scientific concept of development, deepen the science and technology system, achieve the optimal allocation of science and technology investment, promote integration of economic development and science and technology, and make it play a supporting role in economic development,in the next 5-10 years, Beijing is still able to maintain a high growth rate, theindustrial structure and consumption structure will be more reasonable, and it will further narrow the gap between urban and rural areas.

4 Conclusions

The simulation results of the above total investment and structure in science and technologyshow that increasing investment in science and technology will help to increase the GDPand improve the economic structure of Beijing to some extent. The larger the magnitude of technology investment is, the greater the growth rate of GDP is, but the marginal increasing rate is diminishing. Meanwhile, the different amount of scientific and technological inputs will determine the GDP and economic structure. The simulation results shows that the descending order ofthe scientific and technological input is the tertiary industry, the first industry and the industrial sector, which canachieve the economic growth and structural adjustment better in Beijing.

Dynamic CGE model simulation results show that: in the next 5-10 years, ifBeijing wants to remain above 7.0% economic growth rate, the main driving force comes from technological progress. Meanwhile the industrial structure and consumption structure will be more rational in Beijing, and the gap between urban and rural areas will be narrower.Therefore, Beijing should implement the scientific concept of development, deepen the science and technology system, achieve the optimal allocation of science and technology investment，promote the integration of science and technology and the economic development and makethe science and technology play a supporting role in the economic development.

These conclusions above depend on a number of assumptions about the model and the data, so we need to be carefully when we use and explain the impact of science and technology on the macroeconomyt. On the one hand,because the model we use herein this study is CGE model , the inherent defects of CGE model affect the impact of science and technology investment onthe macroeconomic, for example,the CGE model is a balanced analysis model whichassumethat the economic system is perfect competitive and reach the equilibrium under the price mechanism, while the real economy may be out of equilibrium, and there are monopolies ;On the other hand, the study introduces the R & D capital , because there are many uncertainties for the R&D capital’s estimated parametersand the selected parameters may have a greater impact onthe results, the empirical research and model updating need to be improved.

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