Estimating the Contribution of Technical Change in Beijing

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Abstract. *This paper estimates the contribution of technical change in Beijing with Cobb-Douglas function. The results show that the average contribution of technical change in Beijing is 29.03%. At the same time, capital contribution to economic growth is always in the leading position. In recent years, labor contribution to economic growth increases, capital contribution decreases, and the transformation of economic structure has been emerging.*

Key Words: *Capital input, Contribution of technological progress, Labor input, TFP*

1. Introduction

The contribution of technological progress is an important indicator to reflect the influence of scientific and technological progress to economic development. Solow model is the most common way to calculate the contribution of technological progress in the world. But people have different understandings of how to select the parameters and indices, there is large difference between the results calculated by different people. This paper will calculate the contribution of technological progress of Beijing from 1990 to 2012, with considering of the data's statistical availability and accuracy.

2. Model selection

The contribution of technological progress usually refers to TFP (total factor productivity) divided by output growth rate. TFP comes from Cobb-Douglas function ($Y = AK^{\alpha}L^{\beta}$), where Y means output, K means capital input, L means labor input, α means the capital share and β means the labor share, through these we can calculate A's growth which is so called TFP. In this model, constant returns to scale are usually assumed, that means if capital input and labor input double in proportion, the output will double. With this assumption, we can deduce that $\alpha+\beta=1$. TFP reflects all the factors' effects on economic growth but capital or labor input. TFP is not a perfect variable to measure the contribution of technological progress, because besides capital and labor input, some other factors can also effect economic growth, such as industrial structure and agglomeration effect. But for now, this is the most common way to measure it.

3. Parameter selection

When calculating the contribution of technological progress, GDP is always taken as output (Y), but the selection of capital input (K), labor input (L) and their shares (α and β) is still a controversy.

3.1 Selection of capital input

Capital input means durable material inputs, such as machines, buildings and so on. These goods were produced in the past according to some production functions. It usually selects capital stock as capital input, but there is no available statistics for capital stock, so it needs to be calculated in some ways.

The common way to calculate capital stock is perpetual inventory method. That is: $K_t=K_{t-1}*(1-\delta)+I_t$, K is capital stock, δ is depreciation rate and I is capital investment. Capital investment usually selects gross fixed capital investment or gross fixed capital formation, we use gross fixed capital formation. The problem is how to estimate the base year capital stock.

Zhang Jun [1] uses 1952 as the base year, 10 times the gross fixed capital formation as the base year capital stock. The advantage is that, 1952 is more than half a century ago, its capital stock is so small that it can hardly influence the estimation of capital stock in recent years. So using 10 times the gross fixed capital formation as the base year capital stock is acceptable. But early price indices of investment in fixed assets and depreciation have no available statistics, and there are too many parameters have to be estimated, so this method to calculate capital stock will easily lead to large errors.

Ye Zongyu [2] assume that capital-output ratio will not change dramatically in a short period of time, so he uses the value, which can make the capital-output ratio in base year equal to an average over the 5 years after base year, as base year capital stock. This calculation can avoid errors caused by too many estimates of parameters.

Based on analyzing the gained results comprehensively, we take 1990 as base year, and the value that minimizes the variance of first 5 years capital stocks as base year capital stock. In this way, we can avoid errors caused by estimating depreciation rates, because after 1990, depreciation for plant assets is available in Beijing statistical yearbook.

First of all, make those economic indicators into comparable prices, GDP divided by GDP deflator, gross fixed capital formation and depreciation for plant assets divided by price index of investment in fixed assets. Then, let base year capital stock K0=x, Kt=Kt-1+It-Dt-1=x+St, D means depreciation for plant assets, S is defined as the capital stock difference between base year and year t. Capital-output ratio: ct=Kt/Yt=(x+At)/Yt, then the variance of first 5 years capital stocks is a function of x that: $f(x)=\frac{1}{t}\sum_{i=1}^{t}(c_i-\bar{c})^2$. Where $\bar{c}$ is the average of capital-output ratios over these years. The minimum condition is

$$(1):\ x=-\frac{\sum_{i=1}^{t}(\frac{S_i}{Y_i}-S)(\frac{1}{Y_i}-G)}{\sum_{i=1}^{t}(\frac{1}{Y_i}-G)^2}$$

Where

$$S=\frac{1}{t}\sum_{i=1}^{t}\frac{S_i}{Y_i}\ ,\ G=\frac{1}{t}\sum_{i=1}^{t}\frac{1}{Y_i}.$$

In this way, base year capital stock can be calculated to be 168.68 billion Yuan in 1990 prices. Then calculate the following years capital stocks with perpetual inventory method. The results are shown in Chart 1:

Chart 1: Capital stocks estimation

year	capital stock (billion yuan)	capital-output ratio
1990	168.7	337%
1991	181.9	331%
1992	198.9	325%
1993	220.7	321%
1994	253.3	324%
1995	290.6	332%
1996	324.5	340%
1997	360.0	342%
1998	403.0	350%
1999	444.9	349%
2000	489.7	343%
2001	539.5	338%
2002	599.8	337%
2003	673.9	341%
2004	756.1	336%
2005	846.6	335%
2006	945.3	331%
2007	1051.8	322%
2008	1142.7	320%
2009	1250.3	318%
2010	1381.5	319%
2011	1517.0	324%
2012	1682.4	333%

3.2 Selection of labor input

The input of labor refers to input factors related to people, including the number of laborers, working time, labor strength, technology level and health status etc.. But it is hardly to show the overall effect of all the above factors precisely. Usually we use one or two of those factors and assume other factors are constant.

Xu Ying [4] adds human capital into the C-D function, uses number of employees multiplied by human capital level as labor input. Xu defines human capital level as the proportion of people in various educational levels multiplied by each level's years of schooling. But this needs an assumption that the contribution of people in different educational levels is proportional to the schooling year. He Yong think labor input refers to human capital reflected in performance, so He chooses labor remuneration as labor input. Xu Shiyuan point out the most convenient statistic as labor input is the number of employed persons.

At first, we choose the number of employed persons of Beijing as labor input, but number shows a dramatic increase in 2004. The number in 2004 is 21.5% bigger than it in 2003, while the numbers between 1990 and 2003 are relatively stable. This may be caused by some changes in statistical methods, so we choose the number of resident population instead. If we assume employment rate is constant during these years, using the number of resident population will not affect the results. Considering age structures, the resident population means the population between 15 – 64 years old.

3.3 Selection of labor share

The most common way to calculate α and β is regression. Zhao Zhiyun [3] uses different regression ways to estimate α in China between 1978 and 2004: $\alpha=0.69$ using OLS; $0.54<\alpha<0.61$ using non parametric regression; $\alpha=0.59$ using panel data. Xin Yongrong [5] calculates $0.36<\alpha<0.47$ between 1986 and 2006 using non parametric regression. He Guomin calculates $\alpha=0.24$ in Hubei province between 1991 and 2004 using OLS.

Though using mathematical method to calculate α and β can fit the model in data, it usually needs many assumptions and may not be consistent with the principles of economics. For example, when use OLS, we often take the model as $\ln Y = \ln A_0 + bt + \alpha \ln K + \beta \ln L$, where A_0 is scientific and technological level in base year, t is time, b is the average growth of scientific and technological level. This model need to assume that scientific and technological level increased steadily. Using the α and β calculated with this assumption to study how At changes is inappropriate. Besides, the difference among each result is clear, we can reach no common conclusion in this way.

According to C-D function, in a competitive economic environment, capital and labor inputs get paid in accordance with its marginal product. Wage equals to the partial derivative of output respect to labor input.

$$(2):\quad \omega = \frac{\partial Y}{\partial L} = \beta A K^{\alpha} L^{\beta-1}$$

$$(3):\quad \frac{\omega L}{Y} = \frac{L}{Y} \times \frac{\partial Y}{\partial L} = \beta$$

Equation 3 shows that β equals to labor share.

For all these reasons, we take the ratio of wages to output as β, and $\alpha=1-\beta$.

4. Calculation

From Beijing Statistical Yearbook and China Population Statistics Yearbook, we can obtain necessary data, which include Gross Regional Product (GRP), index of GRP, Resident Population, Age Composition Index, Depreciation of fixed assets, Gross fixed capital formation, fixed asset investment price index, Labor compensation. Then by using the calculation method interpreted in part 2, we could compute the Factors of production growth in every 5 years, and the outcome chart is as followed:

Chart 2: Factors of production growth (1990 -- 2012)

year	Output growth (%)	Capital growth (%)	Labor growth (%)	TFP (%)
1990-1995	11.83	11.49	2.71	4.12
1991-1996	11.64	12.27	3.46	3.18
1992-1997	11.41	12.60	3.27	2.83
1993-1998	10.84	12.80	2.89	2.31
1994-1999	10.29	11.93	3.07	2.16
1995-2000	10.25	11.00	3.22	2.55
1996-2001	10.80	10.70	3.09	3.31
1997-2002	11.08	10.75	3.63	3.32
1998-2003	11.40	10.83	3.98	3.46
1999-2004	12.04	11.19	4.50	3.67
2000-2005	12.10	11.57	2.70	4.32
2001-2006	12.36	11.87	2.97	4.34
2002-2007	12.96	11.89	3.95	4.54
2003-2008	12.55	11.14	4.46	4.43
2004-2009	11.77	10.58	4.77	3.89
2005-2010	11.40	10.29	5.95	3.18
2006-2011	10.42	9.92	5.53	2.61
2007-2012	9.08	9.85	4.62	1.80

It should be noted that the results above are geometric growth rates. For example, the output growth during 1990 to 1995 is calculated by following equation:

$$(4):\ y_{1990-1995} = \left(\sqrt[5]{\frac{Y_{1995}}{Y_{1990}}} - 1\right) \times 100\%$$

And the labor share is an arithmetic mean of 6 years correspondingly, for example: $\beta_{1990-1995} = \sum_{i=1990}^{1995} \beta_i / 6$,

Then each factor of product growth divided by the output growth and multiplied by each product share (not for TFP) turn into the contribution rate of each factor. The outcome chart is as followed:

Chart 3：Contribution rate of each factor (1990 -- 2012)

year	Contribution of capital (%)	Contribution of labor (%)	Contribution of technological progress (%)
1990-1995	55.36	9.86	34.78
1991-1996	59.87	12.81	27.32
1992-1997	62.79	12.36	24.85
1993-1998	67.22	11.47	21.31
1994-1999	66.25	12.76	20.99
1995-2000	61.77	13.35	24.88
1996-2001	57.30	12.08	30.62
1997-2002	56.19	13.81	30.00
1998-	55.00	14.70	30.31

2003			
1999-2004	53.74	15.78	30.48
2000-2005	54.76	9.52	35.72
2001-2006	54.51	10.41	35.08
2002-2007	51.58	13.35	35.07
2003-2008	48.64	16.06	35.30
2004-2009	48.03	18.88	33.09
2005-2010	47.30	24.84	27.86
2006-2011	49.35	25.58	25.07
2007-2012	55.17	25.03	19.80

According to chart 2 and chart 3, it is clearly that capital had been a major cause of the outcome growth in Beijing since 1990, that the capital contribution rate reached 67% at its peak and had showed a tendency of decline in the 21 century. The contribution of technological progress ranged from 20% to 35%, with its average value is 29.03%. From 2000 to 2008 the contribution of technological progress remained in a high level around 35% and declined after that. The Labor contribution rate had a slightly raising in this period.

By measuring the contribution of technological progress from 1990 to 2012 we could see that effects of technological progress on the economic were not that impressive. Besides, this work didn't make a distinction between different labor efficiency for the data availability. If the education status and professionalism of labor are taken into account, the growth of labor input will increase correspondingly in the period and the contribution of technological progress would be lower.

Compare to other cities in China, there are more educational resources and human resources in Beijing, while these advantages may not be that obviously helpful for the growth in traditional industrial structure. As the government decided to turn Beijing into the country's technology innovation center, the industrial structural adjustment is having, high pollution or high energy consumption industries are exiting the market gradually, and the innovation-type country with scientific and technological progress as the principal driving force is being formed. It can be inferred from above calculations that Beijing is in a transition period: the output growth slowed down, capital contribution decreased slightly, labor contribution increased gradually and the contribution of technological progress was at a low level for now.

5. Conclusion

This paper calculates the Contribution of technological progress in Beijing from 1990 to 2012, by using the method of minimum variance to determine the base year capital stock, and using the resident population between 15 to 64 years old as labor input. This calculation provides a solution to the lack and inaccurate problem of data. And it's easy to be extended to other cities, because of its data availability and simplicity. However, due to some restrictions, this paper still has some shortcomings: no considering of the tax effects in calculation of labor share; age range of the resident population can be closer to the employment age, and employment rate should be considered.

There isn't a criterion or methodology with common recognition in calculating the contribution of technological progress. In detail, different estimates of physical capital stock, labor input, output share of each factor will have a notable influence in the final value of contribution rate. According to State's Outline of Medium- and Long-term Plan for Science and Technology Development (2006-2020), government requires that the contribution of technological progress should be above 60% by 2020. Then it is necessary to develop a more scientific method to measure and calculate the contribution of technological progress with better explanatory ability and common recognition.

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