Model of Factors Affecting Regional Economic Vitality

Abstract

Regional economic vitality suggests the economic strength and the competitive force of a city. It is not only essential for every city, but also vital for national economic development.

Based on economic knowledge, we find a series of factors that measure the economic vitality of a city. Then, we use **the principal component analysis**, a mathematical model, to analyze the relationship between 13 factors and regional economic vitality. We determine **5 principal components and their weight**. In this process, we illustrate the usefulness of factors and their contributions by **quality of representation**. As a result, we gain the formula and use it to **rank** the economic vitality of 19 cities.

Then, we use **the control variable method** analyze the effect of **economic transformation** on economic vitality in Shenzhen in both short and long term. We let **the percentage of vitality change** as the standard to measure vitality, and conclude that the transformation policy decline vitality at first, but promote the economic vitality in long term. We also compare the economic data of Shenzhen and China to display the long-run influence.

After the above process, we provide some **advice** to improve the economic vitality in the terms of quantity of surviving enterprises, green, resident population and expenditure for science, technology and education.

Besides, we analyze the effect on economic vitality from the perspective of changing trend of population and enterprise vitality by increase values of these two factors, and gain a **principle of wooden barrel**. We also use this method to analyze the **sensitivity** of the model of factors affecting economic vitality.

Finally, we believe our model is success. To sum up, with intelligent use of model, global and partial analysis, qualitative and quantitative analysis, our models have advantage of great robustness and rationality. However, if we could have more data, the model will be more accurate.

Keywords: Principal Component Analysis　Quality of representation　Method of control variable　Principle of wooden barrels

Contents

I. Introduction

In order to indicate the origin of problems, the following background is worth mentioning.

1.1 Background

Economic vitality is the potential and increasing speed of aggregated demand and supply in a country during a period. Based on classic economic theories, the competition always macroscopically focuses on country or microscopically concentrates on companies. With the globalization of economy, technology and competition, city has become the main unit of the game. What's more, the competition between cities and that between countries are more and more interdependent and indivisible. Therefore, measuring the vitality of cities' economy is of great significance to promoting national economic development and being the leader in international competitions.

Regional economic vitality is the power that runs the economic strength in every region. It suggests the competitive force of a city. There are a series of variabilities related to the level of economic vitality in a region. For example, resident income partly reveals economic vitality from the perspective of the amount and quality of labor force because high level of income could attract more migrant labor. Besides, average level of education is the basic of economic long-term development. High-level skilled labor provide new products and innovation that could improve productivity.

As a key factor to display the comprehensive competitive power of an area, the government released lots of policies to stimulate economic vitality, such as limiting excessive income growth to prevent over-high production costs from stifling economic development.Also,some cities implement economic transformation for sustainable development.

In order to promote the better development of the cities, it is inevitable to analyze the factors influencing regional economic vitality to find better ways of city management, thus boosting growth and accelerating the development of city.

1.2 Restatement of question

- Question 1:Based on the data of cities, model the factors affecting economic vitality and find out how to improve regional economic vitality. Besides, use data about changing trend of population and enterprise vitality to analyze the effect of the methods.

- Question 2: According to the appropriate data, select a region and analyze the influence of economic policy transition on economic vitality of the region in the both short and long term.
- Question 3: Choose a proper index system, build a model to measure economic vitality of cities in attachment 3 and rank them.
- Question 4: Offer the regions in question 2 some suggestions for better sustainable development and stronger competitive power on the basis of conclusions for questions 1-3.

II. Analysis

2.1 Question 1.

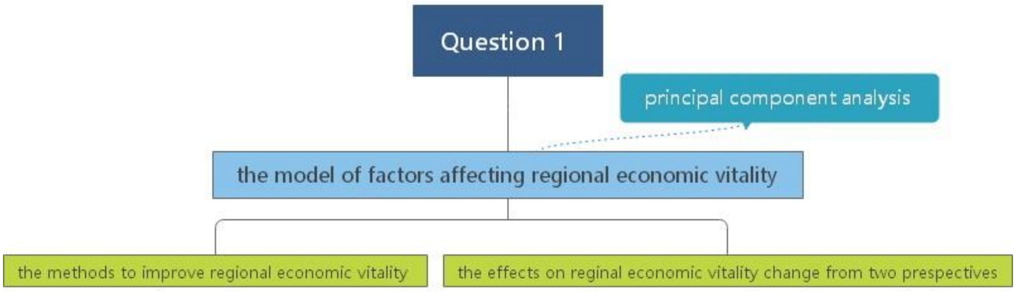

Figure 1 The thinking map of quaestion 1

2.2 Question 2.

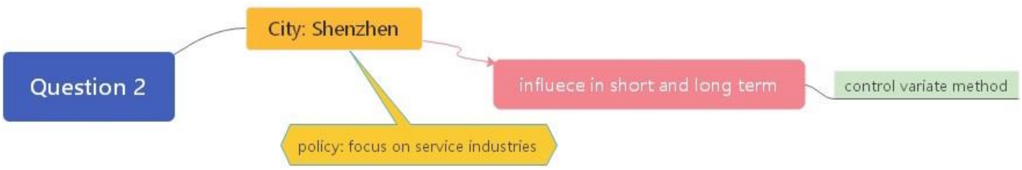

Figure 2 The thinking map of quaestion 2

2.3 Question 3.

Figure 3 The thinking map of quaestion 3

2.4 Question 4.

Figure 4 The thinking map of quaestion 4

III. Assumptions

To simplify the problems and make it convenient for us to simulate real-life conditions, our model is setting up and implemented in a relatively ideal environment. Thus, we make some assumptions as follows:

(1) Assuming all data is reliable and accurate.

(2) Assuming there are no other factors influencing the regional economic vitality.

(3) Assuming the abnormal data is ignored.

(4) Assuming there are no other factors effecting regional economic vitality except 13 discussed factors.

(5) Assuming the remaining 12 factors do not change when the resident population changes in control variable method.

IV. Symbols and definitions

Table 1 The List of symbols

Symbol	Definitions

x	factors effecting regional economic vitality
c	the value Comp.
k	factor load
v	the index of economic vitality
p	the value of proportion of variance for Comp.
P	the value of cumulative proportion for Comp.5
$\Delta v\%$	the percentage change in v
$cos2$	the usefulness of a factor

V. Establishment and solutions of models

5.1 Model of the factors affecting economic vitality

5.1.1 *Collection of data*

Attachment III includes 19 cities including Shanghai, Shenzhen, Beijing, Guangzhou, Chongqing, Chengdu, Shenyang, etc., sorted by quantity of surviving eEnterprises and quantity of cancelled enterprises, so we also sort these 19 cities, and select 13 factors, such as per capita GRP, to estimate the economic vitality of the city. The corresponding data of 19 cities in 2018 were found by citing literature data, as shown in the figure below:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	City	Quantity of Surviving eEnterprises in 2019(2019)	Resident Population in 2019(10,000)	Ratio of Industrial Solid Wastes Comprehensively Utilized (%)	Per Capita GRP (yuan)	GRP Growth Rate (%)	Green(%)	R&Dinternal Outlay (10,000yuan)	Annual Mean Concentration of PM2.5(ug/m3)	Ratio of waste Water Centralized Treated of Sewage Work(%)	Ratio of Consumption Wastes Treated (%)	Expenditure for Science and Technology （10 000yuan）	Expenditure for Education (10000yuan）	Export(USD 10000)
2	Shanghai	157.4	2419.7	94.00	126634	6.90	39.10	12052052	39	94.50	100.00	3898971	8741040	19364000
3	Shenzhen	174.1	1190.84	74.72	184068	8.80	45.10	9769377	28	96.81	100.00	3518252	5090971	24435790
4	Beijing	118.3	2172.9	74.01	128994	6.70	48.42	15796512	58	92.40	99.88	3617191	9645817	5857000
5	Guangzhou	89.6	1404.35	76.62	150678	7.00	42.50	3415528	32	87.08	90.24	1712569	4043335	8531977
6	Chongqing	69.8	683.07	70.00	101536	7.70	40.00	3646308	45	93.71	99.40	325817	3857002	4260000
7	Chengdu	60.6	1194.05	88.54	103757	8.70	41.63	3312620	56	90.00	99.00	387264	1481609	3055919
8	Nanjing	55.8	827	90.40	141103	8.10	44.90	2346269	40	71.00	100.00	672942	2178419	3441455
9	Hangzhou	48.7	787.5	77.06	148794	8.21	39.96	3968200	35	95.10	100.00	877184	2519759	5099533
10	Suzhou	53.6	1068.4	93.40	148427	7.30	39.96	3934301	41	89.00	100.00	620023	1546243	18716062
11	Tianjin	43.7	1562.12	98.87	119238	3.60	36.72	4587227	62	87.20	94.40	1159606	4352701	4356000
12	Qingdao	41	920.4	91.88	136667	9.30	39.05	3070935	30	97.04	100.00	355846	1854999	2953121
13	Dongguan	43.4	826.1	73.44	124324	8.25	42.83	18814187	33	92.58	100.00	912569	2743335	10386135
14	Zhengzhou	43.1	972.4	79.63	94477	6.70	40.40	1588272	40	98.00	100.00	266460	1113908	3456133
15	Wuhan	39.8	1091.4	97.04	123831	8.00	34.47	2588272	52	96.00	100.00	1129906	2679919	1710118
16	Xi'an	37.5	992.32	83.97	84205	7.60	41.11	3601731	73	96.07	99.70	26045	865462	2299213
17	Ningbo	31.1	787.5	95.55	150990	6.80	39.85	2419100	35	82.95	100.00	418617	1344124	7353388
18	Changsha	28.5	731.15	82.42	152441	8.30	45.81	2479808	52	96.12	99.98	248250	1192749	870462
19	Shenyang	21.8	752	90.09	74567	3.00	38.88	1401044	34	95.00	100.00	38163	755155	469172
20	Kunming	23.5	667	72.61	90074	13.00	42.05	351978	29	92.37	100.00	83966	570934	294277

Figure 5 The data of 13 economic vitallity factors in 19 cities in 2018

5.1.2 *Method*

Principal Component Analysis: a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components.

5.1.3 *Language*

R language

5.1.4 *Establishment of model*

1. Log transformation of data:

   In order to simplify process and analyze results easily, we use R to make a log transformation:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	City	Quantity of Surviving eEnterprises in 2019(2019)	Resident Population in 2019(10000)	Ratio of Industrial Solid Wastes Comprehensively Utilized (%)	Per Capita GRP (yuan)	GRP Growth Rate (%)	Green(%)	R&Dinternal Outlay(10000yuan)	Annual Mean Concentration of PM2.5(ug/m3)	Ratio of waste Water Centralized Treated of Sewage Work(%)	Ratio of Consumption Wastes Treated (%)	Expenditure for Science and Technology（10000yuan）	Expenditure for Education (10000yuan)	Export(USD 10000)
2	Shanghai	5.05879	7.791399	4.543295	11.74906	1.931521	3.666122	16.30475	3.663562	4.5486	4.60517	15.17622	15.98354	16.77893
3	Shenzhen	5.15963	7.082414	4.313748	12.12306	2.174752	3.808882	16.09476	3.332205	4.57275	4.60517	15.07347	15.44298	17.01156
4	Beijing	4.773224	7.683818	4.3042	11.76752	1.902108	3.879913	16.5753	4.060443	4.526127	4.603969	15.10121	16.08203	15.58315
5	Guangzhou	4.495355	7.24733	4.338858	11.9229	1.94591	3.749504	15.04384	3.465736	4.466827	4.502473	14.35351	15.21258	15.95933
6	Chongqing	4.245634	6.526597	4.248495	11.52817	2.04122	3.688879	15.10923	3.806662	4.540205	4.599152	12.69409	15.1654	15.26478
7	Chengdu	4.104295	7.085106	4.483454	11.54981	2.163323	3.728821	15.01325	4.025352	4.49981	4.59512	12.86686	14.20864	14.93259
8	Nanjing	4.021774	6.717805	4.504244	11.85725	2.091864	3.804438	14.66834	3.688879	4.26268	4.60517	13.41941	14.59411	15.0514
9	Hangzhou	3.885679	6.668863	4.344584	11.91032	2.105353	3.687879	15.19382	3.555348	4.554929	4.60517	13.68447	14.73967	15.44466
10	Suzhou	3.981549	6.973917	4.536891	11.90785	1.987874	3.687879	15.18524	3.713572	4.488636	4.60517	13.33751	14.25134	16.74489
11	Tianjin	3.777348	7.353799	4.593806	11.68888	1.280934	3.603322	15.33879	4.127134	4.468204	4.547541	13.96359	15.28631	15.28706
12	Qingdao	3.713572	6.824808	4.520483	11.8253	2.230014	3.664843	14.93749	3.401197	4.575123	4.60517	12.78225	14.43339	14.89837
13	Dongguan	3.770459	6.716716	4.296469	11.73065	2.110213	3.757239	16.75012	3.496508	4.528073	4.60517	13.72402	14.82468	16.15598
14	Zhengzhou	3.763523	6.879767	4.377391	11.45611	1.902108	3.69883	14.27816	3.688879	4.584967	4.60517	12.49298	13.92339	15.05566
15	Wuhan	3.683867	6.995217	4.575123	11.72667	2.079442	3.540089	14.7665	3.951244	4.564348	4.60517	13.93765	14.8013	14.35207
16	Xi'an	3.624341	6.900046	4.43046	11.34101	2.028148	3.716251	15.09693	4.290459	4.565077	4.602166	10.16758	13.67102	14.64808
17	Ningbo	3.437208	6.668863	4.55965	11.92497	1.916923	3.685122	14.69891	3.555348	4.418238	4.60517	12.94471	14.11125	15.81067
18	Changsha	3.349904	6.594619	4.411828	11.93453	2.116256	3.824502	14.72369	3.951244	4.565597	4.60497	12.42219	13.99177	13.67678
19	Shenyang	3.08191	6.622736	4.500809	11.21945	1.098612	3.66048	14.15273	3.526361	4.553877	4.60517	10.54962	13.53468	13.05872
20	Kunming	3.157	6.50279	4.285103	11.40839	2.564949	3.738859	12.77132	3.367296	4.525802	4.60517	11.33817	13.25503	12.59228

Figure 6 The data of 13 economic vitallity factors in 19 cities after log tranformation

2. principal component analysis:

   Input assignment and summary statements and gain Table 7:

   Comp.1,2,3...,13 are the corresponding 13 factors. The first line of the data is standard deviation, the second line 'Proportion' is the factor' interpretation degree of the variance. We think data in the second line can show that the percentage of information which this component contains in the original data. The third line 'Cumulative Proportion' is the interpretation of cumulative proportion.

```
city.pr <- princomp(LnCD, cor = T)
summary(city.pr,loadings=T)
Importance of components:
                          Comp.1    Comp.2    Comp.3    Comp.4     Comp.5     Comp.6     Comp.7     Comp.8
Standard deviation     2.2691535 1.4965542 1.2059428 1.0580810 0.99836835 0.80150912 0.67427541 0.61310839
Proportion of Variance 0.3960814 0.1722827 0.1118691 0.0861181 0.07667226 0.04941668 0.03497287 0.02891553
Cumulative Proportion  0.3960814 0.5683640 0.6802331 0.7663512 0.84302345 0.89244014 0.92741301 0.95632854
                           Comp.9    Comp.10     Comp.11     Comp.12      Comp.13
Standard deviation     0.55968989 0.38190509 0.277966239 0.154626900 0.0863134395
Proportion of Variance 0.02409637 0.01121935 0.005943479 0.001839191 0.0005730777
Cumulative Proportion  0.98042491 0.99164425 0.997587732 0.999426922 1.0000000000
```

Figure 7 the result of principal component analysis (1)

3. The other way to show these three data:

   We use a more convenient way to show data in R:

```
city.val=get_eigenvalue(city.city.pra)
city.val
         eigenvalue  Proportion of Variance  Cumulative Proportion
Comp.1  5.14905756        39.60813511            39.60814
Comp.2  2.23967448        17.22826522            56.83640
Comp.3  1.45429814        11.18690879            68.02331
Comp.4  1.11953536         8.61181047            76.63512
Comp.5  0.99673936         7.66722584            84.30235
Comp.6  0.64241687         4.94166823            89.24401
Comp.7  0.45464733         3.49728715            92.74130
Comp.8  0.37590190         2.89155309            95.63285
Comp.9  0.31325277         2.40963673            98.04249
Comp.10 0.14585150         1.12193460            99.16443
Comp.11 0.07726523         0.59434792            99.75877
Comp.12 0.02390948         0.18391906            99.94269
Comp.13 0.00745001         0.05730777           100.00000
```

Figure 8 the result of principal component analysis (2)

4. Determination of the final principal components:

   Generally, it’s best when the cumulative proportion reaches at 85%. According to the Figure 8, the cumulative proportion of Comp.5 is 0.84302345, which is the closest to 0.85. Hence, we decide to consider Comp. 1,2,3,4,5 as the final principal components.

5. Analysis of factor Weight :

   After determining the five principal components, we use the quality of representative to measure the weight of each factor in the principal component analysis method.

Quality of representation We consider the quality of each factor as cos2.

We define three points: The value of cos2 is to measure the usefulness of a factor. The higher the value, the more important this factor is in the principal component analysis.
High value of cos2 means the factor has a great contribution on principal component.
Low value of cos2 means the factor is not well represented by the principal component.

Input corrplot statement in R, and then get Figure 9:

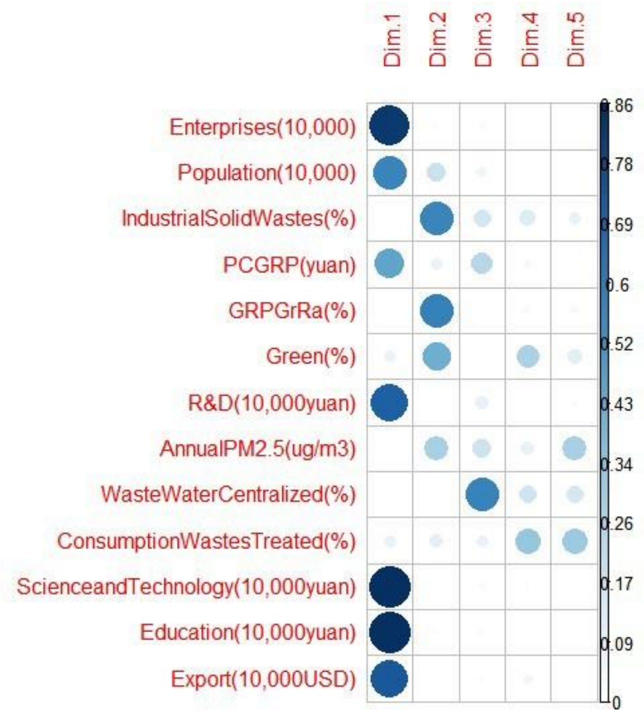

Figure 9 Quality of representation

Contributions of factors to principal components At the same time, we can also measure the importance of the factor in the principal component analysis from another dimension, which is the degree of contribution to the principal components. The contribution ratio of each factors to the principal component is different. The factors that contributes the most to the first and second principal components is the most important, while the factor that contributes little to the principal component can even be removed from the simplified analysis of the data.
Also, we use quality of representation for visualization:
Input corrplot statement in R, and then get Figure 10:

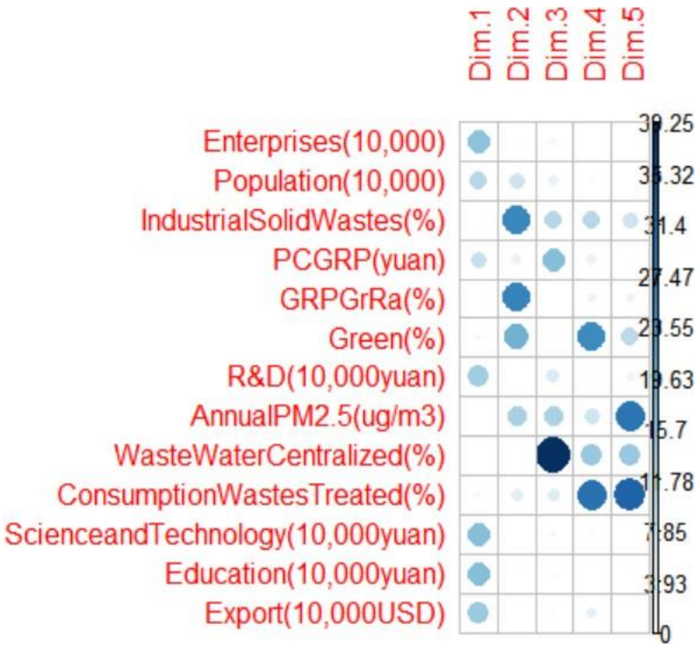

Figure 10 Contributions of factors to principal components

6. Determination the weight of the entire five indicators:

   We input summary statement in step 2 and gain the result in Figure 7 and the following figure.

Loadings:

	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8	Comp.9	Comp.10	Comp.11	Comp.12	Comp.13
Enterprises(10,000)	0.400	0.132		0.350	0.171	0.151	0.521	0.444				0.347	0.215
Population(10,000)	0.330	-0.287	0.195		0.232	0.419	-0.265	0.310	-0.252	-0.278		-0.343	0.327
IndustrialSolidWastes(%)		-0.503	-0.333	-0.328	-0.281		-0.243	0.277	0.328			0.173	-0.386
city.prGRP(yuan)		0.296	0.185	-0.407	-0.181	0.105	-0.479	-0.416	0.256			-0.240	0.361
GRPGrRa(%)		0.509	-0.171	-0.173	0.699	0.237	-0.318	0.117				-0.107	
Green(%)	0.119	0.431	0.495	-0.321	-0.231	-0.407	0.288					-0.373	
R&D(10,000yuan)	0.368	0.239	-0.158	-0.323	-0.324	0.136	0.598	0.284				0.223	0.241
AnnualPM2.5(ug/m3)		-0.356	0.349	0.276	-0.532	0.359	-0.385	0.118	-0.122	0.263	-0.120		-0.222
WasteWaterCentralized(%)		0.626	-0.383	0.386	0.126	-0.262	-0.342	0.202	0.111				
ConsumptionWastesTreated(%)	-0.118	0.208	0.230	-0.542	-0.561	-0.287	0.300	-0.190	0.143	-0.143		-0.122	0.114
ScienceandTechnology(10,000yuan)	0.408	-0.127	-0.104	0.120	-0.204	-0.385	-0.500					0.559	-0.161
Education(10,000yuan)	0.409				-0.527	0.302						-0.504	-0.424
Export(10,000USD)	0.377		-0.199	-0.185	-0.177	0.501	0.444	0.166	-0.374			-0.186	-0.304

Figure 11 the result of principal component analysis (3)

Set the 13 variables in the first row (ex.enterprises) as

$$x_1, x_2, \ldots, x_{13}$$

the value of Comp.1,2,3,4,5 as

$$c_{1,2,3,4,5}$$

and then set

$$c_1 = 0.400 * x_1 + 0.330 * x_2 + 0 * x_3 + 0 * x_4 + 0 * x_5 + 0.119 * x_6 + 0.368 * x_7 + 0 * x_8 + 0 * x_9 - 0.118 * x_{10} + 0.408 * x_{11} + 0.409 * x_{12} + 0.377 * x_{13} \quad (1)$$

$$c_2 = 0.132 * x_1 - 0.287 * x_2 - 0.503 * x_3 + 0.296 * x_4 + 0.509 * x_5 + 0.431 * x_6 + 0.239 * x_7 - 0.356 * x_8 + 0.626 * x_9 + 0.208 * x_{10} - 0.127 * x_{11} + 0 * x_{12} + 0 * x_{13} \quad (2)$$

$$c_3 = 0 * x_1 - 0.195 * x_2 - 0.333 * x_3 + 0.185 * x_4 - 0.171 * x_5 + 0.495 * x_6 - 0.158 * x_7 + 0.349 * x_8 - 0.383 * x_9 + 0.230 * x_{10} - 0.104 * x_{11} + 0 * x_{12} - 0.199 * x_{13} \quad (3)$$

$$c_4 = 0.350 * x_1 + 0 * x_2 - 0.328 * x_3 - 0.407 * x_4 - 0.173 * x_5 + 0.321 * x_6 - 0.323 * x_7 + 0.276 * x_8 + 0.386 * x_9 - 0.542 * x_{10} + 0.120 * x_{11} + 0 * x_{12} - 0.185 * x_{13} \quad (4)$$

$$c_5 = 0.171 * x_1 + 0.232 * x_2 - 0.281 * x_3 - 0.181 * x_4 + 0.699 * x_5 - 0.231 * x_6 - 0.324 * x_7 - 0.532 * x_8 + 0.126 * x_9 - 0.561 * x_{10} - 0.204 * x_{11} - 0.527 * x_{12} - 0.177 * x_{13} \quad (5)$$

According to the principal component analysis, we set

$$v = k_1 * c_1 + k_2 * c_2 + k_3 * c_3 + k_4 * c_4 + k_5 * c_5$$

v is the value of economic vitality

$k_{1,2,3,4,5}$ are factor load, and

$$\sum_{i=1}^{5} k_i = 1$$

We use weighted calculation based on proportion variance to get the value of $k_{1,2,3,4,5}$.

Set the value of proportion of variance for Comp.1,2,3,4,5 as

$$p_{1,2,3,4,5}$$

the value of cumulative proportion for Comp.5 as

$$P$$

and

$$P = p_1 + p_2 + p_3 + p_4 + p_5$$

So, we could calculate $k_{1,2,3,4,5}$

$$k_1 = p_1/P = 0.470$$

$$k_2 = p_2/P = 0.204$$

$$k_3 = p_3/P = 0.133$$

$$k_4 = p_4/P = 0.102$$

$$k_5 = p_5/P = 0.091$$

Hence,

$$v = 0.470 * c_1 + 0.204 * c_2 + 0.133 * c_3 + 0.102 * c_4 + 0.091 * c_5 \tag{6}$$

7. The acquisition of the relationship between reginal economic vitality and 13 factors:
   Plug (1),(2),(3),(4),(5) in (6), we gain the formula:

$$\begin{aligned} v = {} & 0.319006 * x1 + 0.143599 * x2 - 0.205928 * x3 + 0.027004 * x4 + 0.127056 * x5 \\ & + 0.155926 * x6 + 0.138272 * x7 - 0.046467 * x8 + 0.127603 * x9 - 0.088773 * x10 \\ & + 0.145696 * x11 + 0.144273 * x12 + 0.115746 * x13 \end{aligned} \tag{7}$$

5.2 The answer of Question 3

Based on the model of the factors affecting economic vitality, we could use the formula to calculate 19 cities' economic vitality indexes.The result is following:

Table 2 The indexes (v) of regional economic vatility

City	Index (v)
Shanghai	5,740,734
Shenzhen	5,431,453
Beijing	4,784,607
Dongguan	4,335,859
Suzhou	3,027,896
Guangzhou	2,296,965
Tianjin	1,938,846
Hangzhou	1,634,417
Chongqing	1,604,048
Ningbo	1,444,718
Nanjing	1,139,025
Wuhan	1,110,588
Qingdao	1,089,734
Chengdu	1,084,914
Xi'an	895,219.1
Zhengzhou	821,873.3
Changsha	656,113.8
Shenyang	364,656.7
Kunming	179,864.4

5.3 The method of control variable and answer of Question 2

Shenzhen's economic transforation We chose Shenzhen, China to analyze the short-term and long-term effects of economic transformation. After the outbreak of the international financial crisis, Chinese traditional economic model suffered a heavy hit, and the national trade volume fell sharply. This situation has seriously impeded Chinese economic development.

As the starter to reform, Shenzhen encountered an economic bottleneck earlier than the other cities. In fact, since the "Eleventh Five-Year Plan", Shenzhen has begun economic transformation. The structure of the primary, secondary and tertiary industries in Shenzhen has undergone a change in trend. The proportion of the secondary industry decreased from 52.6% in 2006 to 44.3% in 2012, while the proportion of the tertiary industry increased steadily from 47.3% in 2006 and arrived at 55.7% in 2012.

Shenzhen's economy has entered a post-industrial period, and the service industry (the tertiary industry) has begun to play a greater role in the development of Shenzhen's economy. From the "Eleventh Five-Year Plan" to the early period of the "Twelfth Five-Year Plan", the fixed asset investment absorbed by the tertiary industry was much higher than that of the secondary industry. From 2006 to 2011, fixed asset investment in the tertiary industry accounted for 66% to 77% of the total fixed asset investment, and the ratio of fixed asset investment in the secondary industry occupied the total fixed asset investment fluctuated between 22% and 34%. At the same time, the proportion of fixed asset investment attracted by all service industry increased by less than 10%, but that attracted by secondary industry decreased by 10%.

Table 3 Proportions of secondary and tertiary industries in total fixed asset investment in the city (2006-2011)

Year	Total fixed asset investment(billion yuan)	Proportion of secondary industry(%)	Proportion of tertiary industry(%)
2006	1274	33.6	66.4
2007	1345	31.0	69.0
2008	1468	26.3	73.7
2009	1709	22.6	77.4
2010	1945	24.7	75.3
2011	2061	23.0	77.0
Average	- -	26.2	73.8

Table 4 Proportion of Three Industrial Structures in Shenzhen (2006- -2012)

Year	Proportion of first industry(%)	Proportion of secondary industry(%)	Proportion of industry in secondary industry(%)	Proportion of tertiary industry(%)
2006	0.1	52.6	49.8	47.3
2007	0.1	50.2	47.6	49.7
2008	0.1	49.6	47.1	50.3
2009	0.1	46.7	43.8	53.2
2010	0.1	52.6	49.8	47.3
2011	0.1	46.4	43.4	53.5
2012	0.1	44.3	- -	55.7

Short-term and long-term effect From 2006 to 2011, Shenzhen's social labor increased by 1.17 million, which basically entered the tertiary industry. Specifically, the population of labor in the tertiary industry increased from 2.74 million in 2006 to 3.81 million in 2011. At the same time, the population of labor in the secondary industry was relatively stable, which only increased by less than 100,000, and manufacturing has only increased by less than 70,000. The following are the table and curve graph of population density in Shenzhen from 2006 to 2011.

Table 5 The table of population density in Shenzhen from 2006 to 2011

Year	Population density in Shenzhen (per km^2)
2006	4334.00
2007	912.00
2008	4887.00
2009	5095.00
2010	5311.00
2011	5360.00

It can be found that when Shenzhen began to implement economic transformation in 2006, the population per square kilometer of Shenzhen fell sharply from 4334 to 912 in a short period of time. However, it bottomed out at 912 in 2007 and increased rapidly to 4887 in 2008. In the next few years, the population maintained a stable growth. Therefore, we conclude that the economic transformation in 2006 were not trusted by

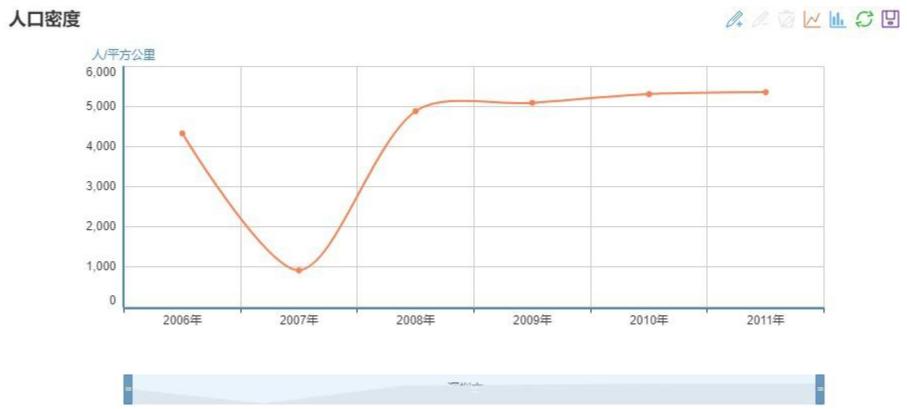

Figure 12 The curve graph of population density in Shenzhen from 2006 to 2011

people during the first several years.

According to our principal component analysis model and the following formula, we know that x_2 represents the resident population, and the factor load (coefficient in front of it) represents the weight that x_2 effects the economic vitality of the city. Then, we rank 13 factors according to the weight of them:

$$v = 0.319006 * x1 + 0.143599 * x2 - 0.205928 * x3 + 0.027004 * x4 + 0.127056 * x5$$
$$+0.155926 * x6 + 0.138272 * x7 - 0.046467 * x8 + 0.127603 * x9 - 0.088773 * x10$$
$$+0.145696 * x11 + 0.144273 * x12 + 0.115746 * x13$$

We find that population-related factors rank fourth in our model,which indicates that the short-term impact of sharp change in population on regional economic vitality is quite weak.

We use the control variable method to perform a quantitative simulation analysis of the urban economic activity in 2018.

In Question 3, we used the data from 2018 to calculate the index of Shenzhen's economic vitality: 5,431,453.

We assume the index in 2006 is also 5,431,453.

Since the population density decreased from 4334 people /km^2 to 912 people / km^2 in 2007, which is about 80% lower, we assume that x_2, the resident population, is also reduced by 80% in 2018, but the remaining 12 factors do not change.

Based on the data we surveyed, we set the value of x_2 decreases from 1190.84 million to 238.168 million, but the values of the remaining factors do not change.

According to the formula (7), we could get a new index after decreasing the value of x_2, which is 4,632,951. Hence, Shenzhen's economic vitality has decreased by 15%.

Table 6 The rank of 13 factors according to weight

Order	Symbol	Factor	Factor Load
1	x_1	Quantity of Surviving eEnterprises in 2019	0.319006
2	x_6	Green(%)	0.155926
3	x_{11}	Expenditure for Science and Technology(10000yuan)	0.145696
4	x_{12}	Expenditure for Education(10000yuan)	0.144273
5	x_2	Resident Population in 2019(10000)	0.143599
6	x_7	R&D Internal Outlay (10,000yuan)(%)	0.138272
7	x_9	Ratio of waste Water Centralized Treated of Sewage Work(%)	0.127603
8	x_5	GRP Growth Rate(%)	0.127056
9	x_{13}	Export(USD 10000)	0.1157462
10	x_4	Per Capita GRP(yuan)	0.027004
11	x_8	Annual Mean Concentration of PM2.5(ug/m^3)	-0.046467
12	x_{10}	Ratio of Consumption Wastes Treated(%)	-0.088773
13	x_3	Ratio of Industrial Solid Wastes Comprehensively Utilized(%)	-0.205928

As we all know, with the decline of the population, it is clear that the remaining 12 factors will also change in various degree. We cannot estimate them all, but it is certain that the economic vitality in 2018 decreases less than 15% and a new balance forms between 13 factors.

In conclusion, with the economic transformation started in Shenzhen in 2006, the economic proportion of the tertiary industry represented by the service industry has gradually increased, while that of the secondary industry represented by the industry has gradually decreased. The impact is to reduce Shenzhen's economic vitality by at least 15% in short term.That means vitality decline occurs. For long-term development, Shenzhen's economic transformation is bound to be a great decision, so Shenzhen's economy is better than the other cities. The following table and graphs are comparing Shenzhen's per capita GDP and GDP growth rate from 2006 to 2018 with those of

China:

Year	Shenzhen	China	Shenzhen	China
	GDP growth rate (%)		per capita GDP(yuan)	
	Shenzhen	China	Shenzhen	China
2018	7.60	6.60	189568.00	64644.00
2017	8.80	6.90	183544.00	59660.00
2016	9.10	6.70	172453.00	53935.00
2015	8.90	6.90	162599.00	50251.00
2014	8.80	7.30	153677.00	47203.00
2013	10.60	7.80	141474.00	43852.00
2012	10.20	7.90	126765.00	40007.00
2011	10.00	9.50	113316.00	36403.00
2010	12.20	10.60	98437.00	30876.00
2009	11.30	9.40	87066.00	26222.00
2008	12.30	9.70	85088.00	24121.00
2007	14.80	14.20	77660.00	20505.00
2006	16.70	12.70	69702.00	16738.00

Figure 13 Comparation Shenzhen's per capita GDP and GDP growth rate from 2006 to 2018 with those of China

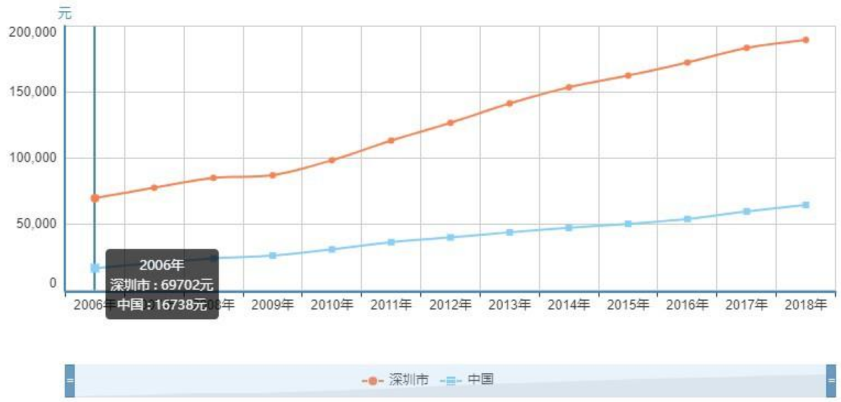

Figure 14 Comparation Shenzhen's per capita GDP from 2006 to 2018 with that of China

Figure 15 Comparation Shenzhen's GDP growth rate from 2006 to 2018 with that of China

5.4 The answer of Question 1

5.4.1 *The actions to improve economic vitality*

According to Table 2 (the rank of 13 factors) in the answer of Question 3, we select five factors from high to low, because these five factors are positively correlated with v (the regional economic vitality index), and have the greatest impact on v. Thus, we propose some suggestions from these 5 perspectives.

1) Quantity of surviving enterprises

It could demonstrate the economic situation of a region very well because only in the region where the economy is developed enterprises can survive.

We believe that the government should focus on high-tech enterprises and advanced manufacturing enterprises. As for enterprises in traditional industries, they could take technology researches, innovate designs and operate their brand. On the other hand, they could combine the technology in four fields of biomedicine, biomedicine, bioagriculture, and bioenvironment with their own products, such as new energy equipment and new energy vehicles.

Apart from those, the government could provide more policies in corporate innovation. For example, the government could increase subsidies for corporate activities, which will stimulate enterprises to increase employees and increase the number of innovative projects.

2) Green:

Green is about the city's environmental problems. We believe that the government should increase the density of urban green and handle the relationship between the land of trees and the land of city.

3) Expenditure for Science and Technology

The government should strengthen support for local basic innovation and strive to train world-class scientists and technology talents. In addition, the institutions could deepen the reform of science and technology management system, optimize the allocation of scientific and technological resources, and improve the legal system that encourages technological innovation and industrialization of scientific and technological achievements.

4) Expenditure for education

Focusing on education is beneficial for sustainable development. Higher level of education means more talents, which could create more productivity.

5) Resident population

In order to increase population, the government could open the migration registration, introduce various preferential policies for the migration of talents and adopt measures such as housing discounts, zero threshold settlement.

5.4.2 *The effect on economic vitality from the perspective of changing trend of population and enterprise vitality*

According to the formula (7) in the model, we increase the values of x_1 and x_2 by 10% and calculte the percentage increase in v(the index of regional economic vitality). The result is

$$\Delta v\% = 0.0004170935\%$$

We find that the data is in line with the well-known principle of wooden barrels. How much water a wooden barrel can hold does not depend on the longest board, but on the shortest one. It is lso known as the short board effect.

We increase 9 factors by 10% later in the sensitivity analysis, and find that $\Delta v\%$ is close to 10%. After comparing these two series of data, it is very clear that we must develop in an all-round way, so that the economic vitality of cities can be significantly improved.

5.5 The answer of Question 4

On the basis of answers of quaestion 1 - -3, we offer the following proposals.

First, encourage starting up business because the most vital factor in principal component analysis is the number of existent companies. The government could create a loose and convenient environment for entrepreneurial access by promoting institutions. Besides, addressing with the problem of difficult in financing is important. The related organization could innovate more ways of financing. What's more, motivate the enthusiasm of scientific researchers. Those who leave the post with consent can retain personnel relations for three years, and have the same rights as other employees to participate in the evaluation of job titles, promotion of posts, and social insurance. Encouraging scientific researchers to start a business is very necessary, because scientific researchers are starting a business with scientific research results, and a clear policy is not only conducive to encourage entrepreneurship, but also helpful for accelerating the transformation of scientific research results into real productivity.

Second, introduce the policy of economic transformation. Although the economic vitality will decrease in short term, a new balance will occur finally and the economy could develop sustainably. The government could develop high-tech industries and transfer existing industries to higher-tech, higher productivity, and higher value-added industrial activities. Meanwhile, it is also important to complete the reform of science and technology management system and the legal system.

VI. Model analysis

6.1 Sensitivity analysis

According to Figure 10 (contributions of factors to principals components),we know that ratio of industrial solid wastes comprehensively utilized per capita GRP, annual mean concentration of PM2.5 and ratio of consumption wastes treated these 4 factors contribute principal components least, and the values of k (factor load) are all less than 0.1.

Hence, we consider the rest 9 factors as principal factors and analyze sensity.

Increase the value of these 9 factors by 10% and calculate $\Delta v\%$ (the percentage change in economic vitality). The result is shown in Table 7.

Table 7 The percentage change in economic vitality

City	$\Delta v\%$
Shanghai	9.99408
Beijing	9.992757
Dongguan	9.992295
Shenzhen	9.990879
Suzhou	9.986832
Tianjin	9.983513
Chongqing	9.983009
Guangzhou	9.982361
Hangzhou	9.975523
Xi'an	9.974831
Chengdu	9.974366
Ningbo	9.971925
Wuhan	9.970092
Zhengzhou	9.96918
Nanjing	9.966727
Qingdao	9.96632
Shenyang	9.945333
Changsha	9.937555
Kunming	9.865673

$\Delta v\%$ (the percentage change in economic vitality): A larger percentage means the regional economic vitality indexes increase more, which indicates that the city has greater development potential.

We found that $\Delta v\%$ in each city is close to the 10% . It shows a strong linear relationship, so the principal component analysis method is used correctly, and the model is very successful.

Also, according to the above table, we find that Shanghai and Beijing have great potential for development, which is also in line with the actual situation. It further verifies the accuracy of the model.

6.2 Strength

1 The principal component method can eliminate the relevant influence between factors by forming Comp.

2 The principal component method can simplify the work of factor selection. Due to transferring to Comp., we could use the cumulative proportion as standard to determine the principal factors.

3 The control variable method can eliminate interference and directly reveal the influence of a single factor on the change of the subject.

6.3 Weakness

1 The principal component method: when the sign of the factor load of the principal component is sometimes negative, the meaning of the formula is unclear.

2 The principal component method: we should ensure that the cumulative proportion of the first several principal components reaches a high level.

3 The control variable method: the experimental environment is artificially set which is different from the complex and changeable conditions in real life, so the results of the experiments often have errors.

4 Due to the lack of data in the China Statistical Yearbook, the amount of available data is small and the results may have errors.

6.4 Extension

6.4.1 *Optimization method*

If we can have enough data to support it, we can make the model data more accurate and select more influential factors, so that we can cover more factors that affect the economic activity of the city. We can even use the model to predict the future economic vitality trend and provide strong support for the current economic development.

VII. References

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VIII. Appendix

Listing 1: The R Source code

```
library("openxlsx")
City=read.xlsx("CityDataShort.xlsx")

CityDataShort=City[-1]
CD=apply(CityDataShort,2,as.numeric)

install.packages("psych")
library("psych")

install.packages(c("FactoMineR", "factoextra"))
library("FactoMineR")
library("factoextra")


LnCD=log(CD)

city.city.pra <- city.prA(X = LnCD, scale.unit = TRUE, ncp = 5, graph =
    FALSE)


city.val=get_eigenvalue(city.city.pra)
city.val
          eigenvalue  Proportion of Variance Cumulative Proportion
Comp.1  5.14905756        39.60813511                 39.60814
Comp.2  2.23967448        17.22826522                 56.83640
Comp.3  1.45429814        11.18690879                 68.02331
Comp.4  1.11953536         8.61181047                 76.63512
Comp.5  0.99673936         7.66722584                 84.30235
Comp.6  0.64241687         4.94166823                 89.24401
Comp.7  0.45464733         3.49728715                 92.74130
Comp.8  0.37590190         2.89155309                 95.63285
Comp.9  0.31325277         2.40963673                 98.04249
Comp.10  0.14585150       1.12193460                 99.16443
```

```
Comp.11  0.07726523          0.59434792                    99.75877
Comp.12  0.02390948          0.18391906                    99.94269
Comp.13  0.00745001          0.05730777                   100.00000


install.packages(c("FactoMineR", "factoextra"))
library("FactoMineR")
library("factoextra")


fviz_eig(city.city.pra, addlabels = TRUE, ylim = c(0, 50))


var <- get_city.pra_var(city.city.pra)

install.packages("corrplot")
library("corrplot")
corrplot(var$cos2, is.corr=FALSE)

corrplot(var$contrib,  is.corr=FALSE)

city.pr <- princomp(LnCD, cor = T)
summary(city.pr,loadings=T)
Importance of components:
                          Comp.1    Comp.2    Comp.3    Comp.4     Comp.5
     Comp.6     Comp.7     Comp.8
Standard deviation   2.2691535 1.4965542 1.2059428 1.0580810 0.99836835
    0.80150912 0.67427541 0.61310839
Proportion of Variance 0.3960814 0.1722827 0.1118691 0.0861181
    0.07667226 0.04941668 0.03497287 0.02891553
Cumulative Proportion 0.3960814 0.5683640 0.6802331 0.7663512
    0.84302345 0.89244014 0.92741301 0.95632854
                          Comp.9    Comp.10     Comp.11     Comp.12      Comp.13
Standard deviation   0.55968989  0.38190509  0.277966239  0.154626900
    0.0863134395
```

```
Proportion of Variance 0.02409637 0.01121935 0.005943479 0.001839191
    0.0005730777
Cumulative Proportion 0.98042491 0.99164425 0.997587732 0.999426922
    1.0000000000


diag(diag(cov(LnCD))^(-1/2))%*%city.pr$loadings%*%diag(city.pr$sdev)
city.pr$loadings%*%diag(city.pr$sdev)
plot(city.pr$scores[,1], city.pr$scores[,2],col="red")
text(city.pr$scores[,1], city.pr$scores[,2],City$City,cex=0.6,pos=1)


citypca<- predict(city.pr)

dim(X)=c(13,19)
xbian=X
j=c(1,2)
xbian[j,]=xbian[j,]*1.1

for(i in 1:19){
     Y[i]=sum(b*xbian[,i])
     baifen[i]=(Y[i]/Y0[i]-1)*100
 }
 baifen
 [1]  0.0006927303  0.0004170935  0.0007310206  0.0003055265 0.0005631630
      0.0010023931 0.0012288726 0.0007869463
 [9]  0.0007503192  0.0008514136  0.0011988934  0.0015255013 0.0013328734
      0.0017586291 0.0017253751 0.0018662831
[17]  0.0017387849  0.0031520269  0.0057419460

Y0=c(5740733.7085922,5431453.20129443
      ,4784607.3531587
      ,4335859.3932883
      ,3027896.10892876
      ,2296965.12773561
      ,1938845.66603644
      ,1634416.57679104
```

```
      ,1604047.81892286
      ,1444718.48842645
      ,1139024.6001096
      ,1110588.3194545
      ,1089734.14171418
      ,1084914.09170501
      ,895219.13891109
      ,821873.28473316
      ,656113.81408977
    ,364656.71671416
    ,179864.41227633)




dim(X)=c(13,19)
xbian=X
xbian[j,]=xbian[j,]*1.1

for(i in 1:19){
     Y[i]=sum(b*xbian[,i])
     baifen[i]=(Y[i]/Y0[i]-1)*100
 }
> baifen
 [1]  9.994080  9.990879  9.992757  9.992295  9.986832  9.982361  9.983513
      9.975523  9.983009  9.971925  9.966727  9.970092
[13]  9.966320  9.974366  9.974831  9.969180  9.937555  9.945333  9.865673
```