The influence of small and medium-sized enterprises on economic growth

INAUGURAL-DISSERTATION
zur Erlangung des akademischen Grades
Doktor der Wirtschaftswissenschaften (Dr. rer. pol.)

Universität Bielefeld
Fakultät für Wirtschaftswissenschaften

vorgelegt von
Ping-Hua Ho
Bielefeld, 2011
1. Gutachter:

Prof. Dr. Alfred Greiner

Fakultät für Wirtschaftswissenschaften

Universität Bielefeld

2. Gutachter:

Prof. Dr. Bernhard Eckwert

Fakultät für Wirtschaftswissenschaften

Universität Bielefeld

Tag der Mündlichen Prüfung: 07.Juni.2011
Acknowledgment

“Endes gut, Alles gut!” It is a wonderful and unforgettable experience for me to live and study in Bielefeld and it will be one of the best things in my life. First of all, I would like to thank my chief supervisor, Prof. Dr. Alfred Greiner, for his professional guidance and valuable suggestions for my dissertation, and his timely assistance during my learning in Germany. Without his support, I probably would not have gone this far today.

Many thanks go especially to my second supervisor, Prof. Dr. Bernhard Eckwert, for his constructive comments and discussion about my dissertation. I also want to thank Prof. Dr. Christiane Clemens for her remarks concerning my dissertation in the doctoral oral defense.

I would also like to express my great thanks to quasi-Dr. Wei-Ming Ho, who proofread my dissertation. I also thank Ms. Diana Grieswald-Schulz for offering an office to me where I could work on this dissertation without distractions, Ms. Helga Radtke and Ms. Christine Charalambous for the process of the submitting to faculty. I also thank all friends who helped me out a lot in Bielefeld.

During the past fourteen years I was fortunate enough to have my lovely wife, Shuo-Hsiu Lee, with me in my life. She was the driving force pushing me forward and always provided me a carefree environment. Without her, I would not have become what I am today.

Finally, I would like to express my immense gratitude towards my parents and my younger brother. Thanks for supporting my decision to pursue my dream.
The influence of small and medium-sized enterprises on economic growth

Ph.D. Dissertation

First Advisor: Professor Alfred Greiner
Second Advisor: Professor Bernhard Eckwert
Advisee: Ping-Hua Ho

Department of Business Administration and Economics,
Bielefeld University, Germany
June 2011
Contents

Chapter 1  Introduction ................................................................................................1

  1.1 Motive ..............................................................................................................1
  1.2 Research contents .............................................................................................8

Chapter 2  One-Sector Model ....................................................................................11

  2.1 Introduction ....................................................................................................11
  2.2 The basic model .............................................................................................13
    2.2.1 The representative household .............................................................13
    2.2.2 The production function .....................................................................14
    2.2.3 The investment function .....................................................................15
  2.3 The social planner optimal solution in one-sector .........................................15
    2.3.1 The small firm .....................................................................................15
    2.3.2 The large firm ......................................................................................18
    2.3.3 The hybrid firm ...................................................................................20
    2.3.4 Transitional dynamic in one-sector .....................................................23

Chapter 3  Two-Sector Models (exogenous variable)................................................25

  3.1 Introduction ....................................................................................................25
  3.2 The production function of firms ...................................................................26
  3.3 The basic model .............................................................................................26
    3.3.1 The representative household .............................................................27
    3.3.2 The production function in the goods sector.......................................28
    3.3.3 The production function in education sector.......................................29
    3.3.4 The investment and education production function............................29
  3.4 The social planner optimal solution in two-sector models ............................30
  3.5 Transitional dynamics and numerical methods ..............................................32

Chapter 4  Two-Sector Models (endogenous variable)..............................................50

  4.1 Introduction and the model ............................................................................50
  4.2 The numerical methods ..................................................................................54
Chapter 5  Evidence and Statistics - (Taiwanese data) ..............................................67

5.1 Introduction ............................................................................................................67
5.2 Recent history of Taiwan’s economic development ..............................................68
5.3 The model assumption .......................................................................................71
5.4 The result of the estimation and regression .......................................................75

Chapter 6  The Factors of Enterprise Growth .............................................................82

6.1 Introduction ............................................................................................................82
6.2 The regression approach (Probit and Logit model) ..............................................84
6.3 The source of data and definition of variables .....................................................87
6.4 The statistical test models and estimation results ...............................................89

Chapter 7  Conclusion ...............................................................................................95

References ..................................................................................................................99

Appendix A: The definition of SMEs ........................................................................103

Appendix B: The data of Taiwan and other countries ..............................................107

Appendix C: The result of questionnaire .................................................................114

Appendix D: The data and the variables in regression ..............................................116
List of Figures

Figure 1-1 The process of firms’ transformation .........................................................10

Figure 3-1 The influence of firms’ scale to convergence paths .................................47

Figure 3-2 The relationship of the multiple convergence paths and economic growth .........................................................................................................................48

Figure 4-1 The process of the representative firm’s optimal choice .........................59

Figure 4-2 The relation between the discount rate of time ($\rho$) and the ratio of human capital in goods sector ($\omega$) .................................................................60

Figure 4-3 The relation between the discount rate of time ($\rho$) and the growth rate ($\gamma$) .................................................................................................................60

Figure 4-4 The relation between the inverse of the intertemporal elasticity of substitution ($\sigma$) and the ratio of human capital in goods sector ($\omega$) .......61

Figure 4-5 The relation between the inverse of the intertemporal elasticity of substitution ($\sigma$) and the growth rate ($\gamma$) .................................................................61

Figure 4-6 The relation between the depreciation rate ($\delta$) and the ratio of human capital in goods sector ($\omega$) .................................................................62

Figure 4-7 The relation between the depreciation rate ($\delta$) and the growth rate ($\gamma$) .................................................................................................................62
Figure 4-8 The relation between the average economy wide capital stock in

production function (β) and the ratio of human capital in goods sector (ω) ...

..........................................................................................................................63

Figure 4-9 The relation between the average economy wide capital stock in

production function (β) and the growth rate (γ) ........................................63

Figure 5-1 The economic growth rate in Taiwan between 1952 and 2006 ...............70
List of Tables

Table 1-1 The global firms and growth rate between countries.................................4

Table 1-2 The relationship between economic growth and the growth rate of large
    enterprises (LE)......................................................................................................7

Table 3-1 The relationship between internal, external effects and growth rate (B=1)........35

Table 3-2 The relationship between internal, external effects and growth rate (B=0.5)
    ......................................................................................................................36

Table 3-3 The relationship between the ratio of large firms and growth rate (B=1)…
    ......................................................................................................................37

Table 3-4 The relationship between the ratio of large firms and growth rate (B=0.5)…
    ......................................................................................................................38

Table 3-5 The situation of character roots ...................................................................46

Table 4-1 The relationship between the investment in education sector and growth rate
    ......................................................................................................................58

Table 4-2 The situation of SMEs among countries......................................................64

Table 5-1 The correlation coefficient between variables.............................................74

Table 5-2 Estimation of physical capital and human model........................................77

Table 5-3 The difference of external effect in countries..............................................79

Table 5-4 The estimation value of internal effects and external effects.......................79
Table 6-1 Estimation of a small firm’s growth factors (8 variables) .........................90
Table 6-2 Estimation of small firm’s growth factors (5 variables) .........................91
Table 6-3 Estimation of small firm’s growth factors (5 variables) .........................92
Table 6-4 Estimation of small firm’s growth factors (3 variables) .........................93
Table A-1 Correlative indictors of nation income in Taiwan ..................................107
Table A-2 The employee’s educational level in Taiwan ......................................109
Table A-3 The proportion of large firms and SME in Taiwan ...............................110
Table A-4 Series of real net fixed capital stock (excluded land) of industrial &
   service sectors (million NT$) .........................................................................111
Table A-5 The proportion of SME in South Korea ..............................................112
Table A-6 The proportion of SME in India .........................................................112
Table A-7 The size distribution of manufacturing industry among countries ....113
Table A-8 The data in regression ......................................................................116
The definition of symbols

$Y$: Total product in production sector (goods sector).

$y$: Average product per labor in production sector (goods sector).

$L$: The labor in the representative firm.

$K$: The total physical capital.

$k$: Physical capital per capita.

$Q$: The total human capital.

$q$: Average production per labor in education sector.

$A$: The basic technical level in goods sector.

$B$: The technical level in education sector.

$k_a$: Average economy wide capital stock.

$\theta_1$: The internal effect scale of firm.

$\theta_2$: The external effect scale of firm.

$C$: The total consumption.

$c$: Consumption per capita.

$\alpha$: The coefficient of the representative firm’s capital in production function.

$\beta$: The coefficient of average widely capital in production function.

$\sigma$: The inverse of the intertemporal elasticity of substitution.

$\rho$: Discount rate of time (constant subjective rate of time preference)

$\delta$: Depreciation rate (it is same in goods section and education section)

$u$: The proportion of human capital, which be used in goods sector.

$1 - \omega$: The ratio of the initial output that the small firm spends in education sector to improve its knowledge base or technology.

$\omega$: The ratio of the initial output that the small firm keeps in goods sector.
Chapter 1  Introduction

1.1 Motive

Small and medium-sized enterprises (SMEs\(^1\)) have been making great contributions to the economic development of developing countries, because SMEs is easier to establish for reducing the unemployment and producing light industrial products. The SMEs also play an important role in the economics of Taiwan.

In 1945, Taiwan's economy suffered from severe damage caused by the Second World War. After the war, the government has dedicated itself to developing light labor-intensive industry. Technology required for production in this industry was relatively simple. Taiwan was able to earn foreign exchange reserves. Private enterprises were encouraged to import raw materials, semi-finished products and machinery to produce consumer goods which could replace imported merchandise in the domestic market; thereby it contributed to establishing a solid foundation for the development of those industries producing everyday necessities. The development of SMEs speeded up, and enterprises with ten or fewer employees came to account for over 90 percent of all enterprises in Taiwan. Most of these enterprises were producing commodities for the domestic market. If there were not so many SMEs, Taiwan ‘s economic miracle might not have happened at all.

From the “White Paper on Small and Medium Enterprises in Taiwan 2008 “, we know that SMEs account for 97% of Taiwanese enterprises. They alone generated 28% of the total corporate sales and 77% of the workforce in the whole country were

\(^1\) The definitions of SMEs in Taiwan are:
\(a\). In the manufacturing, construction, mining and quarrying industries, a paid-in capital is less than NT$80 million (US$2.42 million) or the number of regular employees less than 200.
\(b\). In the agriculture, forestry and fisheries, water, electricity and gas, commercial, transportation, warehousing and communications, finance, insurance and real estate, industrial and commercial services or social and personal services industries, the sales revenue is less than NT$100 million (US$3.03 million) or less than 50 regular employees.
employed in SMEs in 2007. It is widely acknowledged that they are contributive to the reduction of the unemployment rate. Besides, most of large firms started off as small firms, such as Acer, one of the most famous computer manufacturers in Taiwan.

Acer is a Taiwan-based multinational computer technology and electronics corporation that manufactures personal computer, personal digital assistants, servers, monitors, etc. As of the fourth quarter of 2009, Acer was the world's second largest personal computer manufacturer and one of the most well-known brands in Europe. Acer was founded by Stan Shih and his wife Carolyn Yeh in 1976 in Taiwan. It began only with 11 employees and US$25,000 in capital. By 2005, Acer employed 7,800 people and its revenues soared to US$11.31 billion in 2006.

Another economic miracle in the history that attracted most researchers’ attention was Germany’s swift economic recovery from the depression after World War II. This result could be explained on several accounts, such as the trend of international trade and economic liberation, the change of German political and economic conditions. The restructured industrial system in Germany was one of the most important factors in terms of improving the development of the German economy.

It is known that German enterprises were and are still very competitive in the global market. Roy Rothwell and Walter Zwigveld (1982) stated SMEs have played a key role in the post-war development of the West German manufacturing industry. They created a stable, social and economic environment and were central to the post-war economic recovery plans of the West German government. In fact, almost 95% of the German enterprises were classified as SME and 85% of German workers were hired by SMEs in Germany between the 1950s and 1960s. Thus, the success of SMEs had much to do with the prosperity of the German economy.

Like Taiwan’s example, the famous supermarket Aldi which actually transformed
itself from a very small firm is another example. The mother of brothers Albrecht opened a small store in a suburb of Essen in 1913. After the end of World War II, the brothers took over their mother’s business in 1946, but it was simply a very small grocery store back then. With the brothers’ efforts, now, the Aldi group became the largest chain supermarket in Germany. In the beginning, Aldi could only hire two people, but now it hires over thousands of employees and buys lots of material from its upstream firms.

Rothwell (1981) pointed out the role of SMEs in industry development after World War II. He thought small firms are the seed of tomorrow’s large firms and new industries. If a small firm grows into a large firm successfully, it has the potential to hire more workers and demand more resources from other firms. In other words, it creates greater external effects. When SMEs have a higher probability to grow into large firms, it could lead to a higher growth rate.

For example, in Table 1-1, we distinguish these countries into four groups. The countries in group 1 are USA, Germany and Canada. In 1960 these countries were already richer countries than the other groups. In 2007, they were still richer countries and have over 40% of global large firms.

In group 3, we compare Kenya, Taiwan and South Korea. In 1960, the GDP of Kenya was higher than Taiwan and South Korea and they all had nigh on zero international large firms. But between 1960’s and 1990’s Taiwan and South Korea experienced a high economic growth process; meanwhile, there were many small firms growing into large firms. For example, Samsung and LG in South Korea, whereas Acer and Foxconn in Taiwan. There were similar cases in other countries, like Germany, Japan, etc.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per capita (US dollars)</td>
<td>Per capita (US dollars)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>10558.75</td>
<td>36168.29</td>
<td>2.33</td>
<td>16</td>
</tr>
<tr>
<td>USA</td>
<td>14766.36</td>
<td>42886.92</td>
<td>2.28</td>
<td>162</td>
</tr>
<tr>
<td>Germany</td>
<td>15490*</td>
<td>31306.26</td>
<td>1.95</td>
<td>37</td>
</tr>
<tr>
<td><strong>Group 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>5813.99</td>
<td>18381.16</td>
<td>2.76</td>
<td>0</td>
</tr>
<tr>
<td>Japan</td>
<td>5471.59</td>
<td>30585.38</td>
<td>3.99</td>
<td>67</td>
</tr>
<tr>
<td>Mexico</td>
<td>4456.54</td>
<td>11203.82</td>
<td>2.12</td>
<td>0</td>
</tr>
<tr>
<td><strong>Group 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>1817.59</td>
<td>2025.18</td>
<td>0.41</td>
<td>0</td>
</tr>
<tr>
<td>South Korea</td>
<td>1764.73</td>
<td>23849.62</td>
<td>5.64</td>
<td>14</td>
</tr>
<tr>
<td>Taiwan</td>
<td>1591.98</td>
<td>27004.98</td>
<td>6.20</td>
<td>6</td>
</tr>
<tr>
<td><strong>Group 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>508.09</td>
<td>8511.33</td>
<td>6.17</td>
<td>24</td>
</tr>
<tr>
<td>India</td>
<td>961.6</td>
<td>3826.32</td>
<td>3.04</td>
<td>6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1027.81</td>
<td>5185.52</td>
<td>3.58</td>
<td>0</td>
</tr>
</tbody>
</table>

* The year of GDP is 1970


The situations were similar between Germany and Taiwan. We know that the SMEs play an important role in economy. Nevertheless, what is the real influence of the SME on economic growth? Aw, B. Y. and Batra G. (1998) thought SMEs had less physical and human capital, but they subcontracted activities among large firms and learnt new technologies and disseminated that throughout the economy. Romer (1986)
asserted that there exist positive spillover effects in industry and the positive spillover effects are beneficial to economic growth. Caballero and Lyons (1990) and Chan (1995) pointed out that there also exist external economies of scale in Germany and Taiwan. Greiner (2003) indicated that the external effect of investment could explain why countries may converge in terms of the growth paths they were taking in the long run.

Considering these papers, they assumed that the external effects of firms are homogeneous in the same industry and the firms are of the same scale. Meanwhile, the external effects are beneficial to economic growth. However, the external effects of firms may be different in each country and of variant firm scale. In some countries the external effect of SMEs was larger than others and perhaps it offered the SMEs more opportunities to transform themselves into large firms. When they become large firms, they can hire more employees and buy more production material from other firms and create higher economic growth. If we can establish the external effects of firms between the large enterprises and SMEs, and find out which factors could affect small firms to grow up into large firms, we could, perhaps, establish what factors led to the different paths that countries took in terms of their economic system.

In addition, the probability or process that transforms SMEs into large firms may yet be another key factor that accounts for the difference of growth rate in each individual country.

Almost all large firms practically started off small with a limited amount of capital or saving of the owner. The initial number of employees was also small, typically fewer than a dozen. Later, some firms would expand and operated on a medium or large scale, whereas others would shut down or close. If a small firm grows into a large firm successfully, it can hire more workers and need more resources from other firms. In other words, it spurs more external effects and brings
We tried to use the empirical data from three Asian countries in Table 1-2 (South Korea, Taiwan and India) to look at the relationship between the growth rate of GDP and growth rate of large firms. Because our data is limited, we could not use long-term data to establish a regression model. Nonetheless, we still could observe the phenomenon on the trend. Except for India, the relationships between the GDP growth rate and the growth rate of large firms in Taiwan and South Korea are significant. The coefficient for South Korea is 0.664. It means if the numbers of large firms raise 1 percent, the growth rate will increase by 0.664 percent, and the effect in South Korea is larger than in Taiwan. The reason perhaps is that most large firms in South Korea are supported by its government and they could use more resources and hence take a more advantageous position than small firms from government.

Between the 1970’s and 1990’s Taiwan and South Korea experienced a high economic growth rate. Meanwhile, there were many small firms transforming into large firms. We could also find the similar cases in others countries.

Dennis Anderson (1982) claimed that predominance of large firms is due to (1) the economics of scale with respect to plant, (2) the economics of scale with respect to management and marketing, (3) the superior technical and management efficiency, and (4) the preferential access to supporting infrastructure service and external finance. Hence, we assume that there exist higher internal and external effects in large firms.
Table 1-2 The relationship between economic growth and the growth rate of large enterprises (LE)

<table>
<thead>
<tr>
<th>Country</th>
<th>South Korea</th>
<th>Taiwan</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td>13</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Constant</td>
<td>0.036*</td>
<td>0.075*</td>
<td>-1.928</td>
</tr>
<tr>
<td>(0.011)</td>
<td>(0.006)</td>
<td>(4.018)</td>
<td></td>
</tr>
<tr>
<td>(LE_i - LE_{i-1} / LE_{i-1})</td>
<td>0.664**</td>
<td>0.063**</td>
<td>49.70</td>
</tr>
<tr>
<td>(0.289)</td>
<td>(0.029)</td>
<td>(100.82)</td>
<td></td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.32</td>
<td>0.19</td>
<td>0.02</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>1.608</td>
<td>0.955</td>
<td>2.23</td>
</tr>
</tbody>
</table>

Stand errors are in parentheses. The method to estimate equation is ordinary least square (OLS). * means significant level is 1 percent, ** 10 percent.

Date source: Taiwan: The Small and Medium Business Administration of Economic Affair in Taiwan.
South Korea: The Small and Medium Business Administration of Korea.
1.2 Research contents

According to these arguments, the process of small firms transforming into large firms seems to be an important factor on economic growth. We may suggest that there are some connections between the process of small firms’ transformation and economic growth. The present dissertation seeks to fill this gap and detect the relationship and interplay among the influence of the scale of firm, the transformation process, and factors that encourage firms’ transformation. The research questions addressed in the current study are as follows:

- In chapter 2 and chapter 3, we discuss the influence of SMEs’ transformation on the economic growth and improve on the model concerning the process of firms transforming from small ones to large ones with different assumptions. To be exact, we assume an industry where only one-sector or two-sectors exist.

- In chapter 3, we discuss to what extent the share of large firms influences the speed of economic growth.

- In chapter 4, we also discuss to what extent the share of large firms influences the speed of economic growth, but we manipulate the share of large firms to be an endogenous variable. It means small firms could do something to improve the probability transforming into large firms.

- In chapter 5, we use Taiwan’s data to calculate the share of external effect in firms’ production function.

- In chapter 6, we use econometrics method to find out the important factors that make small firms transform to large firms.

- In chapter 7, we sum up the results and close up the whole study with conclusions.

This dissertation is expected to make a contribution to the research field of
small firms’ transformation contributive to economic growth. First, it models the production function which combines two kinds of firms, large and small, and calculates the influence of different parameters on the economic growth. It perhaps could help us to explain why two countries in the same economic condition at the start-up phase could take divergent paths years later. In Figure 1-1 we create a flow chart to help readers easily to understand what the important points are in this dissertation. Moreover, the investigation of the factors that affect small firms transforming into large firms successfully is hopefully to be beneficial for governments to come up with some viable policy.
Figure 1-1 The process of firms’ transformation

*AD: 1960  GDP (U.S. dollars)*

Country A
Ex: Taiwan
GDP: 1591.98
No large firms

Small firms

Right policy
Good financial system
Human resource rise

\[ \lambda \]
\[ 1 - \lambda \]

Large firms  Small firms

External effect

Internal effect

\[ \lambda \]
\[ \theta (1 - \lambda) \]
\[ (1 - \theta)(1 - \lambda) \]

Country B
Ex: Kenya
GDP: 1817.59
No large firms

Small firms

Wrong policy
Bad financial system
Human resource fall

*AD: 2007*

Country A
Taiwan
GDP: 27004.98

Country B
Kenya
GDP: 2025.18
Chapter 2  One-Sector Model

2.1 Introduction

Since the Industrial Revolution in the 18th century, the wealth gap between the poor countries and rich countries has greatly enlarged.

For the reason, many economists pay attention to varying growth rates across countries and try to find the reasons why each country has a different growth path.

The economic growth theories in the earlier period cannot explain the reason for the economic growth, nor why the economy can have a sustainable growth.

Past literature was based on Solow’s (1956) neoclassical growth model. However, the theory cannot properly explain why per capita income grows persistently and how government policy can influence economic growth in reality.

Since Romer (1986), the external effect of the manufacturer's output has become one of the important factors that motivate economic growth.

The recent development of endogenous growth theories emphasizes that the steady state growth is an endogenous outcome, for instance (Barro, 1990; Rebelo, 1991).

Endogenous growth theories propose that the momentum of economic growth comes from endogenous factors of the model, such as the accumulation of human capital, research and development. However, we do not know the influence on the scale of firms in endogenous growth theories.

It is very likely that the structures between large and small firms’ economies would be different. Furthermore, for a large firm’s economy, the stock of physical and human capital is larger than that of a small firm’s economy. That means there would be larger external effects in large firms’ economies.

We can look at the evolution of firms in history. At the early agricultural society,
it was inconvenient to transport goods. The so-called large enterprises, strictly speaking, may be just small regional enterprises.

Thanks to the technological development, the large international enterprises’ influence is not limited to its motherland, but also reaches other faraway nations.

By observing the data of global 500 large companies\(^2\), most of the international large enterprises, are located in developed countries, like USA, Japan and Germany, or even some of the new developed countries, such as South Korea, Singapore and Taiwan.

The external effect of large enterprises, however, is not of the same value across countries in the world. For example, the external effect of a large enterprise between Philippines and USA may be totally different, because the scale of the largest firm in the Philippines may be just a medium firm in the USA.

Except for some large enterprises that are directly supported by governments, most of the large enterprises are transformed from the small enterprises. The process of a small enterprise transformed into a large enterprise and whether it will bring more external effects to other manufacturers is worth discussing.

The purpose of this chapter is to examine the role of a firm’s scale and its effect on the economic growth. We also discuss whether a country with more large-scale enterprises has a higher economic growth rate than a country with fewer large-scale enterprises.

---

2.2 The basic model

The basic model will adopt the assumption of Romer (1986). Consider a closed economy consisting of two parts: a representative household and a productive firm that produces a single commodity.

There exist large enterprises\(^3\), small enterprises and hybrid enterprises in three countries A, B and C. In the country A, all firms are large enterprises. In the country B, all firms are small enterprises and in the country C exists only hybrid enterprises. What is a hybrid enterprise? In this chapter, we define a hybrid enterprise as a new enterprise that couples a large enterprise with a small enterprise. The proportion of large firms is \(\lambda_1\) and the proportion of small firms is \(1 - \lambda_1\), \(0 < \lambda_1 < 1\). There is no government in our model. That means that there is no tax and subsidy. International trade in our model is not allowed for.

2.2.1 The representative household

There exists a representative household in each economy. The representative household is assumed to have an infinite planning horizon in each country. Moreover, the labor supply of the representative household is fixed. It means that there is no birth and death in the representative household. Hence, the number of household is constant. The household is postulated to choose its private level of consumption to maximize the discounted sum of future instantaneous utilities:

\[
\max \quad U = \int_{0}^{\infty} e^{-\rho t} \mu(c(t))Ldt \quad \text{........................(2-1)}
\]

and

\(^3\) We define an enterprise as a large firm if the internal and external effects are larger than 0. A small firm does not have internal and external effects in the production function.
\[
\mu(c(t)) = \frac{c^{1-\sigma}(t) - 1}{1 - \sigma} \quad \text{..................................(2-2)}
\]

subject to:

\[y(t) = c(t) + \delta k(t) + \dot{k}(t)\]

where \(U\) is the utility function and \(\rho\) is the subjective time preference rate. \(c\) is the consumption, \(L\) is the number of labor which is set equal to 1 and \(\sigma\) is the inverse of the elasticity of intertemporal substitution which measures the curvature of the utility function.

### 2.2.2 The production function

The production function is assumed to be

\[y(t) = f(k, k_a) = A(1 + \theta_1)k(t)^\alpha[(1 + \theta_2)k_a(t)]^{1-\alpha} \quad \text{.................(2-3)\textsuperscript{4}}\]

where \(y\) is output per unit of labor, \(k\) is the physical capital of the representative firm, and \(k_a\) is other firm’s average capital (also called average economy wide capital stock), \(\theta_1\) is the internal effect scale of the representative firm; \(\theta_2\) is the external effect scale of the representative firm; \(\alpha\) is the share of firm’s capital in production function; \(1 - \alpha\) is the share of other firm’s average capital in production function. \(A\) is the basic technology level. Here we assume that the internal effect scale \(\theta_1\) of the representative can make greater contribution than the external effect scale \(\theta_2\), because the representative firm could adjust its optimal production process. Even if \(\theta_1\) and \(\theta_2\) is of the same value, the contribution of the parameter \((1 + \theta_1)\) is larger than \((1 + \theta_2)^{1-\alpha}\) in production function.

The production function exhibits diminishing returns to scale with \(k\). If \(\theta_1\) and \(\theta_2\) are both larger than 0 and there exist constant returns to scale. Every firm has the same basic technology level \(A\). However, with the different scale the firms have,

\[\text{\footnotesize{4 In the following we ignore the time argument if no ambiguous results.}}\]
they have different internal effect $A(1 + \theta_i) = A_i$.

2.2.3 The investment function

In the aspects of investment, the representative household did not save anything. The output deducts to consume and depreciate, which will be devoted to next period. The physical capital accumulation constraint of a representative firm is

$$\dot{k} = f(k) - \delta k - c \quad \text{………………………….}(2-4),$$

where $\delta$ is the depreciation rate, and an over dot denotes the time derivative. In this chapter, we assume that $k_a$ could make contribution to production process, it means there exists externality in production function. The decentralized solution will not be the Pareto optimal because it does not consider the spillover of physical capital across the firms. The social planner could internalize the spillover of physical capital across the firms into the production function and it will be the best solution. Therefore, we just consider trying to find “The social planner optimal solution”.

2.3 The social planner optimal solution in one-sector

2.3.1 The small firm

In the beginning, the number of labor is $L$. For convenience, we assume $L$ keeps constant to 1. $u$ is the utility function of consumption and it is assumed to satisfy the Inada conditions.

$$\lim_{c \to 0} \mu'(c) = \infty, \lim_{c \to \infty} \mu'(c) = 0 \quad \text{………………………….}(2-5)$$

$L(t) = L = 1$

$$\mu(c(t)) = \frac{c^{1-\sigma}(t) - 1}{1 - \sigma}$$

15
\[ Y / L = y = f(k, k_a) \]

When all firms are small firms, it means that there are no internal and external effects in the production function. \( \theta_1 = \theta_2 = 0 \), equation (2-6) states the production function per labor.

\[ y = Ak^\alpha k_a^{1-\alpha} \] \hspace{1cm} (2-6)

The present value Hamiltonian for the representative household’s optimization is given by:

\[ H = \frac{e^{1-\sigma}(t)-1}{1-\sigma} e^{-\rho t} + \lambda(k) \] \hspace{1cm} (2-7)

After differentiating equation (2-7) with respect to \( c \) (control variable), we obtain equation (2-8). It means that the present value marginal utility must equal the marginal value of physical capital.

\[ \frac{\partial H}{\partial c} = c^{-\sigma} e^{-\rho t} - \lambda = 0 \rightarrow c^{-\sigma} e^{-\rho t} = \lambda \] \hspace{1cm} (2-8)

equation (2-7) differentiating with respect to \( k \) (state variable), we obtain equation (2-9).

\[ \frac{\partial H}{\partial k} \Rightarrow \lambda(f'(k) - \delta) = -\dot{\lambda} \] \hspace{1cm} (2-9)

We need equation (2-10) as transversality condition; it means that there will be an optimal solution.

\[ \lim_{t \to -\infty} \lambda(t)k(t) = 0 \] \hspace{1cm} (2-10)

From equation (2-9), we get equation (2-11)

\[ (f'(k) - \delta) = \frac{\dot{\lambda}}{\lambda} \] \hspace{1cm} (2-11)

Logarithm equation (2-8) and differentiating with respect to time, we obtain
equation (2-12). We can also put equation (2-11) into equation (2-12) and obtain the common growth rate from the expression for consumption.

\[
\frac{\dot{c}}{c} = \frac{-\lambda}{\sigma} = \frac{f'(k) - \delta - \rho}{\sigma} = \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldot
Then \[ \frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \frac{\dot{y}}{y} \] \hspace{1cm} \text{(2-16)}

So we can induce the growth rate in a country with small firms as equation (2-17)

\[ \frac{\dot{y}}{y} = \frac{f'(k) - \delta - \rho}{\sigma} = \frac{A - \delta - \rho}{\sigma} \] \hspace{1cm} \text{(2-17)}

If \( A > \delta + \rho \), the growth rate will be positive, the result is similar to AK model.

### 2.3.2 The large firm

The other assumptions stay the same as those of small firms, except for the value of the internal effect and external effect, which are both larger than 0. The production function is equation (2-18).

\[ y = f(k, k_a) = A(1 + \theta_1)k^\alpha [(1 + \theta_2)k_a]^{1-\alpha} \] \hspace{1cm} \text{(2-18)}

The present value Hamiltonian for the representative household ’s optimization is illustrated by:

\[ H = \frac{e^{\lambda t} - 1}{1 - \sigma} e^{-\lambda} + \lambda(k) \] \hspace{1cm} \text{(2-19)}

After differentiating equation (2-19) with respect to \( c \) (control variable), we obtain equation (2-20). It means that the present value marginal utility must equal the marginal value of the physical capital.

\[ \frac{\partial H}{\partial c} = c^{-\sigma} e^{-\rho} - \lambda = 0 \rightarrow c^{-\sigma} e^{-\rho} = \lambda \] \hspace{1cm} \text{(2-20)}

By differentiating equation (2-19) with respect to \( k \) (state variable), we obtain equation (2-21).

\[ \frac{\partial H}{\partial k} \Rightarrow \lambda(f'(k) - \delta) = -\dot{\lambda} \] \hspace{1cm} \text{(2-21)}

We need equation (2-22) as a transversality condition; it means that there will exist an optimal solution.
\[
\lim_{t \to \infty} \lambda(t)k(t) = 0 \tag{2-22}
\]

From equation (2-21), we get equation (2-23)

\[
(f'(k) - \delta) = -\frac{\dot{\lambda}}{\lambda} \tag{2-23}
\]

Logarithm equation (2-20) and differentiating with respect to time, we obtain equation (2-24). We can also put equation (2-23) into equation (2-24) and get the common growth rate from the expression for consumption.

\[
\frac{\dot{c}}{c} = -\frac{\dot{\lambda}}{\lambda} \rho = \frac{f'(k) - \delta - \rho}{\sigma} \tag{2-24}
\]

From equation (2-4), we obtain equation (2-25)

\[
\frac{\dot{k}}{k} = \frac{f(k) - \partial k - c}{k} \tag{2-25}
\]

Together with equation (2-18) and equation (2-25), and in social planner optimal equilibrium, \( k = k_a \). We obtain equation (2-26)

\[
-\frac{c}{k} \frac{\dot{k}}{k} = A(1 + \theta_1)(1 + \theta_2)^{1-a} \left(\frac{k_a}{k}\right)^{1-a} + \delta = \frac{\dot{k}}{k} - A(1 + \theta_1)(1 + \theta_2)^{1-a} + \delta \ldots(2-26)
\]

In the steady state, the growth rate of per person capital \( \frac{\dot{k}}{k} \) is a constant value. \( A, \delta, \theta_1 \) and \( \theta_2 \) are all exogenous variables and also constant. Therefore, the right side of equation (2-26) for \( \frac{c}{k} \) is constant. With logarithm equation (2-26) and differentiating with respect to time, we get equation (2-27). The rate of change in consumption equals the rate of change in physical capital.

\[
\frac{\dot{c}}{c} = \frac{\dot{k}}{k} \tag{2-27}
\]

The production function \( y = A(1 + \theta_1)(1 + \theta_2)^{1-a} k \), \( \theta_1, \theta_2 \) and \( \alpha \) are all exogenous.
variables, thus, \( \frac{\dot{k}}{k} = \frac{\dot{y}}{y} \). Because the rate of change in output equals the rate of change in physical capital, we know that the rate of change in output is equal to the rate of change in physical capital and consumption.

\[
\frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \frac{\dot{y}}{y} \hspace{1cm} \text{(2-28)}
\]

Hence, we can obtain the growth rate in a country with large firms as equation (2-29)

\[
\frac{\dot{y}}{y} = \frac{f'(k) - \delta - \rho}{\sigma} = \frac{A(1 + \theta_1)(1 + \theta_2)^{1-a} - \delta - \rho}{\sigma} \hspace{1cm} \text{(2-29)}
\]

If \( A\alpha(1+\theta_1)(1+\theta_2)^{1-a} > \delta + \rho \), we obtain a positive growth rate in this model.

### 2.3.3 The hybrid firm

In this chapter, we assume the production function in large firms is

\[
y = f(k, k_a) = A(1 + \theta_1)k^\alpha [(1 + \theta_2)k_a]^{1-\alpha}
\]

and production function in small firms is

\[
y = f(k, k_a) = Ak^\alpha k_a^{1-\alpha}
\]

In this model, we assume that physical capital is homogeneous, no matter what the firm’s scale is. It means one unit physical capital in both production functions has the same productivity.

Suppose we combine a large firm and a small firm into a new firm. The proportion of large firms is \( \lambda_i \). The proportion of small firms is \( 1 - \lambda_i, 0 < \lambda_i < 1 \).

According to Felipe (2006), we can set up the new production function such as
\[
y = \lambda_t A(1 + \theta_1)k^\alpha [(1 + \theta_2)k_a]^{1-\alpha} + (1 - \lambda_t)Ak^\alpha k_a^{1-\alpha} \\
= Ak^\alpha k_a^{1-\alpha} [\lambda_t (1 + \theta_1) (1 + \theta_2) (1-\alpha) + (1 - \lambda_t)]
\]

Now that we have the production function of a hybrid firm, we can use the previous assumption to calculate the growth rate of a country with a representative hybrid firm. The other assumptions are the same as in the previous subsections:

The present value Hamiltonian for the representative household’s optimization is illustrated by:

\[
H = \frac{c^{1-\sigma}(t)-1}{1-\sigma} e^{-\rho t} + \lambda(k) \text{......................(2-31)}
\]

After differentiating equation (2-31) with respect to \(c\), we get equation (2-32).

It means that the present value marginal utility must equal the marginal value of the physical capital.

\[
\frac{\partial H}{\partial c} = c^{-\sigma}e^{-\rho t} - \lambda = 0 \rightarrow c^{-\sigma}e^{-\rho t} = \lambda \text{ ..............(2-32)}
\]

Differentiating equation (2-31) with respect to \(k\), we obtain equation (2-33).

\[
\frac{\partial H}{\partial k} \Rightarrow \lambda(f'(k) - \delta) = -\lambda \text{ .........(2-33)}
\]

We also need equation (2-34) as a transversality condition; it means that there will exist an optimal solution.

\[
\lim_{t \to \infty} \lambda(t)k(t) = 0 \text{......................(2-34)}
\]

From equation (2-33), we get equation (2-35)

\[
(f'(k) - \delta) = -\frac{\lambda}{\dot{\lambda}} \text{.............(2-35)}
\]

Logarithm equation (2-32) and differentiating with respect to time, we get equation (2-36). We can also put equation (2-35) into equation (2-36) and get the common growth rate from the expression for consumption.

\[
\frac{\dot{c}}{c} = -\frac{\lambda}{\dot{\lambda}} - \rho = \frac{f'(k) - \delta - \rho}{\sigma} \text{...............(2-36)}
\]
From previous equation (2-4), we obtain equation (2-37)

$$\frac{\dot{k}}{k} = \frac{f(k) - \delta k - c}{k} \quad \text{……………………………(2-37)}$$

We know all firms are identical. In the social planner optimal equilibrium,

$$k = k_a.$$  \hspace{1cm} \text{(2-38)}

Together with equation (2-30) and (2-37),

$$-\frac{c}{k} = \frac{\dot{k}}{k} - A[\lambda_1 (1 + \theta_1)(1 + \theta_2)^{1-a} + (1 - \lambda_1) + \delta] \quad \text{………(2-38)}$$

In the steady state, all variables grow at constant rates. The growth rate of capital per person is constant. \(A, \delta, \theta_1, \theta_2\) and \(\lambda_1\) are all exogenous variables and also constant. Therefore, the right side of equation (2-38) for \(\frac{c}{k}\) is constant. With logarithm equation (2-38) and differentiating with respect to time, we obtain equation (2-39). The rate of change in consumption equals the rate of change in the physical capital.

$$\frac{\dot{c}}{c} = \frac{\dot{k}}{k} \quad \text{…………………………(2-39)}$$

Given \(y = A[\lambda_1 (1 + \theta_1)(1 + \theta_2)^{1-a} + (1 - \lambda_1)]k\), it also follows \(\frac{\dot{k}}{k} = \frac{\dot{y}}{y}\). Because the rate of change in output equals to the rate of change in physical capital, we know that the rate of change in output equals the rate of change in physical capital and consumption.

$$\text{Then} \quad \frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \frac{\dot{y}}{y} \quad \text{………………(2-40)}$$

Hence, we can induce the growth rate in a country with small and large firms as equation (2-41)
\[ \frac{\dot{y}}{y} = \frac{A [\lambda_1 (1 + \theta_1)(1 + \theta_2) + (1 - \lambda_1)] - \delta - \rho}{\sigma} \ldots (2-41) \]

Because the parameters are exogenous variables and they are the same among these countries, we can compare the growth rate between these three countries.

Country A (large firms): \[ \frac{\dot{y}}{y} = \gamma_L = \frac{A(1 + \theta_1)(1 + \theta_2)^{1-a} - \delta - \rho}{\sigma} \]

Country B (small firms): \[ \frac{\dot{y}}{y} = \gamma_S = \frac{A - \delta - \rho}{\sigma} \]

Country C (hybrid firms): \[ \frac{\dot{y}}{y} = \gamma_M = \frac{A[\lambda_1 (1 + \theta_1)(1 + \theta_2)^{1-a} + (1 - \lambda_1)] - \delta - \rho}{\sigma} \]

Because \((1 + \theta_1)(1 + \theta_2)^{1-a} > 1\), we know \(\gamma_L > \gamma_M\) and \(\gamma_M > \gamma_S\).

Accordingly, we get the result that reveals the growth rate is positively correlated between the scale of the internal effect and the external effect. Although the internal effect and the external effect are exogenous variables, they could make a difference between those countries. If a country has more large firms, a higher growth rate will exist.

Second, the ratio of large firms \(\lambda_1\) can determine the growth rate in this model. The larger \(\lambda_1\) in a country is, the higher the growth rate it has.

### 2.3.4 Transitional dynamic in one-sector

Transitional dynamic is a process that every variable converge to its stable point. When one-sector model attains long-term equilibrium (i.e., balanced growth path), it means the rate of change in consumption per labor equals the rate of change in the physical capital per labor.
\[
\frac{\dot{c}}{c} = \frac{1}{\sigma} \frac{\dot{\lambda}}{\lambda} - \rho = \frac{A - \delta - \rho}{\sigma} = \frac{\dot{k}}{k} \quad \text{(2-42)}
\]

Here the inverse of the elasticity of intertemporal substitution \( \sigma \) must be large than 0. If \( A > \delta + \rho \), then the economy will grow up continually until the parameters change. Therefore, the situation \( \frac{\dot{c}}{c} = 0 \) does not exist. If some parameters changed, the growth rate will change from one value to another one suddenly. In consequence, in one-sector model (i.e. AK Model\(^5\)), there does not exist transitional dynamic. We will talk about and solve the problem in chapter 3.

In the social planner equilibrium solution, we take the economy wide stock \((k_a)\) as one of the production factors. The representative firm’s capital equals the economy wide stock \((k_k = k)\). If a country has a higher ratio of large firms, the firms would enjoy the higher positive internal effect \((\theta_1)\) and the positive external effect \((\theta_2)\) in the production function. Although the internal effect \((\theta_1)\) and the external effect \((\theta_2)\) are exogenous variables, we do not know what the real values of the exogenous variables are. Nevertheless, we get an important result in this model. If a country has a larger percentage of large firms, it will create a higher economic growth rate.

In addition, the proportion of large firms \(\lambda_i\) can also influence the growth rate in this model. It is beneficial to economic growth with a larger \(\lambda_i\).

In this chapter, the variables that could affect economic growth are all exogenous variables, it means the firms could not do anything (e.g. innovation) or government could not formulate any policy to promote the economic growth. It seems to be a disadvantage to use this model, even the ratio of large firms and the external effect is beneficial to economic growth. We would solve this problem in chapter 3.

\(^5\) The first economist to use a production function of the AK type was von Neumann(1937)
Chapter 3  Two-Sector Models (exogenous variable)

3.1 Introduction

In chapter 2, the one-sector model has confirmed that a country with more large firms will have a higher growth rate. But in the one-sector model, there exists only one physical capital sector and we cannot find the transitional dynamics. Now we would like to modify the model by adding a human capital sector to the production function.

Uzawa (1964) and Lucas (1988) both stated that the accumulation of human capital could raise economic growth. For instance, the workers can enhance their skill through accumulated work experience. It is also called ‘Learning by doing’. Lau (1994) stated that the physical capital and the human capital are substitutable. The human capital can slow down the effect of decreasing return to scale in the physical capital. Romer (1990) and Rebelo (1991) illustrated that the human capital is a reproduction factor in the production function, and most of the human capital does not show decreasing return to scale.

The basic model in this chapter will adopt the Uzawa (1965), Lucas (1988) and Rebelo (1991) approach. Aside from the physical capital in the goods sector, we add human capital in this model. It means that there are two-sectors in a country. One sector produces the physical capital and the other sector produces the human capital. We can image that the first sector is a factory and the second sector is the school.

If we add the human capital into the production function, the human capital should be beneficial to production process. For instance, the workers with higher levels of education can apply their knowledge in the production process. They can pass on their skill to other co-laborers (i.e., the spillover effect) and make other firms produce more efficiently.
3.2 The production function of firms

In this chapter, we assume the physical production function in the representative large firm is

\[ y = f(k, k_a) = A(1 + \theta_1)k^\alpha[(1 + \theta_2)k_a^\beta (uh)^{1-\alpha-\beta} \]

and physical production function in the representative small firm is

\[ y = f(k, k_a) = Ak^\alpha k_a^\beta (uh)^{1-\alpha-\beta} \]

In this model, we also define that physical capital \( k \) have the same quality. No matter what the scale of firms is, the quality of physical capital is always identical. It means one unit physical capital in both production functions has the same utility.

Suppose there exist the large firms and small firms in a country in the meantime. The proportion of large firms is \( \lambda_1 \). The proportion of small firms is \( 1 - \lambda_1, 0 < \lambda_1 < 1 \).

In reference to Felipe (2006), we can suppose the new production function is as follows:

\[ y = \lambda_1 A(1 + \theta_1)k^\alpha[(1 + \theta_2)k_a^\beta (uh)^{1-\alpha-\beta} + (1 - \lambda_1)Ak^\alpha k_a^\beta (uh)^{1-\alpha-\beta} \]

Now that we have the production function of representative firm, we can use the previous assumption to calculate the growth rate in a country.

3.3 The basic model

Consider a closed economy consisting of a representative household and a skill training unit (i.e., the education sector). The representative household is also the producer of a single commodity (i.e., the goods sector), and the skill training unit produces only human capital. For convenience’s sake, there are merely two kinds of firms in this world. There exist large firms and small firms in a country and both of

---

\[ ^6 \text{In this chapter, we still assume only large firms have internal and external effects.} \]
them will form a new company. The ratio of large firms is $\lambda_i$ and the ratio of small firms is $1 - \lambda_i$. We can imagine that the large firm merge the small firm to form a new firm and they keep their own production function. The large firm has the share $\lambda_i$ of the new firm and the small firm has the share $1 - \lambda_i$ of the new firm. Hence, they can combine the two different production functions to a single production function that depends on the number of shares they have. The other assumptions are the same as in chapter 2. There is no government in our model. It means that there is no tax and subsidy in this economic system and international trade is not allowed for.

The two-sectors will be referred to as the goods sector and education sector. There are two reproducible factors in production. One is the physical capital (K), and the other is the human capital (Q). Human capital is used in goods sector and education sector. The physical capital is only used in goods sector, because we assume the process of production in human capital only depends on the quantity of human capital the representative firm used, and it makes it easier to solve the equations below.

### 3.3.1 The representative household

The main assumption is the same as in chapter 2. There exists a representative household in each economy, in which the representative household is the producer of goods. A representative household with an infinite planning horizon is assumed in this model. Moreover, the labor supply in the representative household is fixed (i.e., the number of workers is constant). It means that there is no birth and death in the representative household and the number of household stays constant. The household is postulated to choose its private level of consumption to maximize the discounted sum of future instantaneous utilities:
Max \( U = \int_{0}^{\infty} e^{-\rho t} \mu(c(t))Ldt \) and \( \mu(c(t)) = \frac{c^{1-\sigma}(t)-1}{1-\sigma} \)

In the function above, \( U \) is the utility function and \( \rho \) is the subjective time preference rate. \( c \) is the consumption, \( L \) is the number of labor and \( \sigma \) is the inverse of the elasticity of intertemporal substitution which measures the curvature of the utility function.

### 3.3.2 The production function in the goods sector

We follow the assumptions by Rebelo (1991) and modify some setup. The production function in the goods sector is assumed to be

\[
y = f(k, k_a, h) = A[\lambda_1(1+\theta_1)(1+\theta_2) + (1-\lambda_1)](k)^\alpha k_a^\beta (uh)^{1-\alpha-\beta} \ldots (3-1)
\]

where \( y \) is the output per unit of labor, \( k \) is the physical capital of representative firm, \( k_a \) is the other firm’s average capital (also called average economy wide capital stock), and \( h \) is the human capital per unit of labor. \( \theta_1 \) is the size of the internal effect of the firm\(^7\); \( \theta_2 \) is the size of the external effect of the firm. \( A \) is the basic technology level. \( \alpha \) is the share of a firm’s capital in the production function, while \( \beta \) is the share of the average economy wide capital stock. \( 1-\alpha-\beta \) is the share of human capital in the production function. \( u \) is the proportion of total human capital input in the goods sector.

The production function exhibits diminishing returns to scale with \( k \). However, when \( \theta_1 \) and \( \theta_2 \) is larger than zero, there exists constant or increasing returns to scale.

If there are only small firms, in social planner equilibrium solution the equation (3-1) will become

\(^7\) Different internal effects exist with different \( \theta_1 \). The value of \( \theta_1 \) is related with the scale of firm positively.
\[ y = f(k, h) = A(k)^{\alpha+\beta} (uh)^{1-\alpha-\beta} \]

and the result is just as Lucas (1988) has reported, and we do not discuss the condition without internal and external effects here.

### 3.3.3 The production function in education sector

We follow the assumptions by Uzawa (1965) and Lucas (1988) and apply their setup in the human capital. The production function in the education sector is assumed to be

\[ Q = B(1-u)h \quad \text{(3-2)}, \]

where \( h \) is the human capital per unit of labor and used in the physical sector and education sector, but \( k \) is not productive in the education sector. \( Q \) is the output in education sector. \( B \) is exogenous knowledge level. To simplify our calculation, we assume \( B \) is the same in each country. \( 1-u \) is the proportion of the total human capital used in the education sector.

### 3.3.4 The investment and education production function

In the aspects of physical investment, the representative household does not save. The output deducts to consumption and depreciation and the rest of the output will be devoted to the next period.

The physical capital accumulation constraint of firm is

\[ \dot{k} = f(k) - c - \delta k \quad \text{(3-3)} \]

In the aspects of education production, new human capital for the next period equal to the average output in education sector deducts depreciation.

\[ \dot{h} = Q - \delta h \quad \text{(3-4)} \]
where $\delta$ is depreciation rate and an over dot denotes the time derivative.

In this chapter, in order to find the Pareto optimality, we try to find the solution in “social planner equilibrium solution”.

### 3.4 The social planner optimal solution in two-sector models

As in chapter 2, the number of labor is $L$ and keeps constantly equal to 1.

$$L(t) = L = 1$$

where $U$ is the overall utility of household and is supposed to be the constant intertemporal elasticity of substitution

$$\max U = \int_0^\infty e^{-\eta t} \mu(c(t)) L dt$$

$$\mu(c(t)) = \frac{e^{1-\sigma}(t) - 1}{1 - \sigma}$$

$\mu$ is the utility function of consumption and it is assumed to satisfy the Inada conditions.

$$\lim_{C \to 0} \mu'(c) = \infty, \lim_{C \to \infty} \mu'(c) = 0$$

The present value Hamilton equation for the representative household’s optimization is illustrated by

$$H = \frac{e^{1-\sigma}(t) - 1}{1 - \sigma} e^{-\sigma t} + \dot{\lambda}(k) + \phi(h) \ldots \ldots \ldots \ldots \ldots (3-5)$$

where $\lambda$ and $\phi$ are constant variables of the physical capital and human capital, and it also means the shadow price between $k$ and $h$.

In the social planner optimal equilibrium solution, all firms are identical. Thus, the other firm’s average capital (average economy wide capital stock) equals the capital of the representative firm ($k = k_a$).

After differentiating with respect to $c$ (control variable), we obtain equation (3-6). It means that the present value marginal utility must equal the marginal value of physical capital.

---

Here we assume the social planner is a decision maker who maximizes the social welfare and achieves the best result for all conditions involved. The result will be on Pareto optimality.
\[
\frac{\partial H}{\partial c} = e^{-\alpha} e^{-\beta} - \lambda = 0 \rightarrow e^{-\alpha} e^{-\beta} = \lambda \quad \text{.........................(3-6)}
\]

Equation (3-5) differentiating with respect to \( u \), we obtain equation (3-7)

\[
\frac{\partial H}{\partial u} = \lambda A(1-\alpha-\beta)[\lambda_i(1+\theta_1)(1+\theta_2)^\beta + (1-\lambda_i)]k^{\alpha+\beta} h^{\lambda-\alpha-\beta} u^{-\alpha-\beta} - \phi h = 0 \quad \text{........(3-7)}
\]

Equation (3-5) differentiating with respect to \( k \) and \( h \) (state variable), we obtain equations (3-8) and (3-9).

\[
\frac{\partial H}{\partial k} \Rightarrow \lambda A(\alpha + \beta)[\lambda_i(1+\theta_1)(1+\theta_2)^\beta + (1-\lambda_i)]u^{1-\alpha-\beta} h^{\lambda-\alpha-\beta} k^{\frac{\alpha+\beta-1}{\alpha}} = -\dot{\lambda}
\]

\quad \text{........(3-8)}

\[
\frac{\partial H}{\partial h} \Rightarrow \lambda A(1-\alpha-\beta)[\lambda_i(1+\theta_1)(1+\theta_2)^\beta + (1-\lambda_i)]k^{\alpha+\beta} u^{1-\alpha-\beta} h^{-\alpha-\beta} + \phi[B(1-u) - \delta] = -\dot{\phi}
\]

\quad \text{........(3-9)}

From equation (3-8), we obtain equation (3-10)

\[
\frac{\dot{\lambda}}{\lambda} = -(A(\alpha + \beta)[\lambda_i(1+\theta_1)(1+\theta_2)^\beta + (1-\lambda_i)]u^{1-\alpha-\beta} h^{\lambda-\alpha-\beta} k^{\frac{\alpha+\beta-1}{\alpha}} - \delta) \quad \text{........(3-10)}
\]

From equations (3-3) and (3-4), we obtain equations (3-11)(3-12)

\[
\frac{\dot{k}}{k} = A[\lambda_i(1+\theta_1)(1+\theta_2)^\beta + (1-\lambda_i)k^{\alpha+\beta-1}(uh)^{1-\alpha-\beta} - \frac{c}{k} - \delta \quad \text{............(3-11)}
\]

\[
\frac{\dot{h}}{h} = B(1-u) - \delta \quad \text{..........................(3-12)}
\]

We need equations (3-12.1) and (3-12.2) as a transversality condition, and it means that there will exist an optimal solution.

\[
\lim_{t \to \infty} \lambda(t) k(t) = 0 \quad \text{.........................(3-12.1)}
\]

\[
\lim_{t \to \infty} \phi(t) h(t) = 0 \quad \text{.........................(3-12.2)}
\]
Together with equations (3-6) and (3-10), we get equation (3-13).

\[
\frac{\dot{c}}{c} = A(\alpha + \beta)[\lambda_1(1 + \theta_1)(1 + \theta_2)^\beta + (1 - \lambda_1)]u^{1-\alpha-\beta}h^{1-\alpha-\beta}k^{\alpha+\beta-1} - \delta - \rho \quad \ldots \ldots (3-13)
\]

In the balanced growth path, all variables grow at the same speed. The growth rate of consumption is equal to the growth rate of physical capital.

### 3.5 Transitional dynamics and numerical methods

A steady state is the state where all variables grow at a constant rate. When all variables grow up at a constant rate (Balanced growth path), the growth rate of variable \( c \) equals that of variable \( k \) and variable \( h \).

\[
\frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \frac{\dot{h}}{h}
\]

Then we define \( z = \frac{h}{k} \), \( x = \frac{c}{k} \),

where \( z \) is the proportion of human capital and physical human, and \( x \) is the proportion of consumption and physical human. Because \( h \), \( c \) and \( k \) grow at a common speed, the growth rate of \( z \) and \( x \) is equal to zero. Accordingly, we can find the transitional dynamics in this model.

Equations (3-11), (3-12) and (3-13) taken together, we obtain equations (3-14) and (3-15)

\[
\frac{\dot{z}}{z} = \frac{\dot{h}}{h} - \frac{\dot{k}}{k} = B(1 - u) - \delta - A \left[ \lambda_1 (1 + \theta_1)(1 + \theta_2)^\beta + (1 - \lambda_1) \right] k^{\alpha+\beta-1}(uh)^{\lambda-\alpha-\beta} - \frac{c}{k} - \delta
\]

\[
= B(1 - u) - A \left[ \lambda_1 (1 + \theta_1)(1 + \theta_2)^\beta + (1 - \lambda_1) \right] k^{\alpha+\beta-1}(uh)^{\lambda-\alpha-\beta} + \frac{c}{k}
\]

\[
= B(1 - u) - A \left[ \lambda_1 (1 + \theta_1)(1 + \theta_2)^\beta + (1 - \lambda_1) \right] z^{1-\alpha-\beta}u^{\lambda-\alpha-\beta} + x
\]

\[
\ldots \ldots (3-14)
\]
\[
\begin{align*}
\dot{x} & = \frac{c}{k} \left( \lambda_1 (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) k^{\alpha+\beta} h^{\alpha-\beta} u^{\alpha-\beta} - \frac{c}{k} \right) \\
& = \frac{A}{B} \left[ \lambda_1 (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) k^{\alpha+\beta} h^{\alpha-\beta} u^{\alpha-\beta} \right] \left[ \Delta (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) z^{1-\alpha-\beta} - x \right] \\
& = \frac{\lambda}{\phi} A \left[ \lambda_1 (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) k^{\alpha+\beta} (1 - \beta) u^{1-\alpha-\beta} h^{\alpha-\beta} + [B(1 - u) - \delta] \right] = -\frac{\phi}{\phi} \dot{x} \\
& \text{(3-17)}
\end{align*}
\]

Equations (3-7) and (3-9), we obtain equation (3-16) and (3-17)

\[
\begin{align*}
\dot{x} & = \frac{c}{k} \left( \lambda_1 (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) k^{\alpha+\beta} h^{\alpha-\beta} u^{\alpha-\beta} (1 - \alpha - \beta) \right) = \frac{\phi}{\lambda} \\
& \Rightarrow \frac{A}{B} \left[ \lambda_1 (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) z^{\alpha-\beta} u^{\alpha-\beta} (1 - \alpha - \beta) \right] = \frac{\phi}{\lambda} \\
\end{align*}
\]

Equations (3-16) and (3-17) put together is equation (3-18)

\[
\begin{align*}
\dot{x} & = -\frac{\phi}{\phi} \dot{x} \\
\text{(3-18)}
\end{align*}
\]

By taking logarithms in equation (3-16) and differentiating with respect to time, we obtain equation (3-19)

\[
\begin{align*}
\frac{\phi}{\phi} \frac{\lambda}{\lambda} = - (\alpha + \beta) \frac{\dot{u}}{u} - (\alpha + \beta) \frac{\dot{z}}{z} \\
\text{(3-19)}
\end{align*}
\]

Finally,

\[
\begin{align*}
\frac{\dot{u}}{u} & = - \frac{1}{\alpha + \beta} \left[ \frac{\phi}{\phi} \frac{\lambda}{\lambda} \right] \frac{\dot{z}}{z} \\
& = - \frac{1}{\alpha + \beta} \left[ -B + \delta + A (\alpha + \beta) \left[ \lambda_1 (1 + \theta_1) (1 + \theta_2)^\beta + (1 - \lambda_1) u^{1-\alpha-\beta} z^{1-\alpha-\beta} \right] \right] \left[ B(1 - u) - \delta \right] \left[ B(1 - u) - x \right] \\
& = \frac{B}{\alpha + \beta} - B(1 - u) - x
\end{align*}
\]
Now we have the change rate of $z$, $x$ and $u$. When all variables are in a steady state, the change rates of those variables are equal to zero. The steady state of this system can be found by setting the three time derivatives equations 
\[
\begin{align*}
\dot{x} &= u = \frac{z}{x} = 0
\end{align*}
\]
to zero.

The results are as follows:

\[
\mu^* = \frac{\rho - (1-\sigma)(B-\delta)}{B\sigma}
\]

\[
z^* = \frac{A(\alpha + \beta)^2 g[B[1 + (\alpha + \beta - 1)\sigma] - \rho + \delta(\sigma - 1)] - \sigma B^2}{gA(\alpha + \beta)[\delta(\sigma - 1) + [(\alpha + \beta - 1)\sigma + 1]B - \rho]}
\]

\[
x^* = \frac{B}{\alpha + \beta} + \frac{\rho + \delta - B}{\sigma} - \delta
\]

Here we denote $g = \lambda_1 (1 + \theta_1)(1 + \theta_2)^\beta + (1 - \lambda_1)$.

From these equations above, we would like to estimate the influence of internal and external effects on the growth rate in physical capital and consumption and calculate the real values of them.

In order to explain the influence of internal and external effects on the growth rate, we use some numerical methods to calculate it. In terms of the value of other parameters, we adapt the assumptions from Lucas (1988) and Benhabib (1994). $\rho$ is the discount rate of time at 0.025. $\delta$ is the depreciation rate equal to 0.05. The basic technical levels in both sectors are the same and equal to 1 ($A = B = 1$). $\alpha$ is the coefficient of a firm's capital in the production function at 0.4, whereas $\beta$ is the coefficient of average economy wide capital stock at 0.2. $\sigma$ is the inverse of the constant intertemporal elasticity of substitution at 5. We take the real value from Taiwan about the ratio of large firms $\lambda_1$, and it is about 3 percent.
Table 3-1 The relationship between internal, external effects and growth rate (B=1)

<table>
<thead>
<tr>
<th></th>
<th>α</th>
<th>β</th>
<th>σ</th>
<th>ρ</th>
<th>δ</th>
<th>θ₁</th>
<th>θ₂</th>
<th>(\frac{c}{c})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2638</td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>1</td>
<td>1</td>
<td>0.2699</td>
</tr>
<tr>
<td>2</td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.5</td>
<td>0.2642</td>
</tr>
<tr>
<td>3</td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.5</td>
<td>0.1</td>
<td>0.2659</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>1</td>
<td>0.1</td>
<td>0.2646</td>
</tr>
<tr>
<td>5</td>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td>0.2632</td>
</tr>
</tbody>
</table>

Note: \(A=1, B=1, \lambda_i=0.03\)

From Table 3-1, we observe the influence of the internal effect \(\theta_1\) and external effect \(\theta_2\) on economic growth. The internal effect \(\theta_1\) has a slightly stronger effect on the economic growth than the external effect \(\theta_2\). If the value of the internal effect \(\theta_1\) increases by 0.1, the growth rate will rise by 0.00052. If the value of the external effect \(\theta_2\) increases by 0.1, the growth rate will grow by 0.0001.

If we assume \(B=0.5\), we obtain the same result. The internal effect \(\theta_1\) also has a weak stronger effect on the economic growth than the external effect \(\theta_2\). However, the scale of influence of internal effect will be different. If the value of the internal effect \(\theta_1\) increases by 0.1, the growth rate will rise by 0.0007. If the value of the external effect \(\theta_2\) increases by 0.1, the growth rate will grow by 0.0001. Thus, the internal effect will have larger effects on growth rate, when a country has a higher knowledge level. The internal effect has almost 7 time stronger effect on the growth
rate than the external effect

Table 3-2 The relationship between internal, external effects and growth rate (B=0.5)

<table>
<thead>
<tr>
<th>α</th>
<th>β</th>
<th>σ</th>
<th>ρ</th>
<th>δ</th>
<th>θ₁</th>
<th>θ₂</th>
<th>( \frac{c}{c} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2161</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>1</td>
<td>1</td>
<td>0.2242</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.5</td>
<td>0.2165</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.5</td>
<td>0.1</td>
<td>0.2189</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>1</td>
<td>0.2170</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2224</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td>0.2153</td>
</tr>
</tbody>
</table>

Note: \( A = 1, B = 0.5, \lambda_1 = 0.03 \).

By the simulation process, we know higher external and internal effects will lead to a higher growth rate. If we keep the external and internal effect constant, we can discuss the influence of the ratio of large firm in economic growth.

From Table 3-3, we observe the influence of the ratio of large firms \( \lambda_i \) on economic growth. If a country has a higher proportion of large firms, the country will have higher economic growth. When the ratio of large firms \( \lambda_i \) decreases by 0.1, the growth rate will decline by 0.0018.
Table 3-3 The relationship between the ratio of large firms and growth rate (B=1)

<table>
<thead>
<tr>
<th>α</th>
<th>β</th>
<th>σ</th>
<th>ρ</th>
<th>δ</th>
<th>λ₁</th>
<th>1 - λ₁</th>
<th>c²/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>1</td>
<td>0</td>
<td>0.2838</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.9</td>
<td>0.1</td>
<td>0.2817</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.7</td>
<td>0.3</td>
<td>0.2772</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2736</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.3</td>
<td>0.7</td>
<td>0.2694</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.9</td>
<td>0.2653</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0</td>
<td>1</td>
<td>0.2632</td>
</tr>
</tbody>
</table>

Note: \( A = 1, B = 1, \theta_1 = 0.1, \theta_2 = 0.1. \)

In Table 3-4, we assume \( B = 0.5 \), it means that now this country has a lower knowledge level and we can compare the result with Table 3-3. We just change the value of \( B \) from 1 to 0.5 and keep other parameters at the same value.

We get the similar results as in Table 3-4. A higher proportion of large firms will lead to higher economic growth. When the ratio of large firms \( \lambda_1 \) increases by 0.1, the growth rate will rise by 0.0017.

The economic growth rates in Table 3-4 are smaller than Table 3-3, because the knowledge level in Table 3-4 is low. Therefore, even if the higher ratio of large firms can be beneficial to economic growth, the knowledge level still plays an important role.
Table 3-4 The relationship between the ratio of large firms and growth rate (B=0.5)

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\sigma$</th>
<th>$\rho$</th>
<th>$\delta$</th>
<th>$\lambda_i$</th>
<th>$1-\lambda_i$</th>
<th>$\frac{c}{c^*}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>1</td>
<td>0</td>
<td>0.2329</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.9</td>
<td>0.1</td>
<td>0.2312</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.7</td>
<td>0.3</td>
<td>0.2278</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2243</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.3</td>
<td>0.7</td>
<td>0.2208</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0.1</td>
<td>0.9</td>
<td>0.2173</td>
</tr>
<tr>
<td>0.4</td>
<td>0.2</td>
<td>5</td>
<td>0.025</td>
<td>0.05</td>
<td>0</td>
<td>1</td>
<td>0.2155</td>
</tr>
</tbody>
</table>

Note: $A = 1, B = 0.5, \theta_1 = 0.1, \theta_2 = 0.1.$

Now we will investigate the stability properties of the balanced growth paths (BGPs) and describe the region in the parameter space, which yields unique and indeterminate equilibrium.

Benhabib and Perli (1994) stated a special way to judge how many roots with positive real parts in a matrix. We adopt this method to calculate the number of roots with positive real parts and analyze the situation. For example, if

$$J^* = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

, the characteristic values of $J^*$ are the solutions of its characteristic equation
\[- \lambda^3 + Tr J^* \lambda^2 - BJ^* \lambda + Det J^* = 0 , \]

where

\[
BJ^* = \begin{bmatrix}
a_{11} & a_{12} \\
a_{21} & a_{22}
\end{bmatrix} + \begin{bmatrix}
a_{22} & a_{23} \\
a_{32} & a_{33}
\end{bmatrix} + \begin{bmatrix}
a_{11} & a_{13} \\
a_{31} & a_{33}
\end{bmatrix}
\]

\[
Tr J^* = a_{11} + a_{22} + a_{33}
\]

\[
Det J^* = a_{11} \begin{bmatrix} a_{22} & a_{23} \\ a_{32} & a_{33} \end{bmatrix} - a_{12} \begin{bmatrix} a_{21} & a_{23} \\ a_{31} & a_{33} \end{bmatrix} + a_{13} \begin{bmatrix} a_{21} & a_{22} \\ a_{31} & a_{32} \end{bmatrix}
\]

The number of roots of the polynomial in the characteristic equation with positive real parts is equal to the number of variations of signs in the scheme

\[-1, \text{Trace } J, -BJ+(\text{Det } J/\text{Tr } J) \text{ and Det } J\]

If we calculate how many times the value change from positive to negative between \(-1, \text{Trace } J, -BJ+(\text{Det } J/\text{Tr } J) \text{ and Det } J\), we know the number of positive real roots in the matrix.

For example, the characteristic equation has three roots with positive real parts if \(\text{Trace } J > 0, -BJ+(\text{Det } J/\text{Tr } J) < 0 \text{ and Det } J > 0\), because the sign from the positive to the negative has changed three times.

We know \(z\) is the proportion of human capital and physical human, and that \(x\) is the proportion of consumption and physical human. It means \(z\) and \(x\) are both positive and larger than 0.

From Eq. (3-14), (3-15) and (3-20), we obtain

\[z = B (1 - u) z - A \left[ \lambda_1 (1 + \theta_1) (1 + \theta_2)^{\beta} + (1 - \lambda_1) \right] z^{2 - a - \beta} u^{1 - a - \beta} + xz\]

\[x = \frac{\alpha + \beta - \sigma}{\sigma} A \left[ \lambda_1 (1 + \theta_1) (1 + \theta_2)^{\beta} + (1 - \lambda_1) \right] z^{1 - a - \beta} u^{1 - a - \beta} + x^2 + \frac{\delta (\sigma - 1) - \rho}{\sigma} x\]

\[u = \frac{B}{(\alpha + \beta)} u - B (1 - u) u - xu\]
We use the Jacobian matrix to calculate the characteristic values. First, we compute the Jacobian matrix of the system and obtain

\[
J = \begin{bmatrix}
  J_{11} & J_{12} & J_{13} \\
  J_{21} & J_{22} & J_{23} \\
  J_{31} & J_{32} & J_{33}
\end{bmatrix}
\]

\[
J_{11} = \frac{\partial z}{\partial z} = B(1-\mu) - A(2-\alpha-\beta)[\lambda_{1}(1+\theta_{i})(1+\theta_{z})^{\beta} + (1-\lambda_{1})]z^{-\alpha-\beta}u^{-\alpha-\beta} + x
\]

\[
J_{12} = \frac{\partial z}{\partial \alpha} = z
\]

\[
J_{13} = \frac{\partial z}{\partial \beta} = -Bz - A(1-\alpha-\beta)[\lambda_{1}(1+\theta_{i})(1+\theta_{z})^{\beta} + (1-\lambda_{1})]z^{2-\alpha-\beta}u^{-\alpha-\beta}
\]

\[
J_{21} = \frac{\partial x}{\partial z} = \frac{\alpha + \beta - \sigma}{\sigma} A(1-\alpha-\beta)[\lambda_{1}(1+\theta_{i})(1+\theta_{z})^{\beta} + (1-\lambda_{1})]z^{-\alpha-\beta}u^{-\alpha-\beta}x
\]

\[
J_{22} = \frac{\partial x}{\partial \alpha} = \frac{\alpha + \beta - \sigma}{\sigma} A[\lambda_{1}(1+\theta_{i})(1+\theta_{z})^{\beta} + (1-\lambda_{1})]z^{-\alpha-\beta}u^{-\alpha-\beta} + 2x + \frac{\delta(\sigma-1)-\rho}{\sigma}
\]

\[
J_{23} = \frac{\partial x}{\partial \beta} = \frac{\alpha + \beta - \sigma}{\sigma} A(1-\alpha-\beta)[\lambda_{1}(1+\theta_{i})(1+\theta_{z})^{\beta} + (1-\lambda_{1})]z^{-\alpha-\beta}u^{-\alpha-\beta}x
\]

\[
J_{31} = \frac{\partial u}{\partial z} = 0
\]

\[
J_{32} = \frac{\partial u}{\partial \alpha} = u
\]

\[
J_{33} = \frac{\partial u}{\partial \beta} = \frac{B}{(\alpha + \beta)} + B(2u-1) - x
\]
The Jacobian matrix is huge, and it is very difficult to calculate the result. Since we are interested in the Jacobian matrix evaluated at the equilibrium, we can substitute the steady state values of \( x^* \), \( u^* \) and \( z^* \) in the above matrix, which would lead to an easier method to obtain the result. The matrix can be rewritten as

\[
\begin{align*}
J_{11} &= B(1-u) - A[\lambda_1(1+\theta_1)(1+\theta_2)\gamma + (1-\lambda_1)]x^{1-\alpha-\beta}u^{1-\alpha-\beta} + x - A(1-\alpha-\beta)[\lambda_1(1+\theta_1)(1+\theta_2)\gamma + (1-\lambda_1)]z^{1-\alpha-\beta}u^{1-\alpha-\beta} \\
&= \frac{z}{z} - A(1-\alpha-\beta)[\lambda_1(1+\theta_1)(1+\theta_2)\gamma + (1-\lambda_1)]z^{1-\alpha-\beta}u^{1-\alpha-\beta}
\end{align*}
\]

Because \( \frac{z}{z} = 0 \), on the BGP we have

\[
J_{11}^{*11} \equiv \frac{\partial z}{\partial z} \bigg|_{\text{BGP}} = -A(1-\alpha-\beta)[\lambda_1(1+\theta_1)(1+\theta_2)\gamma + (1-\lambda_1)]z^{1-\alpha-\beta}u^{1-\alpha-\beta}
\]

\[
J_{22} = \frac{\alpha + \beta - \sigma}{\sigma} A[\lambda_1(1+\theta_1)(1+\theta_2)\gamma + (1-\lambda_1)]z^{1-\alpha-\beta}u^{1-\alpha-\beta} + x + \frac{\sigma(\sigma-1)-\rho}{\sigma} + x
\]

Because \( \frac{x}{x} = 0 \), on the BGP we have

\[
J_{22}^{*22} \equiv \frac{\partial x}{\partial x} \bigg|_{\text{BGP}} = x^*
\]

\[
J_{33} = \frac{B}{(\alpha + \beta)} - B(1-u) - x + Bu = \frac{u}{u} + Bu
\]

Because \( \frac{u}{u} = 0 \), on the BGP we have

\[
J_{33}^{*33} \equiv \frac{\partial u}{\partial u} \bigg|_{\text{BGP}} = Bu^*
\]
If we express $J_{13}^*, J_{21}^*$, and $J_{23}^*$ as functions of $J_{11}^*$, as well as relate $J_{22}^*$ to $\dot{\frac{x}{x}}$ and $J_{33}^*$ to $\dot{\frac{u}{u}}$, we can rewrite the Jacobian matrix evaluated at the BGP as

$$J^* = \begin{bmatrix}
  J_{11}^* & z^* & -Bz^* + J_{11}^* \frac{z^*}{u^*} \\
  -\psi J_{11}^* & \frac{x^*}{z^*} & x^* & -\psi J_{11}^* \frac{x^*}{u^*} \\
  0 & u^* & Bu^* & Bz^* + J_{11}^* \frac{z^*}{u^*}
\end{bmatrix}$$

The characteristic values of $J^*$ are the solutions of its characteristic equation

$$-\lambda^3 + TrJ^* \lambda^2 - BJ^* \lambda + DetJ^* = 0,$$

where

$$BJ^* = \begin{bmatrix}
  J_{11}^* & z^* \\
  -\psi J_{11}^* & \frac{x^*}{z^*} \\
  0 & u^* & Bu^*
\end{bmatrix} + \begin{bmatrix}
  x^* & -\psi J_{11}^* \frac{x^*}{u^*} \\
  u^* & Bu^*
\end{bmatrix} + \begin{bmatrix}
  J_{11}^* & 0 \\
  0 & Bu^*
\end{bmatrix}$$

$$= J_{11}^* x^* + 2\psi J_{11}^* x^* + Bx^* u^* + BJ_{11}^* u^*$$

if $\frac{\alpha + \beta - \sigma}{\sigma} = \psi$

$$TrJ^* = J_{11}^* + x^* + Bu^*$$

$$DetJ^* = J_{11}^* Bx^* u^* (1 + 2\psi) + J_{11}^* x^* (\psi - 1)$$

The number of roots of the polynomial in the characteristic equation with positive real parts is equal to the number of signs changed in the scheme

$-1, Trace J, -BJ+(Det J/Tr J)$ and $Det J$

With this method, we can determine the signs of the real parts of the roots of the above characteristic equation.
Condition 1.

$DetJ^*$ is negative if $\sigma < \alpha + \beta < 2\sigma$, while $DetJ^*$ is indeterminate if $\alpha + \beta > 2\sigma$ or $\alpha + \beta < \sigma$.

Consider the $DetJ^* = J_{11}^* Bx^* u^* (1 + 2\psi) + J_{11}^* x^*(\psi - 1)$.

Here $J_{11}^*$ is negative, $(1 + 2\psi)$ is positive and $(\psi - 1)$ is negative while $\sigma < \alpha + \beta < 2\sigma$.

Condition 2.

$BJ^*$ is negative if $\left| x^* \right| < \left| J_{11}^* \right|$; otherwise $BJ^*$ is positive.

Consider the $BJ^* = J_{11}^* x^*(1 + 2\psi) + Bu^*(x^* + J_{11}^*)$.

We assume $\frac{\alpha + \beta - \sigma}{\sigma} = \psi$ and $\alpha + \beta$ is larger than 0. If $0.5\sigma < \alpha + \beta < \sigma$, then $\psi > -0.5$; $\psi > 0$ if $\sigma < \alpha + \beta$; If $2\sigma < \alpha + \beta$, $\psi > 1$.

That means $J_{11}^* x^*(1 + 2\psi) > 0$.

If $\left| x^* \right| > \left| J_{11}^* \right|$, then $Bu^*(x^* + J_{11}^*) > 0$

$BJ^* = J_{11}^* x^*(1 + 2\psi) + Bu^*(x^* + J_{11}^*) > 0$

Condition 3.

$TrJ^*$ is positive if $\left| x^* + Bu^* \right| > \left| J_{11}^* \right|$, while $TrJ^*$ is negative if $\left| x^* + Bu^* \right| < \left| J_{11}^* \right|$

We know $x^* > 0$ and $Bu^* > 0$, hence the sign of $TrJ^*$ is determined by

the absolute value between $x^* + Bu^*$ and $J_{11}^*$

If we can confirm the range of those parameters, we are able to calculate the
number of positive characteristic value in this model. Form the above results, we derive proposition 1, proposition 2 and proposition 3.

Proposition 1:

If \( |J_{11}^*| < |x^*|, \ |x^* + Bu^*| > |J_{11}^*| \) and \( \sigma < \alpha + \beta < 2\sigma \), then \( TrJ^* > 0 \), \( BJ^* > 0 \) and \( 0 < DetJ^* \).

The signs of those variables are

-1, Trace J, -BJ+(Det J/Tr J), Det J
(−) (+) (−) (−)

Proposition 1 has two roots with positive real parts and one root with negative real parts. It means the equilibrium path in this model is a saddle path. There is only one single convergence path.

Proposition 2:

If \( |x^* + Bu^*| < |J_{11}^*|, \ |x^*| > |J_{11}^*| \) and \( \sigma < \alpha + \beta < 2\sigma \), then \( TrJ^* < 0 \), \( BJ^* < 0 \) and \( DetJ^* < 0 \).

The signs of those variables are

-1, Trace J, -BJ+(Det J/Tr J), Det J
(−) (−) (uncertain) (−)

If -BJ+(Det J/Tr J) is negative, there are three roots with negative real parts in proposition 2, and it means all paths are equilibrium paths. If -BJ+(Det J/Tr J) is positive, there is only one root with negative real parts in proposition 2, and it means there exists only one convergence path in this proposition. Hence, there are two possibilities in proposition 2.
Proposition 3:

\[ \text{If } x^* + Bu^* < J_{11}^*, \ |x^*| < |J_{11}^*| \text{ and } \sigma < \alpha + \beta < 2\sigma, \text{ then } TrJ^* < 0, \]

\[ BJ^* > 0 \text{ and } DetJ^* < 0 \]

The signs of those variables are

\[ -1, \ \text{Trace J, } -BJ+ (\text{Det J/Tr J}), \ \text{Det J} \]

\[ (-) \ \ (-) \ \ (\text{uncertain}) \ \ (-) \]

If \(-BJ+ (\text{Det J/Tr J}) > 0\), there are two roots with positive real parts and one root with negative real part in proposition 3. It means the equilibrium path in this model is also a saddle path. If \(-BJ+ (\text{Det J/Tr J}) < 0\), there are not any roots with positive real parts and three roots with negative real parts in proposition 3. The situation is same as proposition 2. Hence, there are also two possibilities in proposition 3. One single convergence path or multiple convergence paths.

Proposition 4: \( DetJ^* \) is indeterminate, if \( \alpha + \beta > 2\sigma \) or \( \alpha + \beta < \sigma \)

In some conditions, the value of \( DetJ^* \) is indeterminate. In order to explain the other conditions, we have to resort to numerical methods.

In terms of the value of parameters, we adapt the assumption from Lucas(1988) and Benhabib (1994). \( \rho \) is the discount rate of time at 0.025. \( \delta \) is the depreciation rate equal to 0.05. The basic technical levels in both sectors are the same and equal to \( 1(A = B = 1) \).
Table 3-5 The situation of character roots

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\sigma$</th>
<th>$\rho$</th>
<th>$\delta$</th>
<th>$\theta_1$</th>
<th>$\theta_2$</th>
<th>Roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.45</td>
<td>0.3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.3</td>
<td>0.45</td>
<td>3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.4</td>
<td>0.35</td>
<td>0.3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.4</td>
<td>0.35</td>
<td>3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.5</td>
<td>0.25</td>
<td>0.3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.5</td>
<td>0.25</td>
<td>3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.6</td>
<td>0.15</td>
<td>0.3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
<tr>
<td>0.6</td>
<td>0.15</td>
<td>3</td>
<td>0.025</td>
<td>0.05</td>
<td>0.01</td>
<td>0.1</td>
<td>-- +</td>
</tr>
</tbody>
</table>

Note: $A=1$ and $B=1$

In the numerical examples of Table 3-5, we know the number of roots with positive real parts and negative real parts. If $\alpha + \beta > 2\sigma$, there always exist two roots with negative real parts and one root with positive real parts. It means there are multiple equilibrium paths. If $\alpha + \beta < \sigma$, there are only one root with negative real parts and two roots with positive real parts. There is a unique equilibrium path in this model.

How could the firms’ scale affect the convergence paths? We could use Fig 3.1 to describe the situation.
The ratio of large firms $\lambda_i$ could determine the value of $J_{11}$, and $J_{11}$ could make the sign of $-BJ+(\text{Det } J/\text{Tr } J)$ to be positive or negative, and finally determine how many convergence paths in this model.

If there are multiple convergence paths in that model, it could explain why two countries had the same economic situation in the beginning and converge to different way in the end.

In fig 3.2, we use Taiwan and Kenya as example. In the initial period, the two countries had same start point $M$ and there are two convergence paths (Path C and path D) could make Taiwan and Kenya converge to their stable point $T$.

The accumulation of human capital on path C is higher than Path D. For some reason, Taiwan chose the path C and Kenya decided the path D. In the process to the
stable point $T$, the value of $Z$ in path C is always higher than path D and it means Taiwan will accumulate more human capital than Kenya in its development process, and the human capital could be used to produce physical capital and more human capital. In the end, even the two countries all converge to their stable point $T$ and the value of $z$ and $x$ are same, the real value of human capital and physical in Taiwan will be larger than Kenya. It perhaps could explain why two countries have different economic situation, even they have similar economic situation in the beginning.

Figure 3-2 The relationship of the multiple convergence paths and economic growth
In this chapter, we extend the one-sector model from chapter 2 to allow for two-sectors. One produces goods to consume and invest, and the other creates human capital. Meanwhile, we put human capital in the production function and observe the relationship between variables and the growth rate. The first result is that a large firm that has a stronger internal effect and external effect can create a higher growth rate, and the internal effect can lead to a higher growth rate than the external effect.

Second, a country with a larger proportion of large firms will create higher economic growth. Nevertheless, the effect is not very strong.

Finally, the stability properties of the transitional dynamics are not identical in each situation. The number of negative roots will be changed with different parameters. There is, at least one negative root in each proposition, and it means this model will converge in different situations. In some conditions, there would exist multiple convergence paths to the steady state and it could explain the differences of economic growth among countries.
Chapter 4  Two-Sector Models (endogenous variable)

4.1 Introduction and the model

In chapter 3, we assume the ratio of large firms $\lambda_i$ is an exogenous variable. It means the small firms cannot do anything to ensure their transformation. Some factors control the process of transformation, but we cannot observe that in the above model.

If we assume that a small firm can do some investment to improve the knowledge of its workforce or technology, it makes the stock of human capital increase and the probability of transforming into a large firm higher. We can imagine the means to this end is, for example, professional training for employees and employers or set up a research department in the company. However, with more investment in technology the firm’s available resource in the goods sector will be lesser. The representative firm must decide on how many percentage of its resource it would devote to improving knowledge and transforming into a large firm. The more the firm spends on education sector, the higher the probability it has to become a big firm. Therefore, we could make $\lambda_i$ as an endogenous variable and calculate the optimal solution.

For the sake of convenience, we assume $\omega$ is the ratio $(0 \leq \omega \leq 1)$ of the human capital that the small firm keeps in goods sector and $1-\omega$ used in education sector to improve its knowledge base or technology. The human capital in goods sector is $\omega h$ and in education sector is $(1-\omega)h$. It is like the firm that has to choose how much of human capital to be used in goods sector to produce physical capital and in education sector to improve human capital.

There exists a positive relationship between the probability of a small firm transforming into a large firm and the ratio of a small firm investing its human capital in education sector. The more human capital in education sector the firm invests, the
higher probability it has for transformation. If the small firm uses all its human capital in education sector, it could become a large firm, but it will not have any human capital used in goods sector and it cannot produce any physical capital. Hence, the small firm has to allocate its human capital and make an optimal decision.

The expected value of a small firm that transforms into a large firm is equal to $1 - \omega$. It means that the probability of small firm staying as $\omega$.

$$0 \leq E(\lambda_1) = 1 - \omega \leq 1 \quad \text{(4-1)}$$
$$0 \leq E(\lambda_2) = \omega \leq 1 \quad \text{(4-2)}$$

Given $\lambda_1 + \lambda_2 = 1$, it means that when we control $\lambda_1$ and the value of $\lambda_2$ is decided, we just need to find the optimal value in one of them. There are many firms in this economic system and all of them are the same. It means the other firms also make the same decision that representative firm made.

And the two-sectors production function could be

$$y = A(\lambda_1(1 + \theta_1)(1 + \theta_2) + \lambda_2)\theta^a k^\beta (\omega h)^{1-a-\beta} \quad \text{(4-3)}$$

$$q = B(1 - \omega)h \quad \text{(4-4)}$$

$y$ is the output in goods sector and $q$ is the output in education sector.

In the aspects of human capital production, new human capital for the next period equal to the average output in education sector deducts depreciation.

$$\dot{k} = f(k) - c - \delta k \quad \text{(4-5)}$$

$$\dot{h} = B(1 - \omega)h - \delta h \quad \text{(4-6)}$$

As the assumption above, the number of labor is $L$ and keeps constantly equal to 1.

$$L(t) = L = 1 \quad \text{(4-7)}$$

where $U$ is the overall utility function of household and is supposed to be constant.
intertemporal elasticity of substitution

$$\max U = \int_0^\infty e^{-\rho t} \mu(c(t)) L dt$$

$$\mu(c(t)) = \frac{c^{1-\sigma}(t) - 1}{1 - \sigma}$$

$\mu$ is the utility function of consumption and it is assumed to satisfy the Inada conditions.

$$\lim_{c \to 0} \mu'(c) = \infty, \lim_{c \to \infty} \mu'(c) = 0 \quad \text{..........................(4-8)}$$

The present value Hamilton equation for the representative household’s optimization is illustrated by

$$H = \frac{c^{1-\sigma}(t) - 1}{1 - \sigma} e^{-\rho t} + \lambda(k) + \phi(h) \quad \text{..........................(4-9)}$$

where $\lambda$ and $\phi$ are constant variables of the physical capital and human capital, and it also means the shadow price between $k$ and $h$.

In the social planner equilibrium solution, all firms are identical. Thus, the other firm’s average capital (average economy-wide capital stock) equals the capital of the representative firm ($k = k_s$).

After differentiating with respect to $c$ (control variable), we obtain equation (4-10). It means that the present value marginal utility must equal the marginal value of physical capital.

$$\frac{\partial H}{\partial c} = c^{-\sigma} e^{-\rho t} - \lambda = 0 \Rightarrow c^{-\sigma} e^{-\rho t} = \lambda \quad \text{..........................(4-10)}$$

Equation (4-9) differentiating with respect to $u$, we obtain equation (4-11). In the beginning, all firms are small firms and $\lambda_1$ is equal to zero.

If we denote $\lambda_1(1 + \theta_1)(1 + \theta_2)^\theta + \lambda_2 = G$, the expected value of $\lambda_1$ is $1 - \omega$. 

52
and the expected value of $\lambda_2$ is $\omega$. There are many identical firms in this economic system. One firm knows there exist a positive relationship between the output in education sector and transforming into a large firm, but it knows just the expected value. Even two identical firms came to the same decision; it does not guarantee the process of transforming will be same. In the beginning, $G$ is like an exogenous variable, because $\lambda_1$ and $\lambda_2$ cannot be decided. The firms make the decision without considering the $\lambda_1$ and $\lambda_2$. Later with all firms making the same decision, we could use the expected value to change the probability to be a certain value.

$$E(\lambda_1) = 1 - \omega \quad \text{and} \quad E(\lambda_2) = \omega.$$  

$$\frac{\partial H}{\partial \omega} = \lambda A(1 - \alpha - \beta) G \omega^{1 - \alpha - \beta} h^{1 - \alpha - \beta} \omega^{-\alpha - \beta} - \phi Bh = 0 \quad \text{.................(4-11)}$$

Equation (4-9) differentiating with respect to $k$ and $h$ (state variable), we obtain equations (4-13) and (4-14).

$$\frac{\partial H}{\partial k} \Rightarrow \lambda A(\alpha + \beta) G \omega^{1 - \alpha - \beta} h^{1 - \alpha - \beta} k^{\alpha + \beta - 1} - \delta) = -\lambda \quad \text{.................(4-13)}$$

$$\frac{\partial H}{\partial h} \Rightarrow \lambda A(1 - \alpha - \beta) Gk^{\alpha + \beta} \omega^{1 - \alpha - \beta} h^{-\alpha - \beta} + \phi [B(1 - \omega) - \delta] = -\phi \quad \text{.................(4-14)}$$

From equation (4-13), we obtain equation (4-15)

$$\frac{\dot{\lambda}}{\lambda} = -(A(\alpha + \beta) G \omega^{1 - \alpha - \beta} h^{1 - \alpha - \beta} k^{\alpha + \beta - 1} - \delta) \quad \text{.................(4-15)}$$

From equations (4-3), (4-5) and (4-6), we obtain equations (4-16)(4-17)

$$\frac{\dot{k}}{k} = AGk^{\alpha + \beta - 1}(\omega h)^{1 - \alpha - \beta} - \frac{c}{k} - \delta \quad \text{.........................(4-16)}$$

$$\frac{\dot{h}}{h} = B(1 - \omega) - \delta \quad \text{.........................(4-17)}$$
We need equations (4-18) and (4-19) as a transversality condition, it means that there will exist an optimal solution.

\[
\lim_{t \to \infty} \lambda(t)k(t) = 0 \quad \text{(4-18)}
\]

\[
\lim_{t \to \infty} \phi(t)h(t) = 0 \quad \text{(4-19)}
\]

Together with equations (4-10) and (4-15), we obtain equation (4-20).

\[
\frac{\dot{c}}{c} = \frac{A(\alpha + \beta)G\omega^{1-a-\beta}h^{1-a-\beta}k^{\alpha + \beta - 1} - \delta - \rho}{\sigma} \quad \text{(4-20)}
\]

In the balanced growth path, all variables grow at the common speed. The growth rate of consumption is equal to physical capital.

\[
\frac{\dot{c}}{c} = \frac{\dot{y}}{y} = \gamma = \frac{A(\alpha + \beta)G\omega^{1-a-\beta}h^{1-a-\beta}k^{\alpha + \beta - 1} - \delta - \rho}{\sigma} \quad \text{(4-20.1)}
\]

4.2 The numerical methods

Here we use the same method as in chapter 3 to analyze the condition. If all variables grow at a constant rate (Balanced growth path), the growth rate of variable \( c \) equals variable \( k \) and variable \( h \).

\[
\frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \frac{\dot{h}}{h}
\]

Then we define \( z = \frac{\dot{h}}{k}, x = \frac{\dot{c}}{k} \),

where \( z \) is the proportion of human capital and physical capital, \( x \) is the proportion of consumption and physical capital. Because \( h, c \) and \( k \) grow at a common speed, the growth rates of \( z \) and \( x \) are equal to zero. \( \omega \) is constant and the growth rate of \( \omega \) is also equal to zero. Accordingly, we could find the social planner
optimal solution in this model.

Equations (4-16), (4-17) and (4-20) taken together, we obtain equations (4-21) and (4-22)

\[
\frac{\dot{z}}{z} = \frac{h}{k} - \frac{k}{h} = B(1 - \omega) - AGz^{1-a-\beta} \omega^{1-a-\beta} + x \quad \text{.........(4-21)}
\]

\[
\frac{\dot{x}}{c} = \frac{\dot{k}}{k} = \frac{\alpha + \beta - \sigma}{\sigma} AGz^{1-a-\beta} \omega^{1-a-\beta} + x + \frac{\delta(\sigma-1)-\rho}{\sigma} \quad \text{.........(4-22)}
\]

Together with equations (4-11) and (4-14), we get equation (4-23) and (4-24)

\[
\frac{A}{B} Gz^{-a-\beta} \omega^{-a-\beta} (1 - \alpha - \beta) = \frac{\phi}{\lambda} \quad \text{.........(4-23)}
\]

\[
\frac{\lambda}{\phi} AGk^{a+\beta} (1 - \alpha - \beta) \omega^{1-a-\beta} h^{1-a-\beta} + [B(1 - \omega) - \delta] = -\frac{\dot{\phi}}{\phi} \quad \text{.........(4-24)}
\]

Put equations (4-23) and (4-24) together, we obtain equation (4-25)

\[
-B + \delta = \frac{\phi}{\phi} \quad \text{.........(4-25)}
\]

By taking logarithm in equation (4-23) and differentiating with respect to time, we obtain equation (4-26)

\[
\frac{\dot{\phi}}{\phi} - \frac{\dot{\lambda}}{\lambda} = (\alpha + \beta) \frac{\omega}{\omega} - (\alpha + \beta) \frac{\dot{z}}{z} \quad \text{...............(4-26)}
\]

Finally,

\[
\frac{\dot{\omega}}{\omega} = \frac{B}{\alpha + \beta} - B(1 - \omega) - x \quad \text{.........(4-27)}
\]

Now we have the change rates of $z$, $x$ and $\omega$. When all variables are in a steady state, the change rates of those variables are all equal to zero. The steady state of this system can be found by setting the three time derivatives equations ($\frac{\dot{x}}{x} = \frac{\dot{z}}{z} = \frac{\dot{\omega}}{\omega} = 0$)
to zero and find the optimal solution.

The results are

\[
\frac{z}{x} = B(1 - \omega) - AGz^{1-\alpha-\beta} \omega^{1-\alpha-\beta} + x = 0 \quad \text{............(4-28.1)}
\]

\[
\frac{x}{x} = \frac{\alpha + \beta - \sigma}{\sigma} AGz^{1-\alpha-\beta} \omega^{1-\alpha-\beta} + x + \frac{\delta(\sigma) - \rho}{\sigma} = 0 \quad \text{........(4-28.2)}
\]

\[
\frac{\omega}{\omega} = -B(1 - \omega) + \delta - x = 0 \quad \text{...........................(4-28.3)}
\]

\[
E(G) = (1 - \omega)(1 + \theta_1)(1 + \theta_2)^{\beta} + \omega \quad \text{..........................(4-28.4)}
\]

Taking expected value of equations (4-28.1)(4-28.2)(4-28.3) together with equation (4-28.4), the optimal solutions are

\[
E\left(\frac{z}{z}\right) = (B(1 - \omega) - A)((1 - \omega)(1 + \theta_1)(1 + \theta_2)^{\beta} + \omega)z^{1-\alpha-\beta} \omega^{1-\alpha-\beta} + x) = 0
\]

\[
\quad \quad \quad \quad \quad \quad \quad \text{..................(4-29.1)}
\]

\[
E\left(\frac{x}{x}\right) = \left(\frac{\alpha + \beta - \sigma}{\sigma} A((1 - \omega)(1 + \theta_1)(1 + \theta_2)^{\beta} + \omega)z^{1-\alpha-\beta} \omega^{1-\alpha-\beta} + x + \frac{\delta(\sigma) - \rho}{\sigma}\right) = 0
\]

\[
\quad \quad \quad \quad \quad \quad \quad \text{..................(4-29.2)}
\]

\[
E\left(\frac{\omega}{\omega}\right) = -B(1 - \omega) + \delta - x = 0 \quad \text{...................(4-29.3)}
\]

Here we denote \( g = (1 + \theta_1)(1 + \theta_2)^{\beta} \)

\[
\frac{Z^*}{Z^*} = \frac{(\alpha + \beta)\{(1 - g)(2\rho - \sigma\delta - \sigma\delta^2 - \rho^2)\} - (1 - \alpha - \beta)\{(1 - g)(\rho - \sigma\delta)(2\delta + g\sigma)\} + B^2\sigma^2}{\{(1 - g)(1 - \alpha - \beta)\delta + \rho - \delta \sigma\} + \sigma B\{(1 - \alpha - \beta)(\delta + \sigma B) + \rho - \delta \sigma\}^2 A + \{(1 - g)(1 - \alpha - \beta)\delta + \rho - \delta \sigma\} + \sigma B\{(1 - \alpha - \beta)(\delta + \sigma B) + \rho - \delta \sigma\} A \delta \sigma^2 B^2}
\]
\[
\omega^* = \frac{\delta(1 - \alpha - \beta) + \sigma(B - \delta) + \rho}{B \sigma} \\
x^* = \frac{\delta(1 - \alpha - \beta) + \rho}{\sigma}
\]

If the range of \( \omega^* \) would be limited between 0 and 1, the condition has to be equation (4-30), the discount rate of time cannot be too large.

\[
B \sigma > \sigma \delta - \rho - \delta(1 - \alpha - \beta) \quad \text{....................(4-30)}
\]

In order to explain the influence resulting from the representative small firm that allocates the resource to improve its human capital, we try to use a numerical method to calculate its result.

In terms of the value of other parameters, we also adopt some assumptions from Lucas(1988) and Benhabib (1994). \( \rho \) is the discount rate of time at 0.025. \( \delta \) is the depreciation rate equal at 0.05. The basic technical levels in both sectors are the same and equal to 1(\( A = B = 1 \)). \( \alpha \) is the coefficient of firm’s capital in the production function at 0.4, whereas \( \beta \) is the coefficient of average economy wide capital stock at 0.2. \( \sigma \) is the inverse of the constant intertemporal elasticity of substitution at 5.

In Figure 4-1 we create a flow chart to help readers easily to understand what the process of the representative firm’s optimal choice is. The representative small firm has to allocate its initial human capital into two sectors.
Table 4-1 The relationship between the investment in education sector and growth rate

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>α</th>
<th>β</th>
<th>ρ</th>
<th>δ</th>
<th>σ</th>
<th>θ₁</th>
<th>θ₂</th>
<th>ω</th>
<th>c/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0.9590</td>
<td>0.089</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9590</td>
<td>0.102</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>10</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9545</td>
<td>0.051</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0.9590</td>
<td>0.197</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0.9590</td>
<td>0.117</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9630</td>
<td>0.00005</td>
</tr>
<tr>
<td>1.5</td>
<td>1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9590</td>
<td>0.156</td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.025</td>
<td>0.05</td>
<td>5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.9726</td>
<td>0.102</td>
</tr>
</tbody>
</table>

Note: All variables are in equilibrium situation.
Figure 4-1 The process of the representative firm’s optimal choice

**Two-sectors.**

<table>
<thead>
<tr>
<th>Physical capital goods sector</th>
<th>Human capital education sector</th>
</tr>
</thead>
</table>

\[ y = A_1 \lambda_1 (1 + \theta_1) (1 + \theta_2)^{\beta} + \lambda_2 k^a k^\beta (\omega h)^{1-\alpha-\beta} \quad Q = B(1-\omega)h \]

Keep \( \omega \times h \) to produce \( (1-\omega) \times h \) to improve skill

If \( \omega = 0.9 \)
\[ 1 - \omega = 0.1 \]
\[ y = A_1 \lambda_1 (1 + \theta_1) (1 + \theta_2)^{\beta} + \lambda_2 k^a k^\beta (0.9h)^{1-\alpha-\beta} \quad Q = B(0.1h) \]

The probability of a small firm that transforms into a large one is positively related to the quantity inputted in education sector, but the firms do not know how the probability actually is. They consider \( \lambda_1 \) being an exogenous variable and just choose the optimal value of \( \omega \)

**Step 1**
10000 small firms make the same decision

\[ \omega = 0.9 \quad 1 - \omega = 0.1 \]
9000 small firms 1000 large firms

**Step 2**

\[ \lambda_2 = \frac{9000}{10000} = 0.9 \quad \lambda_1 = \frac{1000}{10000} = 0.1 \]

Now we assume the expected value of a small firm that transforms into a large firm is equal to \( 1 - \sigma \).
\[ 0 \leq E(\lambda_1) = 1 - \omega \leq 1, \quad 0 \leq E(\lambda_2) = \omega \leq 1 \]

If the representative chooses the optimal \( \sigma \), the ratio of small firms \( \lambda_2 \) is actually determined.
Figure 4-2 The relation between the discount rate of time ($\rho$) and the ratio of human capital in goods sector ($\omega$)

Figure 4-3 The relation between the discount rate of time ($\rho$) and the growth rate ($\gamma$)
Figure 4-4 The relation between the inverse of the intertemporal elasticity of substitution ($\sigma$) and the ratio of human capital in goods sector ($\omega$)

Figure 4-5 The relation between the inverse of the intertemporal elasticity of substitution ($\sigma$) and the growth rate ($\gamma$)
Figure 4-6 The relation between the depreciation rate ($\delta$) and the ratio of human capital in goods sector ($\omega$)

Figure 4-7 The relation between the depreciation rate ($\delta$) and the growth rate ($\gamma$)
Figure 4-8 The relation between the average economy wide capital stock in production function ($\beta$) and the ratio of human capital in goods sector ($\omega$)

Figure 4-9 The relation between the average economy wide capital stock in production function ($\beta$) and the growth rate ($\gamma$)
Table 4-2 The situation of SMEs among countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Industry sector</th>
<th>The number of small firms (ten thousand)</th>
<th>Ratio</th>
<th>Employees (ten thousand)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiwan(2005)</td>
<td></td>
<td>121</td>
<td>97.8</td>
<td>706</td>
<td>75.54</td>
</tr>
<tr>
<td>Australasia(2004)</td>
<td></td>
<td>110</td>
<td>96.0</td>
<td>330</td>
<td>47.00</td>
</tr>
<tr>
<td>Canada(2004)</td>
<td></td>
<td>214</td>
<td>91.44</td>
<td>661</td>
<td>64.10</td>
</tr>
<tr>
<td>Japan(2004)</td>
<td></td>
<td>564</td>
<td>98.94</td>
<td>4,124</td>
<td>79.51</td>
</tr>
<tr>
<td>Malaysia(2001)</td>
<td></td>
<td>21</td>
<td>96.11</td>
<td>38</td>
<td>32.50</td>
</tr>
<tr>
<td>New Zealand(2004)</td>
<td></td>
<td>31</td>
<td>92.47</td>
<td>70</td>
<td>36.08</td>
</tr>
<tr>
<td>Philippics(2001)</td>
<td></td>
<td>80</td>
<td>99.60</td>
<td>410</td>
<td>70.00</td>
</tr>
<tr>
<td>Russia(2003)</td>
<td></td>
<td>873</td>
<td>97.57</td>
<td>3,996</td>
<td>60.86</td>
</tr>
<tr>
<td>Singapore(2003)</td>
<td></td>
<td>13.4</td>
<td>99.67</td>
<td>65.61</td>
<td>69.10</td>
</tr>
<tr>
<td>South Korea(2003)</td>
<td></td>
<td>295</td>
<td>99.81</td>
<td>1,038</td>
<td>86.66</td>
</tr>
<tr>
<td>Thailand(2003)</td>
<td></td>
<td>83</td>
<td>99.70</td>
<td>557</td>
<td>60.69</td>
</tr>
<tr>
<td>England(2004)</td>
<td></td>
<td>411</td>
<td>95.97</td>
<td>1,350</td>
<td>61.38</td>
</tr>
<tr>
<td>USA(2003)</td>
<td></td>
<td>2415</td>
<td>99.83</td>
<td>7,646</td>
<td>58.00</td>
</tr>
</tbody>
</table>


From Table 4-1 to Table 4-2 and Figure 4-2 to Figure 4-9, we could conclude several important results.

First, the internal ($\theta_1$) and external effect ($\theta_2$) could not affect the ratio $\omega^*$ that a firm wants to allocate its human capital in education sector or goods sector, because the representative small firm would not know the exact probability it could transform into a large firm in the beginning. It just chooses the optimal value of $\omega^*$ to invest in goods sector. But a higher value of the internal ($\theta_1$) and external effect ($\theta_2$) in production function will lead to a higher economic growth rate.

Second, if the share of a firm’s physical capital ($\alpha + \beta$) in the production function is less than the share of human capital ($1 - \alpha + \beta$), the representative firm will choose a higher ratio $\omega^*$. It means the physical capital in production function is
not as important as human capital. Thus, the representative firm will spend more human capital in production function to get higher output. The growth rate is going to decrease with a lower share \((\alpha + \beta)\) in the production function. It means the physical capital plays a very important role in production process. The firm cannot produce output just relying on human capital.

Third, the inverse of the elasticity of intertemporal substitution \((\sigma)\) is a significant variable that determines the value of ratio \(\omega^*\) and the growth rate \(\dot{z}^*\). The elasticity of intertemporal substitution measures the extent to which consumers shift total expenditures across time in response to changes in the effective rate of return. Higher \(\sigma\) means the elasticity of intertemporal substitution is lower and it discourages consumers from sacrificing today’s consumption to get more available consumption in the future. If \(\sigma\) is very high, that means people prefer today’s consumption and it will make the saving decrease. It is more difficult for the firm to borrow physical capital and it has to use higher human capital in education sector to compensate for the lack of physical capital and the higher \(\sigma\) decreases the growth rate. Perhaps it could explain why a country has higher saving rate and its growth rate is higher than another country without high saving rate.

Fourth, the technological level of goods sector (A) and education sector (B) both could affect the economic growth rate and the effect in goods sector is larger than education sector. It means the production process in the physical capital sector is more efficiently if the technological level A is larger than B.

Fifth, the representative firm that chooses the ratio of human capital to use in a goods sector just depends on these parameters it faces. The value of \(\omega^*\) always stays in a very high level even though these parameters are total different. We know \(\omega^*\) represent the ratio of small firms, and we can compare the result with the empirical
date for the globe (Table 4-2) to observe a very special phenomenon. We find the ratios of small firms in the most of countries are larger than 90 percent. In some countries, such as the Philippines, South Korea and Thailand, the ratios are larger than 99 percent. It could explain why there exist such a high percentage of small firms among these countries.

Sixth, the coefficient of the average widely capital (β) is positively related to the growth rate and negatively related to the ratio of small firms. It means the firm will have a higher probability to transform into a large one if the external effect is large, because the firm can obtain some benefits without paying for them. The higher external effect will lead to a higher growth rate.

Finally, even the representative firm chooses the same ratio ω* to allocate its human capital in the goods sector, the growth rate could be still different with different parameters, such as the technological level, the elasticity of intertemporal substitution and the share of a firm’s physical capital in the production function, etc. It could explain why two countries have the same proportion of large firms, but the growth rates between these countries diverge to different paths.
Chapter 5 Evidence and Statistics -( Taiwanese data)

5.1 Introduction

The neoclassical growth model of Solow (1956), which has been for a long time the central framework to account for economic growth, focuses on exogenous technological, population or saving rate factors that determine equilibrium capital per capita.

Despite the growth model of Solow being widely used in various applications, Lucas (1988) and Romer (1989) emphasized the major drawback was that in empirical applications over half of the growth in output went unexplained.

Schultz (1961) noted that the growth rate of output exceeded the growth rate of the relevant input measures (employment and physical capital). He suggested that investment in human capital is probably the main explanation for this difference.

Azariadis and Drazen (1990) found that no country was able to grow quickly during the postwar period without a highly literate workforce. Uzawa (1965) and Rosen (1976) also stressed the important role of human capital.

Romer (1986) stated external economics of scale (external effect) is the major factor that sustains economic growth.

In this chapter, we postulate that the external effect in production function is the locomotive of growth and argue for the theory; the relative scale of external effect plays a role in motivating and supporting physical capital accumulation.

At the same time, we focus on a single industrialized country. The main advantages of analyzing the economic growth in a single case are: (a) The use of a data set comprised of the most appropriate and the highest quality measures unconstrained by the need for measurement consistency, and (b) A more detailed account of the dynamic evolution of the economy. We first use Taiwan’s data,
covering the period 1974 to 2002. If we get an acceptable result, then we might continue to explain another country’s situation in the future research.

5.2 Recent history of Taiwan’s economic development

Taiwan is a small island economy with an extremely high population density and with very few natural resources. However, the country in the past few decades has experienced rapid output growth with moderate inflation. Its real gross domestic product (GDP) per capita has increased by more than six-fold since 1954 with an average annual growth rate of over 6 percent, while its personal income distribution index measured by the ratio of household income share of the richest to the poorest quintile decreased from 5.33 to 4.94 over the period of 1964-89.

Taiwan’s economy began to take off in the years from 1963 to 1965. Between these years, the per capita growth in real GDP increased from less than 3 percent to more than 6 percent; the investment to NNP (Net National Product) ratio increased from roughly 6 percent to above 10 percent; the net saving to NNP (Net National Product) ratio rose from below 8 percent to about 13 percent. The rate of domestic savings increased from 13 percent in the early 1960s to 20 percent by the late sixties, and reached 30 percent through the 1970s and 1980s. Furthermore, the output of industrial sectors began to exceed the output of agricultural sectors, and employees started moving from agriculture to other industries.

Beginning in the 1980s, the situation changes of social and political landscape took place in Taiwan. The economy became increasingly open and free from earlier restrictive and protectionist tendencies.

Due to the rapid growth of trade and a sharp increase in trade surplus, Taiwan’s foreign exchange reserves reached the US$70 billion in 1987. The massive trade
surpluses led to a rapid accrual of foreign exchange assets and a sharp appreciation of the New Taiwan Dollar against the US Dollar, which thus lowered Taiwan's competitiveness. Many small and medium sized enterprises with labor-intensive operations were unable to keep their foothold in Taiwan and relocated to Southeast Asia or the China, seeking new business opportunities and room to expand.

The greatest changes in the structure of Taiwan's industrial sector took place in the 1980s. Labor-intensive industry was no longer the mainstay of the industrial sector and was gradually being replaced by technology and capital intensive industry.

The transition of Taiwan's industrial sector from light to heavy industries is quite apparent. In terms of the production value, the ratio of light industries to heavy chemical industries dropped from 51.52 percent to 48.48 percent in 1986. In 1995, the output of the light industries dropped to only 33.63 percent, while the heavy chemical industries' share rose to 66.37 percent.

From 1981 to 1995 in Taiwan's economic development, the annual growth rate dropped to 7.52 percent from the near 10 percent average seen over the preceding 18 years (1963-1980). This mild slowdown was perhaps a natural consequence of structural changes in the nation's industrial sector. During this period of time, the agricultural sector had the lowest performance, with an average annual growth rate of a mere 1.24 percent and a GDP share of 4.74 percent. The average annual growth rate of the industrial sector was 6.46 percent, far below the 14 percent of the preceding 18 years; its GDP share dropped to 43.16 percent. The service sector, meanwhile, experienced the highest growth rate, with an average of 9 percent per annum. The sector's GDP share rose to 51.67 percent, far above that of the industrial sector.

Between 1952 and 1995, Taiwan set economic performance records in comparison to other countries around the world by attaining an average annual economic growth rate of 8.63 percent.
In recent years the structure of industry is stable. Although some firms relocated their factories to China or some Southeast Asia countries, the government of Taiwan made some policies to attract foreign capital (i.e., tax reduction and financial subsidy). The average annual economic growth rate can thus be maintained between 3 and 6 percent.

Figure 5-1 The economic growth rate in Taiwan between 1952 and 2006

Source: National Statistics, R.O.C. (Taiwan)
5.3 The model assumption

In the real world, there is no country, which has either large firms or small firms alone. All countries have large firms and small firms at the same time. So we adopt the production function of firms (chapter 3) to estimate the value of these parameters in Taiwan.

\[ y = A[\lambda_1(1 + \theta_1)(1 + \theta_2)\beta + (1 - \lambda_1)](k)^\alpha k_a^\beta (uh)^{1-\alpha-\beta} \ldots \ldots (5-1), \]

where \( y \) is the output per capita, \( k \) is the capital of the representative firm, \( k_a \) is average economy wide capital stock, and \( h \) is the human capital. \( \theta_1 \) is the internal effect scale of the large firm, \( \theta_2 \) is the external effect scale of the large firm, \( A \) is the basic technology level, \( \alpha \) is the share of the representative firm’s capital in production function, and \( \beta \) is the share of the average economy wide capital stock in the production function. \( 1 - \alpha - \beta \) is the share of human capital in the production function. \( u \) is the proportion of the total human capital input in the goods sector. The proportion of large firms is \( \lambda_1 \). The proportion of small firms is \( 1 - \lambda_1 \).

If we assume \( R = A[\lambda_1(1 + \theta_1)(1 + \theta_2)\beta + (1 - \lambda_1)] \ldots \ldots (5-2), \)

from equation (5-1), we can take natural logarithm and derive the following estimable form.

\[ \log(y) = \log(R) + \alpha \log(k) + \beta \log(k_a) + (1 - \alpha - \beta) \log(uh) \ldots \ldots (5-3) \]

On the condition of \( k = k_a \), the estimate equation is,

\[ \log(y) = \log(R) + (\alpha + \beta) \log(k) + (1 - \alpha - \beta) \log(uh) \ldots \ldots (5-4) \]

How do we define these variables? For our output measure, we set the real gross domestic product (GDP) per capita as output \( y \). The gross capital stock per capita is \( k \) and the human capital stock \( h \) is measured by various education attainment measures.
That here we use gross domestic product (GDP) as output ($y$) is uncontroversial, because Mankiw, Romer and Weil (1992), Caballero Ricardo J. and Ricardo K. Lyons (1990), and Chan (1995) all used the definition.

In fact, the measurement of human capital has great practical difficulties. We do not know the exact amount of human capital and, moreover, not all spending on education is intended to yield productive human capital. For example, family education is also important for human capital, but it is impossible to measure it. In this model, we try to use several proxy variables for the real value of human capital and compare the result.

The proportion of total human capital input in goods sector is also not easy to be estimated. Therefore, we use the ratio of education expenditure to GDP as a proxy variable and we get the proportion ($u$).

In this model, we assume the higher the education level of employees is, the higher the human capital they have. Here we distinguish three sub-parts of the labor: basic, prior and advanced labor.

Basic labor is a worker who completes only primary education or below (education years $\leq 9$); prior labor is a worker, who finishes the secondary education ($9 < \text{education years} \leq 12$); advanced labor means a worker completes the higher education (education years $> 12$)

We define the number of basic labor as $h_1$; prior labor as $h_2$ and advanced labor as $h_3$, but how can we decide the influence degree between those labors? And how is the proportion a worker with a bachelor degree can create, as compared with a worker who only studied in a junior high school? Here we use the average salary of elementary school, senior high school and university of workers in Taiwan to define the difference between these people.

According to the labor data from the National Statistics, R.O.C. (Taiwan), we
obtain the average salary for people who finished, respectively, elementary school, senior high school and higher than university in Taiwan and we could try to define the human capital in Taiwan.

First, because the wage rate is equal to the marginal products of labor, we suppose the difference between salaries is the divergence of human capital. For convenience, we define the average salary as the proxy variable of human capital ($h$).

Second, the labor data from National Statistics, R.O.C.(Taiwan) shows the average salary of elemental school, senior high school and university in Taiwan (A.D. 2007) are N.T. 19000, N.T. 23000 and N.T. 45000.

In terms of physical capital, we adapt and modify the assumption from Mankiw, Romer and Weil (1992). We use the real net fix capital stock of industrial and service sectors per capita as the proxy of physical capital ($k$).

Here we first use the data from Taiwan to set up a regression equation and prove the theory.

The definitions of variables are:

$y$: real gross domestic product (GDP) per capita

$h$: human capital stock

$$h = \frac{(h1\text{salary} \times h1) + (h2\text{salary} \times h2) + (h3\text{salary} \times h3)}{h1 + h2 + h3}$$

The number of basic labor as $h1$; prior labor as $h2$ and advanced labor as $h3$

$\lambda_i$: The proportion of large firms ($0 \leq \lambda_i \leq 1$)

$1 - \lambda_i$: The proportion of small firms ($0 \leq 1 - \lambda_i \leq 1$)

$k$: Net fix capital stock of industrial and service sectors per capita.

$u$: The proportion of total human capital input in goods sector

(We use the ratio of education expenditure to GDP as proxy variable)
Before we run the regression, we could check the correlation between the growth rate, the ratio of large firms and the change rate of large firms in Taiwan.

Table 5-1 The correlation coefficient between variables

<table>
<thead>
<tr>
<th></th>
<th>Growth rate</th>
<th>Ratio of large firms</th>
<th>The change rate of large firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth rate</td>
<td>1</td>
<td>0.173</td>
<td>0.124</td>
</tr>
<tr>
<td>Ratio of large firms</td>
<td>0.173</td>
<td>1</td>
<td>0.286</td>
</tr>
<tr>
<td>The change rate of</td>
<td>0.124</td>
<td>0.286</td>
<td>1</td>
</tr>
<tr>
<td>large firms</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data coverage: 1983-2006

Even though the value of correlation is not very large, it appears that there exists a positive correlation between the growth rate and the ratio of large firms.

After we run the regression, we could get the estimate variables $R$

$$R = A[\lambda_i(1 + \theta_1)(1 + \theta_2)^\beta + (1 - \lambda_i)]$$

Now that we have the real value about the proportion of small and large firms ($\lambda_1$ and $\lambda_2$) in Taiwan, we could get the relationship between $\theta_1, \theta_2, \beta$ and $A$.

Caballero and Lyons (1990) estimated the indexes of internal returns to scale and external economies for two-digit manufacturing industries in four European countries (West Germany, France, U.K and Belgium). They found very little evidence of increasing internal return to scale. In external economies, there existed for all four countries, and the effect was especially strong in France and Belgium.

Chen and Cheung (1995) estimated the indexes of internal returns to scale and
external economies for two-digit manufacturing industries in Taiwan. The data strongly supported the presence of increasing external return to scale in all Taiwan’s two-digit manufacturing industries. However, no observable evidence indicated that there existed an internal increasing return to scale in two-digit manufacturing industries.

Caballero and Lyons (1992) stated that estimates of degree of return to scale are larger for manufacturing than for two-digit industries in U.S.

From the aforementioned literature, we know that estimating the external effect and internal effect is very difficult, and with different estimation methods emerge different results regarding the amount of external effects and internal effects. Despite that, now we have just one equation and there are four variables. If we can define the value of the internal effect $\theta_1$, external effect $\theta_2$ and the share of average economy wide capital stock in the production function $\beta$, we can calculate the basic technology level $A$.

### 5.4 The result of the estimation and regression

Here we set up four models. The differences between those models are the estimation methods in the regression. In model 1 we use the OLS (Ordinary Least Square), in model 2 we use 2SLS$^9$ (Two-Stage Least Squares), in model 3 we use WLS$^{10}$ (Weight Least Squares) and in model 4 we adopt feasible generalized least squares (FGLS).

Mankiw, Romer and Weil (1992) observed the data of United States. They expected the value of $\alpha$ (physical capital’s share of income) is one-third and the

---

$^9$ In 2SLS, we use the 4 lagged independent variable as the instrumental variable.

$^{10}$ In WLS, we use the $1/\ln(k)$ as the weighted parameter.
value of \(1 - \alpha - \beta\) (human capital’s share) is between one-third and one half.

However, the value of \(\alpha\) (physical capital’s share of income) might be different in Taiwan. Tallman and Wang (1994) stated the value of \(\alpha\) (physical capital’s share of income) might be between 0.383 to 0.454. But they ignored the parameter \(\beta\) in the production function.

In our model, we assume \(\alpha\) and \(\beta\) to be both larger than zero and smaller than one. The range of \(\alpha + \beta\) and \(1 - \alpha - \beta\) will be between 0 and 1 if our model is correct.

In model 1, the coefficient of physical capital is positive (0.132), but it is not statistically significant. The coefficient of human capital is positive (0.88) and statistically significant. The sum of both coefficients closed to 1. In model 2, we try to use the 2SLS (Two-Stage Least Squares) to estimate these parameters. Both coefficient of physical capital and human capital are positive and statistically significant. The sum of both coefficients is a bit larger than 1. In model 3, only human capital is statistically significant, but there all exist serious problems in these models.

First, we make White heteroskedasticity test to check whether there are heteroskedasticity in residual term and it shows that the p-value is very small and significant from model 1 to model 3. The effect of heteroskedasticity in the residual term will make the standard errors underestimated and overestimated t-value. Second, we use Breusch-Godfrey Serial Correlation LM test to examine whether in these models there exists autocorrelated disturbance term. Meanwhile, we also use the Durbin-Watson value to check the result. The result is similar. It reveals that disturbance term is autocorrelated. The consequences of autocorrelation in the residual will also make the standard errors be underestimated and overestimated t-value. Besides, the higher values of \(R^2\) are observed and lead to seriously misleading results.
### Table 5-2 Estimation of physical capital and human model

<table>
<thead>
<tr>
<th>Sample Observation</th>
<th>Model 1 (OLS)</th>
<th>Model 2 (2SLS)</th>
<th>Model 3 (WLS)</th>
<th>Model 4 (FGLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.986</td>
<td>-2.142</td>
<td>0.829</td>
<td>-0.87</td>
</tr>
<tr>
<td></td>
<td>(1.74)</td>
<td>(2.39)</td>
<td>(3.54)</td>
<td>(0.70)</td>
</tr>
<tr>
<td>Ln(k)</td>
<td>0.132</td>
<td>0.471*</td>
<td>0.155</td>
<td>0.764**</td>
</tr>
<tr>
<td></td>
<td>(0.193)</td>
<td>(0.259)</td>
<td>(0.223)</td>
<td>(0.297)</td>
</tr>
<tr>
<td>Ln(u*h)</td>
<td>0.88*</td>
<td>0.722***</td>
<td>0.861***</td>
<td>0.458***</td>
</tr>
<tr>
<td></td>
<td>(0.099)</td>
<td>(0.132)</td>
<td>(0.11)</td>
<td>(0.146)</td>
</tr>
</tbody>
</table>

\[ R^2 = \]

| Durbin-Watson      | 0.66          | 0.52           | 0.63          | 1.65           |
|                    | White         |                |               |                |
| Heteroskedasticity test | 0.009#           | 0.0009#        | 0.014#        | 0.631          |
| Breusch-Godfrey    | 0.0007#       | 0.0002#        | 0.0001#       | 0.90           |

Standard errors are in parentheses. We estimate the equation with ordinary least square (OLS), two-stage least squares (2SLS), weighted least squares (WLS) and feasible generalized least squares (FGLS).

* means significance level is 10 percent. ** 5 percent. *** 1 percent.

# means there are autocorrelation and heteroskedasticity in disturbance term.
How can we know whether there exists a first-order autocorrelation in this regression? If the first-order autocorrelation coefficient is \( \rho \)

\[
e_t = \rho e_{t-1} + \nu_t \quad \text{and} \quad \nu_t \sim iid(0, \sigma^2),
\]

we can estimate the coefficient \( \rho \) by saving the residuals from the previous regression and running a least square regression of \( e_t \) on \( e_{t-1} \).

If the p-value of \( \rho \) is significant, we could reject the null hypothesis of no serial correlation in this regression. We obtain the residuals from of OLS from model 1 and run a least square regression. The result is \( e_t = 0.65e_{t-1} + 0.35e_{t-2} + \nu_t \), which means there exists the AR(2) in model 1, and then, we could use the FGLS\(^{12}\) to estimate the parameters and the result in Table 5-2 shows that there does not exist heteroskedasticity and autocorrelation in residual term.

The coefficients of physical and human capital in model 4 conform to our theory and we can continue to estimate the parameters.

Although the sum of the coefficient of physical capital and human capital seems close to 1 and coincide with the Cobb-Douglas production function in model 1,2 and 3, the existence of heteroskedasticity and autocorrelation seems a serious problem for us to estimate and trust the parameters. For convenience’ sake, we adopt the result from model 4 in Table 5-2.

In order to estimate the share of the average economy wide capital stock in Taiwan, we could adapt the assumption from Tallman and Wang (1994). They stated the value of \( \alpha \) (physical capital’s share of income) in Taiwan might be between 0.383 and 0.454. The coefficient of \( \alpha + \beta \) in model 4 is 0.764. Therefore, we can calculate the value of \( \beta \) (the average economy wide capital stock in the production function)

---

\(^{11}\) \( e_t \) is sample disturbance term and \( e_t \) is population disturbance term

\(^{12}\) The disturbance term in OLS is an AR(2) process. So there exists an autocorrelated disturbance term to this model, and then the OLS estimates are biased, inconsistent and inefficient. Here we use feasible generalized least squares twice to solve the problem and obtain the suitable estimates.
might stand somewhere between 0.310 and 0.381.

Table 5-3 The difference of external effect in countries

<table>
<thead>
<tr>
<th>Writer</th>
<th>Country</th>
<th>Estimate method</th>
<th>Internal effect</th>
<th>External effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caballero and Lyons (1990)</td>
<td>West Germany</td>
<td>Seemingly unrelated regression</td>
<td>Not significant</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td></td>
<td></td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td>U.K.</td>
<td></td>
<td></td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Belgium</td>
<td></td>
<td></td>
<td>1.15</td>
</tr>
<tr>
<td>Chen and Chung (1995)</td>
<td>Taiwan</td>
<td>Seemingly unrelated regression</td>
<td>1.26</td>
<td>1.28</td>
</tr>
<tr>
<td></td>
<td>Taiwan</td>
<td>Three-stage least square</td>
<td>1.30-1.69</td>
<td>1.06-1.42</td>
</tr>
</tbody>
</table>

Table 5-4 The estimation value of internal effects and external effects

<table>
<thead>
<tr>
<th>Country</th>
<th>Estimate method</th>
<th>Basic technology level $A$</th>
<th>The share of the average economy wide capital stock in the production function $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiwan</td>
<td>OLS</td>
<td>2.669</td>
<td>-0.322 ~ -0.251</td>
</tr>
<tr>
<td>Taiwan</td>
<td>2SLS</td>
<td>0.013</td>
<td>-0.063 ~ -0.008</td>
</tr>
<tr>
<td>Taiwan</td>
<td>WLS</td>
<td>3.532</td>
<td>-0.241 ~ -0.170</td>
</tr>
<tr>
<td>Taiwan</td>
<td>FGLS</td>
<td>0.133</td>
<td>0.310 ~ 0.411</td>
</tr>
</tbody>
</table>
Tallman and Wang (1994) also stated the value of human capital’s share of income in Taiwan might be between 0.553 and 0.617. In model 4, the parameter of human capital we obtain is equal to 0.458. It is a little smaller but still very closed to the result Tallman and Wang (1994) had done. The reason for the different value in these parameters might be:

1. There exist both internal and external effects in this production function.
2. The definition of human capital is different.
3. The sample period\(^{13}\) that we adopt is different.

In our model, we assume \( R = A[\lambda_1(1 + \theta_1)(1 + \theta_2)^\theta + (1 - \lambda_1)] \). Even if the value of \( R \) is not statistically significant, we still try to calculate the value of \( \theta_1 \), \( \theta_2 \) and \( A \) (the basic technical level). We do not know what the exact value of \( A \) is, but \( A \) represents the basic technical level, which is a constant in the production function. If we use the parameters from Chen and Chung (1995) who had estimated the internal effect \( \theta_1 = 0.26 \), the external effect \( \theta_2 = 0.28 \) and the ratio of large firms \( \lambda_1 = 0.022 \), then we can get the basic technical level \( A \) (See Table 5-4).

In this chapter, we first introduced the recent history of Taiwan’s economic development and established a regression to estimate the coefficient of physical capital and human capital in the production function. In this regression, we did not set any restriction, but the sum of coefficients from human capital and physical capital are close to 1 and statistically significant.

In these regressions, we found the different relationship between internal effects, external effects, the ratio of large firms and the basic technical level. We also can estimate the physical and human capital’s share in the production function with the

\(^{13}\) Tallman and Wang (1994) used the data of Taiwan in period 1965-1989. In this chapter we use the data of Taiwan in period 1974-2002. In the aspect of human capital, Tallman and Wang (1994) used weighted labor as the proxy variable of human capital. Here we use the average salary of labor as the proxy variable of human capital.
Meanwhile, we estimated the average economy wide capital stock share in production function $\beta$ is between 0.310 and 0.381 and the human capital share in production function is 0.458. The result is similar to that of what other economists had done. However, we used a common and relatively easier method to get this result. The finding here were mainly empirical, but we just used Taiwan’s data to validate the assumption. There might be different results that are country-specific.
Chapter 6  The Factors of Enterprise Growth

6.1 Introduction

How is it that a small firm transforms into a large firm? Firms practically always begin as very small entities, with low amounts of capital drawn from the saving of the owner or borrowed from friends and relatives. Initial levels of employment are low, typically less than a dozen. The social and occupational backgrounds of the owners vary greatly. Some firms would eventually expand into medium or large-scale activities and go on growing, while other would witness the slowdown of their growth.

Dennis Anderson (1982) stated the possible predominance of large firms results from economy of scale with respect to plant size, economy of scale with respect to management and marketing, superior technical and management efficiency, preferential access to infrastructure service and external finance.

Caballero and Leyons (1990) found that the external economies exist in four European countries (West Germany, France, U. K. and Belgium); the effect of external economies is especially strong in France and Belgium. Chan, Chen and Cheung (1995) stated in the industry in Taiwan also existed strong external effects. It means external effect seems beneficial to economic growth and we assume that large firms possess higher external effects in the production function.

In chapter 3, we proved the internal effect and external effect are beneficial to the economic growth. The internal effect $\theta_i$ is positively correlated to the firm’s physical capital. The more physical capital a firm owns, the higher $\theta_i$ a firm has. The higher probability of transforming from a small one into a large one, the more physical capital and higher internal effect a firm will have in future. Therefore, we can
assume the internal effect $\theta_i$ is a function of probability. For convenience sake, in our model all firms are identified and have the same internal and external effects.

Many economists have different arguments in terms of growth theory. Arrow (1962) constructed models in which ideas were unbounded by products of production. In these models, each worker’s new skill and discovery will spill over to the entire economy immediately. It is possible to spread technology and knowledge from person to other person, because knowledge is nonrival. The mechanism is described as learning by doing.

Romer (1986), Lucas (1988) and Rebelo (1991) introduced a theory built on the work of Arrow (1962) and Uzawa (1965). In these models, growth may go on indefinitely because the return to investment in a broad class of capital goods includes human capital. The spillover of knowledge across producers and external benefits from human capital are part of the process in economy development, because they help to avoid the tendency of diminishing returns to the accumulation of capital.

Aghion and Howitt (1992) supposed technological advance results from the purpose R&D activity, and the activity is rewarded by some form of monopoly power. The growth rate remains positive in the long run, if the new R&D for the economy is created continually.

In this dissertation, we assume a large firm has higher internal effect and external effect than a small firm. A country with higher percentage of large firms will see a higher economic growth.

We think the factors that make small firms transform into large firms are also the momentum of economics growth. In this chapter, we try to find out the factors which influence an enterprise’s growth.
6.2 The regression approach (Probit and Logit model)

We presume a firm has higher internal and external effects with the larger scale of firm. External and internal effects may not be of the same value, but it could have a positive relationship between them.

\[ \theta_1 = q \theta_2 \quad q > 0 \] \hspace{1cm} (6-1)

where \( \theta_1 \) is the internal effect and \( \theta_2 \) is the external effect.

If we assume a variable \( p^* \), \( p^* \) is a value of a firm’s ability or talent. With a higher \( p^* \) the firm will have a higher potential transforming into a large firm. We can imagine that ability \( p^* \) is normally distributed across all firms, i.e.,

\[ p^* \sim N(\mu, \sigma_p^2) \]

If there exists a critical ability value \( p \) and a firm’s ability is lesser than the value \( p \), the firm will still stay as a small firm or close down. If a firm’s ability is larger than the value \( p \), the firm will turn into a large firm.

Unfortunately, we cannot observe the ability \( p^* \) of a given firm, we only observe whether the firm grows up or closes down. That means that we would observe \( y_i \).

Hence,

\[ y_i = \begin{cases} 1 & \text{the } i\text{-th small firm transforms into a large firm} \\ 0 & \text{otherwise} \end{cases} \] \hspace{1cm} (6-2)

In our model, we assume the internal and external effects are the important factors for economic growth. When a small firm in a society or economic system has a higher probability of transforming into a larger firm, the growth rate in this economic system will be higher. But how can we measure the probability? It seems impossible, however, that we can use the probit or logit model to solve the problem.

In probit model, we do not know the value of firm’s ability \( p^* \), but we can observe the variable \( y \) that takes on only two values, 0 or 1. The value of \( y \) equal
to 0 means a small firm stays in the same situation or closes down. The value of 1 means a small firm has transformed into a large one successfully.

Although we cannot observe the variable $p^*$, there exists a correlation between $p^*$ and $y$.

$$p^*_i = X_i \beta + \epsilon_i = \beta_{i1}x_1 + \beta_{i2}x_2 + \ldots + \beta_{in}x_n + \epsilon_i, \quad \epsilon_i \sim N(0, \sigma^2)$$

Large firm $y_i = \{1 \text{ if } p^*_i > 0 \}$

Small firm $y_i = \{0 \text{ if } p^*_i \leq 0 \}$ ...........................................(6-3),

where $p^*_i$ is the $i$-th firm’s ability, and $x_i$ is the $i$-th firm’s independent variables. $\beta_i$ is the parameter of regression. $\epsilon_i$ is the error term.

Now we can obtain the probability of $i$-th small firm which transforms into large firm ($y_i=1$).

$$\text{Prob} (y_i=1) = \text{prob} (p^*_i > 0)$$

$$= \text{prob} (X_i \beta + \epsilon_i > 0) = \text{prob} (\epsilon_i > -X_i \beta)$$

$$= \text{prob} (\epsilon_i / \sigma > -X_i \beta / \sigma) = \text{prob} (\epsilon_i / \sigma < X_i \beta / \sigma) = \phi(X_i \beta / \sigma)$$

$$\text{Prob} (y_i=0) = 1 - \phi(X_i \beta / \sigma) ..........................................................(6-4)$$

In logit model, the development of the logit is identical to that of the probit model. The formulation of the model can be written as

$$\text{Prob} (y_i=1) = \Lambda(-X_i \beta)$$

$$= \frac{\exp(X_i \beta)}{1 + \exp(X_i \beta)} .............................................(6-5)$$

With the formulation, the predicted probability will lie between 0 and 1.
If we take sampling, we can take the likelihood to estimate the parameters. The likelihood for the sample is the product of the probability of each observation.

We assume there are \( m \) observations \((0,1,2\ldots n,n+1\ldots m)\), from 0 to \( n \) as the \( n \) observations such as \( y_i=0 \), and \( n+1 \) to \( m \) as the \( m-n \) observations such as \( y_i=1 \), yields

\[
\text{LL} = \text{prob}(y_1=0).\text{prob}(y_2=0)\ldots\text{prob}(y_n=0)\ldots\text{prob}(y_{n+1}=1).\text{prob}(y_{n+2}=1)\ldots\text{prob}(y_m=1)
\]

\[
= \prod_{i=1}^{n}[1 - \Phi(X_i/\delta)] \prod_{i=n+1}^{m} \Phi(X_i/\delta)
\]

\[
= \prod_{i=1}^{n} \Phi(X_i/\delta)^{y_i}[1 - \Phi(X_i/\delta)]^{1-y_i} \quad \text{..................................................(6-6)}
\]

We could image the equation (6-6) is like the several binary variables that combine together. Finally, we take logarithm \( \text{LL} \) and differentiate with respect to \( \beta \) and make the value equal to 0. The name of the model is log-likelihood function.

A standard procedure to calculate estimation from a linear probability model is to “guess” what to begin with in finding a solution. As each guess gets better and better, the value of a log-likelihood function rises at each step until no improvement is possible, and the solution is found.

Johnston (1997) illustrated a model in which he described several factors affecting a worker to affiliate to a union number (potential experience, the number of years of schooling completed, etc.). In this example, he did not know the characteristics that determine a person’s propensity to join a union, but he could observe exactly whether a worker join a union. He used a simple linear probability model to prove that potential experience of workers and a highly unionized industry are significant to determine whether a worker would join a union. We also use the similar regression approach to calculate the value of parameters in our model and to figure out which factors are significant for an enterprise’s growth.
6.3 The source of data and definition of variables

From the data of Taiwan Bureau of Labor Insurance, it is known that the average surviving years of small firms in Taiwan is about 13 years. It means that we can find a firm, which has survived over 13 years. At the beginning of its business it was a small firm, but it is a large firm now.

For example, suppose that we found 100 firms and all of them were SMEs in the 1980s, of which half of them had transformed into large firms in 1999. We are able to get some information about these firms, like the age and education level of employers, and the average education level of employees, whether they received subsidy from government, what kind of product the firms produce, how long the firms have been running in business, and how many percentage product are exported, etc.

So we can create a regression

\[ p_i^* = X_i \beta + \epsilon_i = \beta_{1x}x_1 + \beta_{2x}x_2 + \ldots + \beta_{7x}x_7 + \beta_{8x}x_8 + \epsilon_i \]

\[ y_i = \begin{cases} 1 \{ \text{large firm, if } p_i^* > 0 \} \\ 0 \{ \text{small firm, if } p_i^* < 0 \} \end{cases} \]

\[ x_1 = \text{The type of company.} \]
\[ x_2 = \text{Receiving any subsidy from the government or not.} \]
\[ x_3 = \text{The education level of employer.} \]
\[ x_4 = \text{The average education level of employees.} \]
\[ x_5 = \text{The percentage of the product exported.} \]
\[ x_6 = \text{Having a research department in the company or not.} \]
\[ x_7 = \text{The company ever borrowing capital from a bank or not.} \]
\[ x_8 = \text{The location of the company.} \]
We can use a log-likelihood function to estimate these parameters and obtain a regression. With this regression, we might find some variables significant and prove it is useful to explain which factors are influential for small firms transforming into large firms and lead to economic growth.

With the help of Small and Medium Enterprise Administration at Ministry of Economic Affairs Taiwan, we have sent 300 questionnaires to 300 firms and the number of responses is 42. 41 of the responses are valid. 12 of them are large firms and the remaining 29 are small firms. All valid samples at the beginning of their business were small enterprises.

The types of firms in valid samples of large firms are: eleven in the manufacturing industry and one in the commercial industry. For small firms there are fifteen in the manufacturing industry, nine in the commercial, four hotel and restaurant operation and one leisure service. We design eight questions in the questionnaire and the details are in Appendix C.

Under the assumption, we think the quality of employers and employees are very important factors for a small firm’s growth. The employers who have a higher education level can make intellectual decision to improve the enterprise and the employees who have a higher education level can perform tasks better.

Grossman and Helpman (1991) stated the increasing sorts of intermediate goods in the research department are the momentum of economic growth. We also think a small firm with a research unit perhaps has a higher probability of growing than other firms without a research unit. Besides, the location and the financial support for small firms should also be important factors. We put those variables in our regression model.

Band, Wang and Yip (1996) stated that each type of factor tax would reduce the rate of growth while the subsidy will increase it, regardless of the sector factor intensities. They also use the factor intensities in the transitional dynamic
(Stolper-samuelson effect)\(^\text{14}\). For the reason, we also assume the subsidy from the government plays an important role in a firm’s growth in the regression above. When a small firm gets subsidy from government, the probability of this small firm transforming into a large firm is higher than other small firms without subsidy.

In this chapter, the mathematic software that we used to estimate the parameters is Eviews 5.

### 6.4 The statistical test models and estimation results

The coefficients from probit and logit model are not certain probability values of firms’ transformation. The coefficients must be translated into a mathematic function, and then we can get the i-th firm’s growth probability. In the probit model, the derivation of the probability with respect to a specific \( X_i \) in the set of variables \( X \) is

\[
\frac{\partial E(y)}{\partial X_i} = \phi(X\beta)\beta_i;
\]

we define \( z = \frac{X\beta}{\sigma} \), here \( \phi(z) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}z^2\right) \), which is the standard normal density.

However, we are interested in the dimension of the sign and significance of the coefficients, because finding out which factors can influence a firm’s growth is the most important task in this chapter. In Table 6-1, we use probit and logit model and put all variables in the regression. Table 6-1 reports the results for all firms with all variables. The results show that the probability of a small firm’s growth increases

\(^{14}\) Stolper-samuelson effect means a rise in the relative price of a good will lead to a rise in the return to that factor which is used most intensively in the production of the good, and conversely, to a fall in the return to the other factor.
with the education level of employers, but it decreases with the average education level of employees. Apart from the two variables, the other variables are not significant.

Table 6-1 Estimation of a small firm’s growth factors (8 variables)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Probit</th>
<th></th>
<th>Logit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>Prob.&gt;t</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Type</td>
<td>2.79</td>
<td>0.139</td>
<td>5.07</td>
</tr>
<tr>
<td></td>
<td>(1.89)</td>
<td>(3.55)</td>
<td></td>
</tr>
<tr>
<td>Subsidy</td>
<td>-0.57</td>
<td>0.447</td>
<td>-1.04</td>
</tr>
<tr>
<td></td>
<td>(0.76)</td>
<td>(1.34)</td>
<td></td>
</tr>
<tr>
<td>Year er</td>
<td>0.21</td>
<td>0.052**</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>Year ee</td>
<td>-0.491</td>
<td>0.004*</td>
<td>-0.87</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
<td>(0.33)</td>
<td></td>
</tr>
<tr>
<td>Export</td>
<td>-1.79</td>
<td>0.210</td>
<td>-0.30</td>
</tr>
<tr>
<td></td>
<td>(1.42)</td>
<td>(2.45)</td>
<td></td>
</tr>
<tr>
<td>Rd</td>
<td>0.51</td>
<td>0.523</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>(0.80)</td>
<td>(1.35)</td>
<td></td>
</tr>
<tr>
<td>Loan</td>
<td>0.32</td>
<td>0.731</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>(0.95)</td>
<td>(1.35)</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>0.84</td>
<td>0.205</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>(0.66)</td>
<td>(1.12)</td>
<td></td>
</tr>
</tbody>
</table>

Obs. with Dep.=0 29 Total observations 41
Obs. with Dep.=1 12

* Significance level is 1 percent.  ** Significance level is 10 percent.

Convergence achieved after 7 iterations
In Table 6-2, in order to observe and decrease the influence of multicollinearity in this regression, we eliminate three insignificant variables (Rd, Loan and Export) in the probit and logit model and get the results.

The results are slightly different. It shows that the probability of a small firm’s growth increases with the education level of employers and the type of the firm, but decreases with the average education level of employees. Except for the three variables, the other variables are insignificant.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Probit Coefficient</th>
<th>Prob.&gt;t</th>
<th>Logit Coefficient</th>
<th>Prob.&gt;t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>2.48</td>
<td>0.09**</td>
<td>4.21</td>
<td>0.10**</td>
</tr>
<tr>
<td></td>
<td>(1.48)</td>
<td></td>
<td>(2.59)</td>
<td></td>
</tr>
<tr>
<td>Subsidy</td>
<td>-0.51</td>
<td>0.41</td>
<td>-0.81</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>(0.63)</td>
<td></td>
<td>(1.10)</td>
<td></td>
</tr>
<tr>
<td>Year er</td>
<td>0.22</td>
<td>0.04**</td>
<td>0.38</td>
<td>0.05**</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td></td>
<td>(0.20)</td>
<td></td>
</tr>
<tr>
<td>Year ee</td>
<td>-0.47</td>
<td>0.002*</td>
<td>-0.82</td>
<td>0.004*</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td></td>
<td>(0.29)</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>0.70</td>
<td>0.24</td>
<td>1.22</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>(0.60)</td>
<td></td>
<td>(1.04)</td>
<td></td>
</tr>
</tbody>
</table>

Obs. with Dep.=0: 29, Total observations: 41
Obs. with Dep.=1: 12

* Significance level is 1 percent. ** Significance level is 10 percent.

Convergence achieved after 7 iterations
In Table 6-3, we change the eliminated insignificant variables (Subsidy, Export and Area) in these models and get the results. The results are different from table 6-2. The coefficients of the education level of employer, the type of firm and the average education level of employee are still significant and the sign of the variables are the same as in Table 6-1. But the coefficient of the firm’s type is significant and the sign of the type is positive. Aside from that, the other variables are insignificant.

Table 6-3 Estimation of small firm’s growth factors (5 variables)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Probit Coefficient</th>
<th>Prob. &gt;t</th>
<th>Logit Coefficient</th>
<th>Prob. &gt;t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>2.30 (1.29)</td>
<td>0.07**</td>
<td>3.87 (2.29)</td>
<td>0.09**</td>
</tr>
<tr>
<td>Rd</td>
<td>-0.11 (0.54)</td>
<td>0.82</td>
<td>-0.19 (0.92)</td>
<td>0.83</td>
</tr>
<tr>
<td>Year er</td>
<td>0.23 (0.11)</td>
<td>0.03**</td>
<td>0.42 (0.20)</td>
<td>0.04**</td>
</tr>
<tr>
<td>Year ee</td>
<td>-0.47 (0.15)</td>
<td>0.002*</td>
<td>-0.82 (0.29)</td>
<td>0.004*</td>
</tr>
<tr>
<td>Loan</td>
<td>0.13 (0.78)</td>
<td>0.86</td>
<td>0.37 (1.35)</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Obs. with Dep.=0 29, Total observations 41
Obs. with Dep.=1 12

* Significance level is 1 percent. ** 5 percent. *** 10 percent.

Convergence achieved after 6 iterations
Table 6-4 Estimation of small firm’s growth factors (3 variables)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Probit Coefficient</th>
<th>Prob. &gt;t</th>
<th>Logit Coefficient</th>
<th>Prob. &gt;t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>2.29</td>
<td>0.06***</td>
<td>3.80</td>
<td>0.08***</td>
</tr>
<tr>
<td></td>
<td>(1.25)</td>
<td></td>
<td>(2.20)</td>
<td></td>
</tr>
<tr>
<td>Year er</td>
<td>0.23</td>
<td>0.02**</td>
<td>0.40</td>
<td>0.03**</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td></td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>Year ee</td>
<td>-0.46</td>
<td>0.001*</td>
<td>-0.79</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td></td>
<td>(0.26)</td>
<td></td>
</tr>
</tbody>
</table>

Obs. with Dep.=0 29 Total observations 41
Obs. with Dep.=1 12

* Significance level is 1 percent. ** 5 percent. *** 10 percent.

Convergence achieved after 6 iterations

In Table 6-4, we just take three variables (the education level of employers and employees, the type of the company) in the probit and the logit model. The results in the both models are satisfying. All variables (the education level of employers and employees, the type of the firm) are significant. The education level of employers and the type of the firms are positively correlated to a firm’s growth, but the average education level of employees is negatively correlated to a firm’s growth.

The goal of this chapter is to investigate several econometric explanations that have been assumed to find a correlation between a firm’s growth and several other factors. The first key finding of this study is that the education level of employer is an important determinant of a firm’s growth. The correlation between a firm’s growth and the education level of employer is positive.

It may be due to the fact that a employer has a higher education level that helps
make intellectual decision to improve the firm and the firm can have a higher probability to transform into a large firm. Employers who have a higher education level also can perform tasks better in their own company.

The second key finding is that the type of the firms is also an important factor for a firm’s growth. If the firm is a corporation organization, there are more owners in a firm and they can make the policy decision together. Those policymakers can discuss and reach an optimal decision on the firm’s policy. It can decrease the occurrence of making the wrong policy and the firm could be more capable of taking on risks.

The third key finding is that the average education level of employees is a negative factor in a firm’s growth. If a firm has a higher academic level in the workforce at the start-up phase, it is not beneficial to the firm’s growth. It seems to be against conventional wisdom. Considering the special economic condition of Taiwan, the reason might be that small firms usually have a smaller amount of capital and possess lowly technology in Taiwan. It is difficult for a small firm to hire workers with a high education background and keep the workers staying in the same firm.

Inversely, it is not easy for workers with low education levels to find and get a new job in a large firm. When workers with lower academic education get a job from a small firm, they usually stick to the job for a long time and stay loyal to the firm. They could have much experience and execute the production process with fewer mistakes. It could be beneficial to a small firm’s growth.

The situation may be different in other countries, because we just use the data from Taiwan’s firms. If we could collect the data from other countries, we may obtain different results and prove that different factors would also influence a firm’s growth.
Chapter 7 Conclusion

The objective of this dissertation may shed light on the process and influence of the small firm’s transformation on economic growth. We have extended Lucas (1988) and Rebelo (1991) model and added different features of the representative firm into the model. Meanwhile, we also added the process of transformation of a small firm into a large one as an endogenous variable and investigate how the representative firm allocated its resource.

The main purpose of this dissertation is to explore the contribution and influence of large firms to economic growth and which factors could help a small firm transform into a large one successfully.

In the first part of this dissertation, we only used one-sector (production sector or goods sector) to explain the role of large firms in economic growth. Under the assumption that large firms have higher external and internal effects, we used a simple model to prove a country which has higher proportion of large firms could create a higher growth rate. But ignoring the human capital in the production function seems a problem to explain the change of economic growth; hence, we added education sector in the chapter 3 and compared the results.

In order to make the model more complete and closer to the real-life economic situation, we first combined two different kinds of firms in goods sector and added another education sector in the meanwhile. By the process of simulations, we obtained several important conclusions about the converging paths.

We found there exist several different convergence paths in an economic system which depends on the value of the parameters it faces. The high percentage of large firms is beneficial for a country’s growth, but the effect will be inconsistent with different parameters. In some conditions, there would exist multiple paths to the
steady state. It means even though two countries have the same constitution of firms, the difference in parameters, like the depreciation rate or the inverse of the intertemporal elasticity of substitution would make each country move towards its specific path and equilibrium point.

Considering the disadvantage of a small firm could not control or promote the process of transformation, we changed some assumptions about the representative firm to make the process of transforming into a large one to be an endogenous variable. It gave us another view to investigate the representative effort and decision to transformation. We used the percentage of human capital spent in education sector as a variable which related to the probability of a small firm transforming into a large one and did some simulations about the influence from each kind of parameters on the growth rate. We also used the empirical data of the world to compare with the result that we found. It has shown that the simulation was very close to the data of the real world. The ratios of small firms in most countries were very high, and the optimal value of human capital kept in goods sector in our model was also very high (the optimal value of human capital kept in goods sector is positively related to the ratio of small firms). But it was similar to the result in chapter 3, with different economic parameters the two countries with the same structure will have different growth rate and convergence paths. It could explain the divergence between countries.

In order to find the real value of external effect in production function, we tried to use the data from Taiwan and some econometric models to calculate the value. The definition of human capital is difficult and controversial, and we tried to use the divergence of the average salary according to academic degrees to represent the differences in labors. We also used four different regression methods to estimate the parameters in production. By using feasible generalized least squares (FGLS) we solved the problem about autocorrelation in error term and obtained the best result
about the ranges of external effect in Taiwan.

One of the most important things in this dissertation was to find which factors could affect the chance that a small firm transforms into a large one. For this purpose, we sent lots of questionnaires to firms in Taiwan to investigate this issue and obtained the information about them.

Considering the characteristics of the data that we have collected from the firms in Taiwan, using probit and logit models could be a way to help us find the important factors which are beneficial to the transformation of small firms. We found the education level of employer, the education level of employees and the type of the firms are important determinants for a firm’s growth, but the direction and extent of their influence are different. Because the limitation of the corrected data, we could just use the firms’ data from Taiwan to illustrate our theory. The results could be different in other countries because of the difference in labor culture and entrepreneurship.

In this dissertation, we always thought the process for small firms transforming into large ones is beneficial and positive for economic growth, but it is not the only factor to make a country continue to develop. In endogenous growth theory, there exist lots of variables that could affect economic growth, like government expenditure, the allocation of taxes, human capital and the freedom of finance, etc. In this dissertation, we hoped we could provide a different view and make some contributions to this field.

Many points in the dissertation can be studied further in the future research. First, we do not consider the role of government in this model. In fact, we found the government expenditure and the structure of taxation were related to economic growth from some literature, like Nader and Ramirez (1997), Wang and Yip (1992). Meanwhile, we also ignored the international trade in this model. We just considered
that the closed economy and the small firms grow up independently without the influence from foreign countries.

Second, the data we have collected from Taiwan can be enriched in the future. The quantity of the valid sample was not quite sufficient, and it perhaps could not thoroughly show the real factors which affect the process of a small firm’s transformation into a large one. Furthermore, we wish to consider a more realistic structure of firms such as micro-firms and international firms in the model in our future research.
References


White Paper On Small And Medium Enterprises In Taiwan (2008), Small and Medium Enterprise Administration Of The Ministry of Economic Affairs, Taiwan (R.O.C.)

Appendix A: The definition of SMEs

In Taiwan

1. In the manufacturing, construction, mining and quarrying industries, the number of regular employees must be less than 200.

2. For enterprises in the following industries, those enterprises with less than 50 regular employees are classified as small and medium enterprises: agriculture, forestry, fisheries and animal husbandry, water, electricity and gas, wholesaling and retailing, hotel and restaurant operation, transportation, warehousing and communications, finance and insurance, real estate and leasing, professional, scientific and technical services, educational services, medical, healthcare and social welfare services, cultural, sporting and leisure services; other service industries.

Source: The Small and Medium Business Administration of Economic Affair, Taiwan

http://www.moeasmea.gov.tw

In European union

<table>
<thead>
<tr>
<th>Enterprise category</th>
<th>Headcount</th>
<th>Turnover (or) Balance sheet total</th>
</tr>
</thead>
<tbody>
<tr>
<td>medium-sized</td>
<td>&lt; 250</td>
<td>≤ € 50 million</td>
</tr>
<tr>
<td>small</td>
<td>&lt; 50</td>
<td>≤ € 10 million</td>
</tr>
<tr>
<td>micro</td>
<td>&lt; 10</td>
<td>≤ € 2 million</td>
</tr>
</tbody>
</table>

Source: http://ec.europa.eu

In New Zealand

SMEs are defined as enterprises with 19 or fewer employees

Source: Ministry of Economic Development, New Zealand.

http://www.med.govt.nz
In U.S.A

- 500 employees for most manufacturing and mining industries.
- 100 employees for wholesale trade industries.
- $7 million of annual receipts for most retail and service industries.
- $33.5 million of annual receipts for most general & heavy construction industries.
- $14 million of receipts for all special trade contractors.
- $0.75 million of receipts for most agricultural industries.

Source: Small Business Administration (SBA) Size Standards Office.

In Australia

The numbers of employees

<table>
<thead>
<tr>
<th></th>
<th>Micro</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>X&lt; 5</td>
<td>5-19</td>
<td>20-200</td>
<td>200+</td>
</tr>
</tbody>
</table>

Source: Department of Resources, Energy and Tourism, Australia.
http://www.ret.gov.au

In Singapore

<table>
<thead>
<tr>
<th>Fixed assets</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>X&lt; 8 million Singapore dollars</td>
<td>X&lt; 50</td>
</tr>
</tbody>
</table>

Source: Ministry of Trade and Industry, Singapore
http://www.mti.gov.sg
### In Japan

<table>
<thead>
<tr>
<th>Sector</th>
<th>Employees</th>
<th>Turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>X&lt; 300</td>
<td>X&lt; 300 million Japanese yen</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>X&lt; 100</td>
<td>X&lt; 100 million Japanese yen</td>
</tr>
<tr>
<td>Services industry:</td>
<td>X&lt; 100</td>
<td>X&lt; 50 million Japanese yen</td>
</tr>
<tr>
<td>Retailing</td>
<td>X&lt; 50</td>
<td>X&lt; 50 million Japanese yen</td>
</tr>
</tbody>
</table>

Source: Statistics Bureau, Japan


### In South Korea

<table>
<thead>
<tr>
<th>Sector</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>X&lt; 300</td>
</tr>
<tr>
<td>Mining</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>X&lt; 200</td>
</tr>
<tr>
<td>Commerce</td>
<td></td>
</tr>
<tr>
<td>Service industries</td>
<td>X&lt; 20</td>
</tr>
</tbody>
</table>

Source: Small and Medium Business Administration, Korea

[http://www.smba.go.kr](http://www.smba.go.kr)
### In China

<table>
<thead>
<tr>
<th>Sector</th>
<th>Employees</th>
<th>Turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>X&lt; 2000</td>
<td>X&lt; 300 million RMB</td>
</tr>
<tr>
<td>Construction</td>
<td>X&lt; 3000</td>
<td>X&lt; 300 million RMB</td>
</tr>
<tr>
<td>Retailing</td>
<td>X&lt; 500</td>
<td>X&lt; 150 million RMB</td>
</tr>
<tr>
<td>Transportation</td>
<td>X&lt; 3000</td>
<td>X&lt; 300 million RMB</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>X&lt; 200</td>
<td>X&lt; 300 million RMB</td>
</tr>
<tr>
<td>Hotel and Restaurant operation</td>
<td>X&lt; 800</td>
<td>X&lt; 150 million RMB</td>
</tr>
</tbody>
</table>

Source: National Bureau of Statistics of China


### In OECD

<table>
<thead>
<tr>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>Small</td>
</tr>
<tr>
<td>Very small</td>
</tr>
</tbody>
</table>

| 500 ≤ X                    |
| 100-499                    |
| 20-99                      |
| X ≤ 19                     |

Source: Organisation for Economic Cooperation and Development (OECD)
### Appendix B: The data of Taiwan and other countries

Table A-1 Correlative indicators of nation income in Taiwan

<table>
<thead>
<tr>
<th>Year</th>
<th>Industrial Production Index (2001=100)</th>
<th>Percentage Distribution (%)</th>
<th>Unemployment Rate</th>
<th>Annual Changes in CPI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Agriculture</td>
<td>Industry</td>
<td>Services</td>
</tr>
<tr>
<td>1951</td>
<td>0.73</td>
<td>56.69</td>
<td>16.31</td>
<td>27.00</td>
</tr>
<tr>
<td>1952</td>
<td>0.92</td>
<td>56.06</td>
<td>16.90</td>
<td>27.04</td>
</tr>
<tr>
<td>1953</td>
<td>1.15</td>
<td>55.57</td>
<td>17.61</td>
<td>26.82</td>
</tr>
<tr>
<td>1954</td>
<td>1.21</td>
<td>54.76</td>
<td>17.71</td>
<td>27.53</td>
</tr>
<tr>
<td>1955</td>
<td>1.38</td>
<td>53.63</td>
<td>18.02</td>
<td>28.35</td>
</tr>
<tr>
<td>1956</td>
<td>1.42</td>
<td>53.19</td>
<td>18.32</td>
<td>28.49</td>
</tr>
<tr>
<td>1957</td>
<td>1.60</td>
<td>52.31</td>
<td>18.95</td>
<td>28.74</td>
</tr>
<tr>
<td>1958</td>
<td>1.74</td>
<td>51.11</td>
<td>19.73</td>
<td>29.16</td>
</tr>
<tr>
<td>1959</td>
<td>1.95</td>
<td>50.32</td>
<td>20.31</td>
<td>29.37</td>
</tr>
<tr>
<td>1960</td>
<td>2.22</td>
<td>50.16</td>
<td>20.53</td>
<td>29.31</td>
</tr>
<tr>
<td>1961</td>
<td>2.57</td>
<td>49.84</td>
<td>20.89</td>
<td>29.27</td>
</tr>
<tr>
<td>1962</td>
<td>2.77</td>
<td>49.70</td>
<td>21.04</td>
<td>29.26</td>
</tr>
<tr>
<td>1963</td>
<td>3.03</td>
<td>49.42</td>
<td>21.27</td>
<td>29.31</td>
</tr>
<tr>
<td>1964</td>
<td>3.67</td>
<td>49.48</td>
<td>21.30</td>
<td>29.22</td>
</tr>
<tr>
<td>1965</td>
<td>4.27</td>
<td>46.45</td>
<td>22.30</td>
<td>31.25</td>
</tr>
<tr>
<td>1966</td>
<td>4.94</td>
<td>44.99</td>
<td>22.59</td>
<td>32.42</td>
</tr>
<tr>
<td>1967</td>
<td>5.76</td>
<td>42.54</td>
<td>24.57</td>
<td>32.89</td>
</tr>
<tr>
<td>1968</td>
<td>7.05</td>
<td>40.83</td>
<td>25.37</td>
<td>33.80</td>
</tr>
<tr>
<td>1969</td>
<td>8.45</td>
<td>39.32</td>
<td>26.31</td>
<td>34.37</td>
</tr>
<tr>
<td>1970</td>
<td>10.16</td>
<td>36.73</td>
<td>27.93</td>
<td>35.34</td>
</tr>
<tr>
<td>1971</td>
<td>12.54</td>
<td>35.14</td>
<td>29.91</td>
<td>34.95</td>
</tr>
<tr>
<td>1972</td>
<td>15.20</td>
<td>32.98</td>
<td>31.83</td>
<td>35.19</td>
</tr>
<tr>
<td>1973</td>
<td>17.67</td>
<td>30.49</td>
<td>33.70</td>
<td>35.81</td>
</tr>
<tr>
<td>1974</td>
<td>16.87</td>
<td>30.93</td>
<td>34.31</td>
<td>34.76</td>
</tr>
<tr>
<td>1975</td>
<td>18.46</td>
<td>30.45</td>
<td>34.90</td>
<td>34.65</td>
</tr>
<tr>
<td>1976</td>
<td>22.77</td>
<td>28.95</td>
<td>36.43</td>
<td>34.62</td>
</tr>
<tr>
<td>1977</td>
<td>25.81</td>
<td>26.71</td>
<td>37.63</td>
<td>35.66</td>
</tr>
<tr>
<td>1978</td>
<td>31.63</td>
<td>24.92</td>
<td>39.48</td>
<td>35.61</td>
</tr>
<tr>
<td>Year</td>
<td>Value1</td>
<td>Value2</td>
<td>Value3</td>
<td>Value4</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>1979</td>
<td>33.64</td>
<td>21.46</td>
<td>41.60</td>
<td>36.92</td>
</tr>
<tr>
<td>1970</td>
<td>35.95</td>
<td>19.51</td>
<td>42.52</td>
<td>37.99</td>
</tr>
<tr>
<td>1981</td>
<td>37.21</td>
<td>18.84</td>
<td>42.39</td>
<td>38.77</td>
</tr>
<tr>
<td>1982</td>
<td>36.89</td>
<td>18.85</td>
<td>41.30</td>
<td>39.83</td>
</tr>
<tr>
<td>1983</td>
<td>41.56</td>
<td>18.63</td>
<td>41.15</td>
<td>40.23</td>
</tr>
<tr>
<td>1984</td>
<td>46.48</td>
<td>17.60</td>
<td>42.27</td>
<td>40.15</td>
</tr>
<tr>
<td>1985</td>
<td>47.72</td>
<td>17.46</td>
<td>41.57</td>
<td>40.98</td>
</tr>
<tr>
<td>1986</td>
<td>54.40</td>
<td>17.03</td>
<td>41.58</td>
<td>41.39</td>
</tr>
<tr>
<td>1987</td>
<td>60.18</td>
<td>15.28</td>
<td>42.77</td>
<td>41.96</td>
</tr>
<tr>
<td>1988</td>
<td>62.74</td>
<td>13.73</td>
<td>42.47</td>
<td>43.80</td>
</tr>
<tr>
<td>1989</td>
<td>65.10</td>
<td>12.91</td>
<td>42.09</td>
<td>45.01</td>
</tr>
<tr>
<td>1990</td>
<td>64.96</td>
<td>12.85</td>
<td>40.83</td>
<td>46.32</td>
</tr>
<tr>
<td>1991</td>
<td>69.76</td>
<td>12.95</td>
<td>39.93</td>
<td>47.13</td>
</tr>
<tr>
<td>1992</td>
<td>72.84</td>
<td>12.34</td>
<td>39.61</td>
<td>48.05</td>
</tr>
<tr>
<td>1993</td>
<td>75.65</td>
<td>11.49</td>
<td>39.09</td>
<td>49.43</td>
</tr>
<tr>
<td>1994</td>
<td>80.65</td>
<td>10.92</td>
<td>39.22</td>
<td>49.85</td>
</tr>
<tr>
<td>1995</td>
<td>84.51</td>
<td>10.55</td>
<td>38.74</td>
<td>50.71</td>
</tr>
<tr>
<td>1996</td>
<td>86.09</td>
<td>10.12</td>
<td>37.48</td>
<td>52.39</td>
</tr>
<tr>
<td>1997</td>
<td>91.39</td>
<td>9.57</td>
<td>38.16</td>
<td>52.26</td>
</tr>
<tr>
<td>1998</td>
<td>94.49</td>
<td>8.85</td>
<td>37.93</td>
<td>53.22</td>
</tr>
<tr>
<td>1999</td>
<td>101.45</td>
<td>8.25</td>
<td>37.21</td>
<td>54.53</td>
</tr>
<tr>
<td>2000</td>
<td>108.47</td>
<td>7.78</td>
<td>37.24</td>
<td>55.00</td>
</tr>
<tr>
<td>2001</td>
<td>100.00</td>
<td>7.52</td>
<td>35.99</td>
<td>56.47</td>
</tr>
<tr>
<td>2002</td>
<td>107.92</td>
<td>7.50</td>
<td>35.24</td>
<td>57.26</td>
</tr>
<tr>
<td>2003</td>
<td>115.61</td>
<td>7.27</td>
<td>34.83</td>
<td>57.90</td>
</tr>
<tr>
<td>2004</td>
<td>126.96</td>
<td>6.56</td>
<td>35.21</td>
<td>58.23</td>
</tr>
<tr>
<td>2005</td>
<td>132.75</td>
<td>5.94</td>
<td>35.79</td>
<td>58.27</td>
</tr>
<tr>
<td>2006</td>
<td>139.38</td>
<td>5.49</td>
<td>36.02</td>
<td>58.49</td>
</tr>
</tbody>
</table>

Source: National Statistics, R.O.C.(Taiwan)
Table A-2 The employee’s educational level in Taiwan

<table>
<thead>
<tr>
<th>Year</th>
<th>The number of employee(Thousand people)</th>
<th>primary education or lower (h \leq 9 year)</th>
<th>secondary education (9 &lt; h \leq 12 year)</th>
<th>higher education (h &gt; 12 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>Man</td>
<td>Woman</td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>6231</td>
<td>4183</td>
<td>2048</td>
<td>4660</td>
</tr>
<tr>
<td>1979</td>
<td>6432</td>
<td>4306</td>
<td>2126</td>
<td>4699</td>
</tr>
<tr>
<td>1980</td>
<td>6547</td>
<td>4357</td>
<td>2191</td>
<td>4588</td>
</tr>
<tr>
<td>1981</td>
<td>6672</td>
<td>4448</td>
<td>2224</td>
<td>4589</td>
</tr>
<tr>
<td>1982</td>
<td>6811</td>
<td>4509</td>
<td>2301</td>
<td>4587</td>
</tr>
<tr>
<td>1983</td>
<td>7070</td>
<td>4561</td>
<td>2509</td>
<td>4672</td>
</tr>
<tr>
<td>1984</td>
<td>7308</td>
<td>4661</td>
<td>2647</td>
<td>4715</td>
</tr>
<tr>
<td>1985</td>
<td>7428</td>
<td>4719</td>
<td>2709</td>
<td>4703</td>
</tr>
<tr>
<td>1986</td>
<td>7733</td>
<td>4821</td>
<td>2912</td>
<td>4762</td>
</tr>
<tr>
<td>1987</td>
<td>8022</td>
<td>4966</td>
<td>3057</td>
<td>4779</td>
</tr>
<tr>
<td>1988</td>
<td>8107</td>
<td>5043</td>
<td>3064</td>
<td>4655</td>
</tr>
<tr>
<td>1989</td>
<td>8258</td>
<td>5149</td>
<td>3110</td>
<td>4603</td>
</tr>
<tr>
<td>1990</td>
<td>8283</td>
<td>5175</td>
<td>3108</td>
<td>4456</td>
</tr>
<tr>
<td>1991</td>
<td>8439</td>
<td>5274</td>
<td>3165</td>
<td>4460</td>
</tr>
<tr>
<td>1992</td>
<td>8632</td>
<td>5380</td>
<td>3252</td>
<td>4414</td>
</tr>
<tr>
<td>1993</td>
<td>8745</td>
<td>5422</td>
<td>3323</td>
<td>4265</td>
</tr>
<tr>
<td>1994</td>
<td>8939</td>
<td>5511</td>
<td>3428</td>
<td>4262</td>
</tr>
<tr>
<td>1995</td>
<td>9045</td>
<td>5558</td>
<td>3487</td>
<td>4180</td>
</tr>
<tr>
<td>1996</td>
<td>9068</td>
<td>5508</td>
<td>3560</td>
<td>3953</td>
</tr>
<tr>
<td>1997</td>
<td>9176</td>
<td>5562</td>
<td>3613</td>
<td>3877</td>
</tr>
<tr>
<td>1998</td>
<td>9289</td>
<td>5610</td>
<td>3679</td>
<td>3762</td>
</tr>
<tr>
<td>1999</td>
<td>9385</td>
<td>5624</td>
<td>3761</td>
<td>3609</td>
</tr>
<tr>
<td>2000</td>
<td>9491</td>
<td>5670</td>
<td>3821</td>
<td>3520</td>
</tr>
<tr>
<td>2001</td>
<td>9383</td>
<td>5553</td>
<td>3830</td>
<td>3318</td>
</tr>
<tr>
<td>2002</td>
<td>9454</td>
<td>5547</td>
<td>3907</td>
<td>3179</td>
</tr>
<tr>
<td>2003</td>
<td>9573</td>
<td>5579</td>
<td>3994</td>
<td>3063</td>
</tr>
<tr>
<td>2004</td>
<td>9786</td>
<td>5680</td>
<td>4106</td>
<td>2975</td>
</tr>
<tr>
<td>2005</td>
<td>9942</td>
<td>5753</td>
<td>4190</td>
<td>2880</td>
</tr>
<tr>
<td>2006</td>
<td>10111</td>
<td>5810</td>
<td>4301</td>
<td>2770</td>
</tr>
<tr>
<td>2007</td>
<td>10294</td>
<td>5868</td>
<td>4426</td>
<td>2689</td>
</tr>
</tbody>
</table>

Source: National Statistics, R.O.C.(Taiwan)
Table A-3 The proportion of large firms and SME in Taiwan

<table>
<thead>
<tr>
<th>Year</th>
<th>All Firms</th>
<th>Large Firms</th>
<th>Small and Medium firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>706,526</td>
<td>10,088</td>
<td>696,438</td>
</tr>
<tr>
<td>1984</td>
<td>731,610</td>
<td>12,170</td>
<td>719,440</td>
</tr>
<tr>
<td>1985</td>
<td>727,230</td>
<td>11,006</td>
<td>716,224</td>
</tr>
<tr>
<td>1986</td>
<td>751,273</td>
<td>13,923</td>
<td>737,350</td>
</tr>
<tr>
<td>1987</td>
<td>761,553</td>
<td>18,279</td>
<td>743,274</td>
</tr>
<tr>
<td>1988</td>
<td>791,592</td>
<td>18,081</td>
<td>773,511</td>
</tr>
<tr>
<td>1989</td>
<td>798,865</td>
<td>20,823</td>
<td>778,042</td>
</tr>
<tr>
<td>1990</td>
<td>818,061</td>
<td>23,227</td>
<td>794,834</td>
</tr>
<tr>
<td>1991</td>
<td>850,679</td>
<td>25,123</td>
<td>825,556</td>
</tr>
<tr>
<td>1992</td>
<td>900,801</td>
<td>29,075</td>
<td>871,726</td>
</tr>
<tr>
<td>1993</td>
<td>934,588</td>
<td>32,820</td>
<td>901,768</td>
</tr>
<tr>
<td>1994</td>
<td>969,094</td>
<td>36,242</td>
<td>932,852</td>
</tr>
<tr>
<td>1995</td>
<td>1,012,212</td>
<td>20,597</td>
<td>991,615</td>
</tr>
<tr>
<td>1996</td>
<td>1,024,360</td>
<td>21,035</td>
<td>1,003,325</td>
</tr>
<tr>
<td>1997</td>
<td>1,043,286</td>
<td>22,851</td>
<td>1,020,435</td>
</tr>
<tr>
<td>1998</td>
<td>1,069,116</td>
<td>23,999</td>
<td>1,045,117</td>
</tr>
<tr>
<td>1999</td>
<td>1,085,430</td>
<td>24,692</td>
<td>1,060,738</td>
</tr>
<tr>
<td>2000</td>
<td>1,091,245</td>
<td>20,935</td>
<td>1,070,310</td>
</tr>
<tr>
<td>2001</td>
<td>1,098,185</td>
<td>20,023</td>
<td>1,078,162</td>
</tr>
<tr>
<td>2002</td>
<td>1,130,525</td>
<td>25,819</td>
<td>1,104,706</td>
</tr>
<tr>
<td>2003</td>
<td>1,171,780</td>
<td>24,580</td>
<td>1,147,200</td>
</tr>
<tr>
<td>2004</td>
<td>1,190,176</td>
<td>13,190</td>
<td>1,176,986</td>
</tr>
<tr>
<td>2005</td>
<td>1,253,604</td>
<td>27,509</td>
<td>1,226,095</td>
</tr>
<tr>
<td>2006</td>
<td>1,275,508</td>
<td>31,409</td>
<td>1,244,099</td>
</tr>
</tbody>
</table>

Source: Small and Medium Enterprise Administration.(Taiwan)
Table A-4 Series of real net fixed capital stock (excluded land) of industrial &
service sectors (million NT$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Industrial Sector</th>
<th>Service Sector</th>
<th>Total Capital Stock</th>
<th>Capital Stock Per capita (NT.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>664672</td>
<td>349407</td>
<td>1014079</td>
<td>67,276.88</td>
</tr>
<tr>
<td>1972</td>
<td>729766</td>
<td>395290</td>
<td>1125056</td>
<td>73,208.78</td>
</tr>
<tr>
<td>1973</td>
<td>808720</td>
<td>436985</td>
<td>1245705</td>
<td>79,636.10</td>
</tr>
<tr>
<td>1974</td>
<td>905934</td>
<td>474818</td>
<td>1380752</td>
<td>86,691.63</td>
</tr>
<tr>
<td>1975</td>
<td>1030681</td>
<td>514698</td>
<td>1545379</td>
<td>95,258.00</td>
</tr>
<tr>
<td>1976</td>
<td>1165377</td>
<td>567827</td>
<td>1733204</td>
<td>104,537.48</td>
</tr>
<tr>
<td>1977</td>
<td>1283065</td>
<td>637580</td>
<td>1920645</td>
<td>113,768.45</td>
</tr>
<tr>
<td>1978</td>
<td>1390551</td>
<td>730758</td>
<td>2121309</td>
<td>123,314.06</td>
</tr>
<tr>
<td>1979</td>
<td>1515329</td>
<td>850782</td>
<td>2366111</td>
<td>134,874.42</td>
</tr>
<tr>
<td>1980</td>
<td>1675693</td>
<td>994555</td>
<td>2670248</td>
<td>149,459.69</td>
</tr>
<tr>
<td>1981</td>
<td>1805727</td>
<td>1189811</td>
<td>2995538</td>
<td>164,644.69</td>
</tr>
<tr>
<td>1982</td>
<td>1962283</td>
<td>1314119</td>
<td>3276402</td>
<td>176,952.12</td>
</tr>
<tr>
<td>1983</td>
<td>2095272</td>
<td>1414077</td>
<td>3509349</td>
<td>186,761.50</td>
</tr>
<tr>
<td>1984</td>
<td>2223452</td>
<td>1509516</td>
<td>3732968</td>
<td>195,759.09</td>
</tr>
<tr>
<td>1985</td>
<td>2326259</td>
<td>1594972</td>
<td>3921231</td>
<td>203,027.16</td>
</tr>
<tr>
<td>1986</td>
<td>2416925</td>
<td>1673085</td>
<td>4090010</td>
<td>209,646.46</td>
</tr>
<tr>
<td>1987</td>
<td>2543114</td>
<td>1760222</td>
<td>4303336</td>
<td>218,166.48</td>
</tr>
<tr>
<td>1988</td>
<td>2701194</td>
<td>1868201</td>
<td>4569395</td>
<td>228,991.89</td>
</tr>
<tr>
<td>1989</td>
<td>2868750</td>
<td>1984401</td>
<td>4853151</td>
<td>240,772.46</td>
</tr>
<tr>
<td>1990</td>
<td>3039802</td>
<td>2102347</td>
<td>5142149</td>
<td>252,050.00</td>
</tr>
<tr>
<td>1991</td>
<td>3209033</td>
<td>2227791</td>
<td>5436824</td>
<td>263,848.81</td>
</tr>
<tr>
<td>1992</td>
<td>3388321</td>
<td>2373825</td>
<td>5762146</td>
<td>276,991.33</td>
</tr>
<tr>
<td>1993</td>
<td>3565493</td>
<td>2533074</td>
<td>6098567</td>
<td>290,471.36</td>
</tr>
<tr>
<td>1994</td>
<td>3749083</td>
<td>2688467</td>
<td>6437550</td>
<td>303,975.27</td>
</tr>
<tr>
<td>1995</td>
<td>3988205</td>
<td>2859611</td>
<td>6847816</td>
<td>320,629.20</td>
</tr>
<tr>
<td>1996</td>
<td>4271214</td>
<td>3048633</td>
<td>7319847</td>
<td>340,055.74</td>
</tr>
<tr>
<td>1997</td>
<td>4630338</td>
<td>3255567</td>
<td>7885905</td>
<td>362,690.16</td>
</tr>
<tr>
<td>1998</td>
<td>5083671</td>
<td>3518020</td>
<td>8601691</td>
<td>392,259.17</td>
</tr>
<tr>
<td>1999</td>
<td>5588544</td>
<td>3787192</td>
<td>9375736</td>
<td>424,387.64</td>
</tr>
<tr>
<td>2000</td>
<td>6206979</td>
<td>4019675</td>
<td>10226654</td>
<td>459,074.59</td>
</tr>
<tr>
<td>2001</td>
<td>6725050</td>
<td>4204975</td>
<td>10930025</td>
<td>487,826.28</td>
</tr>
<tr>
<td>2002</td>
<td>7221185</td>
<td>4364231</td>
<td>11585416</td>
<td>514,432.36</td>
</tr>
</tbody>
</table>

Source: National Statistics, R.O.C.(Taiwan)  
Base period: 1996 year
Table A-5 The proportion of SME in South Korea

<table>
<thead>
<tr>
<th>Year</th>
<th>GDP</th>
<th>All Firms</th>
<th>Large Firms</th>
<th>Small and Medium firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>13,376.15</td>
<td>2,382,571</td>
<td>17,253</td>
<td>2,365,318</td>
</tr>
<tr>
<td>1995</td>
<td>14,736.43</td>
<td>2,622,259</td>
<td>20,506</td>
<td>2,601,753</td>
</tr>
<tr>
<td>1996</td>
<td>15,650.24</td>
<td>2,648,261</td>
<td>19,212</td>
<td>2,629,049</td>
</tr>
<tr>
<td>1997</td>
<td>15,956.8</td>
<td>2,689,557</td>
<td>18,932</td>
<td>2,670,625</td>
</tr>
<tr>
<td>1998</td>
<td>14,685.35</td>
<td>2,622,356</td>
<td>17,132</td>
<td>2,605,224</td>
</tr>
<tr>
<td>1999</td>
<td>15,863.67</td>
<td>2,758,627</td>
<td>18,844</td>
<td>2,739,783</td>
</tr>
<tr>
<td>2000</td>
<td>16,890.31</td>
<td>2,729,957</td>
<td>22,152</td>
<td>2,707,805</td>
</tr>
<tr>
<td>2001</td>
<td>17,575.33</td>
<td>2,658,860</td>
<td>9,169</td>
<td>2,649,691</td>
</tr>
<tr>
<td>2002</td>
<td>18,921.85</td>
<td>2,861,830</td>
<td>4,917</td>
<td>2,856,913</td>
</tr>
<tr>
<td>2003</td>
<td>19,696.55</td>
<td>2,939,661</td>
<td>4,764</td>
<td>2,934,897</td>
</tr>
<tr>
<td>2004</td>
<td>21,088.12</td>
<td>2,927,436</td>
<td>4,903</td>
<td>2,922,533</td>
</tr>
<tr>
<td>2005</td>
<td>22,048.39</td>
<td>2,867,749</td>
<td>4,166</td>
<td>2,863,583</td>
</tr>
<tr>
<td>2006</td>
<td>23,323.5</td>
<td>2,940,345</td>
<td>4,231</td>
<td>2,936,114</td>
</tr>
<tr>
<td>2007</td>
<td>24,949.65</td>
<td>2,976,646</td>
<td>2,461</td>
<td>2,974,185</td>
</tr>
</tbody>
</table>

Source: The Small and Medium Business Administration of Korea.

Table A-6 The proportion of SME in India

<table>
<thead>
<tr>
<th>Year</th>
<th>GDP</th>
<th>Small and Medium firms</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>1,603.65</td>
<td>7,0630</td>
<td>0.959334</td>
</tr>
<tr>
<td>1993</td>
<td>1,670.5</td>
<td>7,3510</td>
<td>0.959224</td>
</tr>
<tr>
<td>1994</td>
<td>1,763.1</td>
<td>7,6490</td>
<td>0.959461</td>
</tr>
<tr>
<td>1995</td>
<td>1,906.67</td>
<td>7,9600</td>
<td>0.959341</td>
</tr>
<tr>
<td>1996</td>
<td>1,969.89</td>
<td>8,2840</td>
<td>0.959296</td>
</tr>
<tr>
<td>1997</td>
<td>2,075.23</td>
<td>8,6210</td>
<td>0.959319</td>
</tr>
<tr>
<td>1998</td>
<td>2,193.85</td>
<td>8,9710</td>
<td>0.959401</td>
</tr>
<tr>
<td>1999</td>
<td>2,395.61</td>
<td>9,3360</td>
<td>0.959313</td>
</tr>
<tr>
<td>2000</td>
<td>2,456.5</td>
<td>9,7150</td>
<td>0.959404</td>
</tr>
<tr>
<td>2001</td>
<td>2,580.39</td>
<td>1,01100</td>
<td>0.959341</td>
</tr>
<tr>
<td>2002</td>
<td>2,650.86</td>
<td>1,05210</td>
<td>0.959347</td>
</tr>
<tr>
<td>2003</td>
<td>2,832.85</td>
<td>1,09490</td>
<td>0.959319</td>
</tr>
<tr>
<td>2004</td>
<td>3,053.04</td>
<td>1,13950</td>
<td>0.959266</td>
</tr>
</tbody>
</table>

Table A-7 The size distribution of manufacturing industry among countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>1-19</th>
<th>20-99</th>
<th>100-499</th>
<th>500+</th>
<th>1-19</th>
<th>20-99</th>
<th>100-499</th>
<th>500+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1994</td>
<td>82.0</td>
<td>14.1</td>
<td>3.4</td>
<td>0.4</td>
<td>22.3</td>
<td>27.5</td>
<td>32.7</td>
<td>17.5</td>
</tr>
<tr>
<td>Austria</td>
<td>1993</td>
<td>43.2</td>
<td>41.5</td>
<td>10.0</td>
<td>5.2</td>
<td>4.3</td>
<td>26.9</td>
<td>23.4</td>
<td>45.5</td>
</tr>
<tr>
<td>Canada</td>
<td>1994</td>
<td>50.6</td>
<td>37.8</td>
<td>10.2</td>
<td>1.4</td>
<td>7.6</td>
<td>27.8</td>
<td>39.4</td>
<td>25.2</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1995</td>
<td>94.9</td>
<td>2.9</td>
<td>1.6</td>
<td>0.5</td>
<td>18.0</td>
<td>10.3</td>
<td>24.6</td>
<td>47.1</td>
</tr>
<tr>
<td>Germany</td>
<td>1993</td>
<td>71.5</td>
<td>19.4</td>
<td>4.1</td>
<td>5.0</td>
<td>19.9</td>
<td>22.1</td>
<td>10.8</td>
<td>47.2</td>
</tr>
<tr>
<td>Greece</td>
<td>1992</td>
<td>59.0</td>
<td>34.3</td>
<td>6.0</td>
<td>0.7</td>
<td>20.4</td>
<td>35.0</td>
<td>27.5</td>
<td>17.2</td>
</tr>
<tr>
<td>Italy</td>
<td>1992</td>
<td>89.7</td>
<td>9.0</td>
<td>1.2</td>
<td>0.2</td>
<td>38.7</td>
<td>25.0</td>
<td>17.3</td>
<td>19.0</td>
</tr>
<tr>
<td>Japan</td>
<td>1994</td>
<td>74.3</td>
<td>21.6</td>
<td>3.6</td>
<td>0.5</td>
<td>22.4</td>
<td>30.9</td>
<td>25.0</td>
<td>21.6</td>
</tr>
<tr>
<td>Korea</td>
<td>1994</td>
<td>69.5</td>
<td>26.1</td>
<td>3.0</td>
<td>1.3</td>
<td>20.5</td>
<td>32.0</td>
<td>14.2</td>
<td>33.3</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>1992</td>
<td>79.4</td>
<td>15.0</td>
<td>4.7</td>
<td>0.9</td>
<td>13.0</td>
<td>22.1</td>
<td>35.0</td>
<td>29.9</td>
</tr>
<tr>
<td>Mexico</td>
<td>1994</td>
<td>80.3</td>
<td>15.1</td>
<td>2.7</td>
<td>2.0</td>
<td>12.2</td>
<td>21.2</td>
<td>15.6</td>
<td>51.0</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1993</td>
<td>78.0</td>
<td>17.2</td>
<td>4.3</td>
<td>0.6</td>
<td>15.7</td>
<td>24.8</td>
<td>27.8</td>
<td>31.7</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1994</td>
<td>90.6</td>
<td>7.7</td>
<td>1.5</td>
<td>0.3</td>
<td>27.3</td>
<td>24.7</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Norway</td>
<td>1994</td>
<td>40.2</td>
<td>47.4</td>
<td>7.5</td>
<td>4.9</td>
<td>9.3</td>
<td>34.9</td>
<td>18.2</td>
<td>37.6</td>
</tr>
<tr>
<td>Portugal</td>
<td>1994</td>
<td>85.8</td>
<td>11.8</td>
<td>2.2</td>
<td>0.2</td>
<td>23.5</td>
<td>32.3</td>
<td>27.8</td>
<td>16.5</td>
</tr>
<tr>
<td>Sweden</td>
<td>1993</td>
<td>44.4</td>
<td>40.8</td>
<td>12.4</td>
<td>2.4</td>
<td>6.9</td>
<td>23.1</td>
<td>35.3</td>
<td>34.7</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1991</td>
<td>84.2</td>
<td>12.3</td>
<td>3.1</td>
<td>0.4</td>
<td>20.2</td>
<td>26.9</td>
<td>31.3</td>
<td>21.5</td>
</tr>
<tr>
<td>Turkey</td>
<td>1992</td>
<td>36.6</td>
<td>47.1</td>
<td>13.3</td>
<td>3.0</td>
<td>5.5</td>
<td>22.2</td>
<td>32.2</td>
<td>40.1</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1994</td>
<td>82.7</td>
<td>12.9</td>
<td>3.7</td>
<td>0.8</td>
<td>13.2</td>
<td>21.6</td>
<td>28.9</td>
<td>36.3</td>
</tr>
<tr>
<td>United States</td>
<td>1993</td>
<td>73.7</td>
<td>19.8</td>
<td>5.1</td>
<td>1.4</td>
<td>7.4</td>
<td>14.6</td>
<td>16.5</td>
<td>61.5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>70.5</td>
<td>22.7</td>
<td>5.2</td>
<td>1.6</td>
<td>16.4</td>
<td>25.3</td>
<td>25.4</td>
<td>32.9</td>
</tr>
</tbody>
</table>

Source: OECD, Small Business, Job Creation and Growth: Facts, Obstacles and Best Practices (Paris: OECD, 1997), Table 1.1.
Appendix C: The result of questionnaire

The result of questionnaire

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturing</th>
<th>Commercial</th>
<th>Hotel and restaurant</th>
<th>Leisure service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large firms</td>
<td>11</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small firms</td>
<td>15</td>
<td>9</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total questionnaires</th>
<th>The number of responses</th>
<th>The response rate</th>
<th>The valid sample</th>
<th>Large firms</th>
<th>Small firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>42</td>
<td>14%</td>
<td>41</td>
<td>12</td>
<td>29</td>
</tr>
</tbody>
</table>

Invalid sample:

- Large firms: 1
- Small firms: 1
- Invalid sample: 1
The questions I designed in the questionnaire

1. What is the age and educational level of boss in your company?
   (Elementary school=6, Junior high school=9, Senior high school=12, Bachelor=15, Master=17, Doctor=21)

2. What kind of company do you have? (Single owner, corporation organization)
   (Single owner=0, corporation organization=1)

3. What is the average educational level of employee in your company?
   (Elementary school=6, Junior high school=9, Senior high school=12, Bachelor=15, Master=17, Doctor=21)

4. Have your company ever received any subsidy from government or any organization?
   (Never receive subsidy=0, ever receive subsidy=1)

5. How many percent product are exported to foreign countries?
   (The value from 0~1, for example, 78 percent=0.78)

6. Is there any research department in your company? If there is, How many percent expenditure do the research department have?
   (Don’t have research department=0, with research department=1)

7. Have your company ever borrowed capital from bank?
   (Never=0, at least one=1)

8. Where is your company’s location? Is it in industry area?
   (Not in industry area=0, in industry area=1)
Appendix D: The data and the variables in regression

Type: The sort of company.
Subsidy: If the firm receive any subsidy from government
Year er: The academic years of employer.
Year ee: The average academic years of employees.
Export: The ratio of production are exported to foreign countries.
Rd: If the firm had research department.
Loan: If the firm borrowed money from bank.
Area: If the firm was in industry area.

Table A-8 The data in regression

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Subsidy</th>
<th>Year er</th>
<th>Year ee</th>
<th>Export</th>
<th>Rd</th>
<th>Loan</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm 1</td>
<td>L</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 2</td>
<td>L</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 3</td>
<td>L</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 4</td>
<td>L</td>
<td>0</td>
<td>9</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 5</td>
<td>L</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 6</td>
<td>L</td>
<td>0</td>
<td>12</td>
<td>6</td>
<td>0.8</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 7</td>
<td>L</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 8</td>
<td>L</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 9</td>
<td>L</td>
<td>0</td>
<td>16</td>
<td>14</td>
<td>0.49</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Firm 10</td>
<td>L</td>
<td>0</td>
<td>14</td>
<td>14</td>
<td>0.4</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 11</td>
<td>L</td>
<td>0</td>
<td>18</td>
<td>12</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 12</td>
<td>L</td>
<td>0</td>
<td>14</td>
<td>9</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Larg e=L Sma ll=S</td>
<td>Type</td>
<td>Subsidy</td>
<td>Year er</td>
<td>Year ee</td>
<td>Export</td>
<td>Rd</td>
<td>Loan</td>
<td>Area</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>--------</td>
<td>-----</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Firm 13</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>12</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 14</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 15</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 16</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 17</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 18</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 19</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 20</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 21</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 22</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 23</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>12</td>
<td>0.25</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 24</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 25</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 26</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Firm 27</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 28</td>
<td>S</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 29</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>11</td>
<td>0.85</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 30</td>
<td>S</td>
<td>0</td>
<td>1</td>
<td>16</td>
<td>12</td>
<td>0.1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 31</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 32</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>12</td>
<td>0.05</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 33</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 34</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>14</td>
<td>12</td>
<td>0.8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 35</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>14</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 36</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>14</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Firm 37</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>14</td>
<td>0.1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 38</td>
<td>S</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 39</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>11</td>
<td>0.2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 40</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>14</td>
<td>0.4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Firm 41</td>
<td>S</td>
<td>1</td>
<td>0</td>
<td>14</td>
<td>12</td>
<td>0.75</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>0.6829</strong></td>
<td><strong>0.3170</strong></td>
<td><strong>12.4634</strong></td>
<td><strong>11.6585</strong></td>
<td><strong>0.1717</strong></td>
<td><strong>0.4390</strong></td>
<td><strong>0.1463</strong></td>
</tr>
</tbody>
</table>
Curriculum Vitae

Name: Ping-Hua Ho

Date and Place of Birth: 16. October. 1972 in Ping-Tung, Taiwan

Education:
07. 06. 2011 Ph.D. Defense

10. 2006 – 06. 2011 Ph.D. student at Department of Business administration and Economics, Bielefeld University, Germany

10. 2005 – 08. 2006 German Study, Bildungswerk des Bielefelder Schulvereins e.V., Bielefeld, Germany

09. 1999 – 06. 2001 MA at Graduate Institute of Economics, National Chi-Nan University, Nantou Country, Taiwan

09. 1992 – 06. 1996 BA at Department of Economics Tung-Hai University, Taichung, Taiwan

Profession:
07. 2001 – 07. 2002 Research Assistant, Department of Politics, National Chung-Cheng University, Chaiyi Country, Taiwan

08. 2002 – 04. 2004 Senior Research Analyst, Taiwan Research Institute, Taipei, Taiwan

07. 2004 – 07. 2005 Research Assistant, Department of Economics, Soochow University, Taipei, Taiwan
Gedruckt auf alterungsbeständigem Papier - ISO 9706