Revisiting Taiwanese Economic Growth from 1961 to 2002

Through the Lens of a Neoclassical Model

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Abstract

This paper studies the sources of growth for Taiwan from 1961 to 2002 using a diagnostic tool, known as business cycle accounting, developed in the recent business cycle literature. The results show that the path of Taiwanese growth would not have been achieved without improvements in total factor productivity (TFP). In addition, there are significant distortions in capital markets in the equilibrium investment decisions of agents operating in otherwise competitive capital markets. Finally, frictions in labor markets also contribute to growth but are minor relative to TFP growth and frictions in capital markets.

Keywords: Source of Growth, Taiwanese Economy
JEL Classification: O11, O53

1. Introduction

The focal point of this paper is to use a neoclassical model to understand the sources of growth in Taiwan from 1961 to 2002. Despite the tremendous amount of research that has been conducted on East Asian growth, most literature uses growth accounting which only focuses on the production side to identify the source of growth for these countries. In this paper, I apply a diagnostic tool, known as business cycle accounting (Cole and Ohanian, 1999 and Chari, Kehoe and McGrattan 2004) to the Taiwanese case. This approach takes into account the dynamics of agents' interactions in the economy and enables researchers to empirically identify the sources of growth.

Why Taiwan is an exceptional case to study growth? Taiwan is one of the fastest growing economies among the newly industrial countries (NICs) since 1951. Figure 1, Figure

2, and Figure 3 show the Real Per Capita GDP of Taiwan relative to the U.S as well as the series for selected economics in Asian[1], Latin America, and Europe. As can be seen, compared with the rest of the world, the growth of Taiwan has been spectacular. In 1951, its real GDP per capita relative to the U.S. was 8% of the U.S. per capita GDP (equivalent to India's relative income to the US in 2002); and the corresponding figure was 56% in 2002. The 2002 value exceeded that of a number of countries whose real GDP per capita was three times the Taiwanese value in 1951 – e.g., Portugal, Mexico and Greece. Therefore, Taiwanese economic growth is a success story and investigating its source of growth may clarify why it has managed to grow rapidly and other have not.

Some of the literature on Taiwanese growth claims that factor accumulation was an important explanation for the source of growth. Among the studies on the growth of the East Asian NICs – Hong Kong, Singapore, South Korea and Taiwan – scholars supporting factor accumulations argue that total factor productivity in these NICs is not abnormally high. Instead, either labor deepening or capital accumulation accounts for the growth. (Young 1994, 1995, 1998; Rodrik 1995; Hsieh 1999) Among these researchers, some, e.g. Rodrik (1995), and Chang-Tai Hsieh (1999), argue that the source of growth was capital accumulation; whereas others, e.g. Young (1998), claim that the major source was labor deepening from 1966 to 1990. On the other hand, yet other scholars claim that total factor productivity, or real cost reduction, e.g. Harberger (1998), is important in explaining the East Asian economic boom.

Despite the tremendous work in the literature, the sources of growth for the East Asian NICs remain as an unsettled question. Therefore, in this paper, I would like to adopt business cycle accounting and use the neoclassical model to revisit the sources of growth for Taiwan.

The rest of the paper is organized as follows: First, I review the literatures on growth in Taiwan. Second, I present major trends in several macroeconomic data series with respect to output, labor and capital input, and labor share. Third, I set up a model and conduct a simulation using the business cycle accounting to diagnose the economy and identify the major sources of growth. Finally, I offer concluding remarks in the last section.

[1] I did not include the data for these two economies because they are city-states. Hong Kong was 23.59% of the U.S. GDP per capita in 1960 and was 78% in 2000; Singapore was 16.7% in 1960 and 80.42% in 2000.

2. Literature Review for the Source of East Asian Growth

The source of growth is either growth in labor input, capital input, or total factor productivity (TFP) improvement.

Alwyn Young, in his papers about the East Asian growth argues that improvement of labor input is most important cause of the growth. Young (1995), in his paper," The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience" carefully analyzed the "historical patterns of output growth, factor accumulation and productivity growth for Hong Kong, Singapore, South Korea and Taiwan." (p.641) He argues that both labor and capital input (except Hong Kong) grew rapidly in these NICs. The augmented labor force arose from post war baby boom and increased female labor participation. Furthermore, the data also showed higher education attainment in these countries. As a result, the high economic growth in the NICs did not result from abnormally high total factor productivity but from "rising participation rate, intersectoral transfers of labour, improving levels of education, and expanding investment rates." (p.645)

Moreover, Young (1998), in his paper, "Alternative Estimates of Productivity Growth in the NIC's: A Comment on the Findings of Chang-Tai Hsieh" further argues, "one sees that 'labor deepening', i.e. the rise in participation rates, transfer of labour out of agriculture, and increase in the human capital of the workforce, accounts for at least two-thirds of the difference in all of the economies except Singapore, where it still accounts for 59% of [Young's] results." (P.5) Thus, he suggests that the source of growth is mainly the labor deepening.

On the other hand, Dani Rodrik and Chang-Tai Hsieh, though convinced by Young that the improvement of total factor productivity is not the momentum of East Asian growth, believe that the rapid capital accumulation explains the prosperity. Rodrik (1995), in his paper, "Getting Invention Right: How South Korea and Taiwan Grew Rich" shows that the rapid growth in non-city state (therefore exclude Hong Kong and Singapore in the study) were due to investment boom which resulted from government intervention. Two important conclusions from his study were: first, the growth is the result of investment boom toward manufacturing exportable goods; second, the economy move toward export-oriented industry is due to government intervention. He argues that given relative price of these tradable was constant during that period, the investment boom toward manufacturing exportable good during the period of take-off was mainly due to the government intervention in "engineering a

significant increase in the private return on capital" to direct the investment orientation toward favored industries. Furthermore, the equality in income distribution prevents rent seeking or the lobbying of interest groups while internalizing the coordination externality for the private sector: the government intervention effectively resolves the problem of coordination failure[2] of investment and consequentially induces economic growth under the preconditions of equality in income and highly educated labor.

If Rodirk is correct about the role of government in improving "investment climate" (p. 30) during the process of development, the premise is that capital accumulation is the momentum for growth. Namely, Rodrik indirectly emphasizes the role of investment to explain the source of growth in Taiwan. Although, between revisionists (e.g. Wade) and the 'market governance' school[3], there is another debate about whether or not government's role in development is important, this will be another issue for discussion if I identify capital accumulation is the Taiwanese source of growth.

Hsieh (1999), in his paper, "Productivity Growth and Factor Prices in East Asia" argues, "if East Asia's growth was largely driven by capital accumulation with little technological progress, the return on capital should have fallen dramatically as capital accumulation encounters diminishing returns." (p. 133). However, the effect of diminishing return on capital only reveals when there is no increase in labor input at the same time. Therefore, for the scholars accepting factor accumulation as an explanation for the rise of the East Asian Tigers, Hsieh's analysis is tend to supporting those who believe rapid capital accumulation is the explanation for the East Asian growth.

However, Arnold Harberger interprets Young's data in another perspective, and finds total factor productivity may still be valid for explaining the East Asian growth. Harberger (1998), in his paper, "Reflections on Economic Growth in Asian and the Pacific" shows that "differences in TFP growth account for a significant fraction of difference in GDP growth." (p. 27) He also includes Young's result in the paper, simply re-sorted the date by rate of GDP growth, and found that the high rate of GDP growth episodes have higher mean and median

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[2] Rodirk argued," both countries, [South Korea and Taiwan], were ready for economic take-off by the early to mid sixties, but economic growth was blocked by a coordination failure, that is, inability of market force alone to generate the large and coordinated investments required to place these economies on a self-sustaining growth path." (p. 76)

[3] For example, as mentioned in Lal (2002), "the World Bank Miracle study's empirics based on total factor productivity calculations, …found that interventions in both Korea and Taiwan had little effect in altering the structure of production at the sectoral level." (p. 237)

rate of TFP growth than low rate of GDP growth episodes and reconfirm his argument above. Therefore, he claims, " In both [East Asian and Latin data] sets of countries differences in TFP contribution were major factors accounting for the difference in GDP performance, as between low-growth and high-growth periods." (p.39)

As Young (1995) concluded, "[I]f the remarkable post-war rise in East Asian living standards is primarily the result of one-shot increase in output brought about by the rise in participation rate, investment to GDP ratios, and educational standards and the intersectoral transfer of labour from agriculture to other sectors (e.g. manufacturing) with high valued added per worker, then economic theory is admirably well-equipped to explain the East Asian experience. Neo-classical growth theory, with its emphasis on level changes in income and its well-articulated quantitative framework, can explain most of the difference between the performance of the NICs and that of other post-war economies." (p. 673, 675) Therefore, I will adopt the neoclassical methodology to further investigate the source of growth for Taiwan.

In the business cycle literature, Cole and Ohanian (1999), and Chari, Kehoe and McGrattan (2004) suggest a methodology to diagnose the cause of the economic downturns and recoveries. Similarly, such an approach can be adopted to diagnose the source of economic booms.

Therefore, after I show the major macroeconomic data characteristics in the following section, I show the prototypical neoclassical growth model and adopt the diagnostic tool to identify the sources of the Taiwanese growth. First, I define "wedges" in the diagnostic tool; second, I calibrate the parameters for the model. Third, I conduct a simulation controlling the presence of different wedges and provide new insight into the sources of growth of Taiwan.

3. Major Macro Data Characteristics

The data used in this paper is taken from DataStream, World Penn Tables and various Taiwanese government web pages and statistical data books. The period of study is from 1961 to 2002, which is the longest period with the largest complete dataset. I will discuss details for output, labor input, capital input, labor share and other relevant macro economic data from the earliest data I have. In addition, I will compare my data with those of Young's in his 1995 paper.

3.1. Output: Real Per Capita Output

The total output in Taiwan has steadily increased since 1961. Figure 4 shows the real per capita output. As can be seen, the values for GNP and GDP coincide. Therefore, in the following analysis, I choose GDP as my base value for output since the economic shocks generally impact an economy according to geographical region, rather than by nationality. In addition, the output I use in my following analysis excludes the net indirect tax (equivalent to National Income plus depreciation) for calibration purposes since taxes are not payments to factor inputs.

Table I summarizes output and capita growth rate for Taiwan from 1961 to 2002. As shown in the table, the annual average growth rate for Taiwanese real GDP was 7.91% during the period from 1961 to 2002 while that for the real per capita GDP is 6.29%. Excluding net indirect taxes from GDP or the agricultural sector will increase the average annual growth rate for output. Despite the fact that excluding net indirect tax raises the annual growth rate of output slightly, the impact on the trend of GDP growth on yearly basis is small. (As shown in Figure 5)

Table I: Taiwanese growth rate, output and capita, from 1961 to 2002

Item	*Annual Growth Rate*
Output	
Real GDP	7.76%
Real GDP – Net Indirect Tax	**7.91%**
Real GDP – Agriculture	8.46%
Real GDP – Net Indirect Tax –Agriculture	8.77%
Real GDP: Manufacturing	9.55%
Capita	
Population	**1.62%**
Worker	2.45%
Working Age Population	2.63%
Real per capita GDP (GDP excludes indirect tax)	**6.29%**

3.2. Labor Income Share

The labor income share measures the percentage of output attributed to labor input. For most developing countries, the naïve way of calculating the labor share tends to underestimate the real labor share in production. This is because in the data, entrepreneurial

income includes income from property; as a consequence, the naïve estimate overestimates capital and underestimates the labor contribution to output.

Douglas Gollins (2002), in his paper, "Getting Income Shares Right" pointed out that a reasonable labor share after adjustment is between 0.65 and 0.80. Gollins suggests three possible approaches to adjust the labor income to reflect self-employed personnel. The first method takes all the operating surplus of private unincorporated enterprises (OSPUE) as labor income. The second method assumes the labor income share for OSPUE is the same as the labor income share for the rest of the economy and takes the sum of OSPUE and compensation to employee as the compensation to employee of the entire economy. The third method obtains the employee compensation by multiplying the average compensation to employees by the working force. Unfortunately, he did not provide labor share for Taiwan in his paper. As a consequence, I follow the suggested approaches[4] to estimate the labor share of Taiwan, and present the result in column two and column three in Table II.

Table II shows the results of different approaches 6f calculating labor share using a different definition of employee compensation. The labor share is the ratio of employee compensation to the adjusted real GDP. I report the result of the naïve calculation in the first column. As can be seen, during 1973 to 2002, the maximum labor share is 60% while the minimum is 49%, and the average is 56%. In column two and three, I use the same data for average monthly labor wages. Column two is the result from multiplying the average yearly wage by the number of employees whereas the result in column three is from multiplying that by number of people in the labor force. As can be seen, labor share increases: the maximum is 77% and 78%, the minimum is 51% and 52%, and the average is 66% and 67% respectively. Based on the result of column two and three, one may choose the standard labor share 2/3 for Taiwan.

Table II: Labor share from different definition for employee compensation

(1973 – 2002)	*Naïve*	*Employee*	*Labor force*
Max Labor Share	0.599017	0.766559	0.778361
Min Labor Share	0.486859	0.514318	0.520883
Average	0.555312	0.661491	0.676245

[4] I cannot implement his first and the second method since Taiwanese National account only reports operating surplus; instead, it mixed the corporate and unincorporated (OSPUE) income together.

Young (1995) also estimate labor share for Taiwan. He constructed the estimates of the hourly income of employees similar to Jorgenson et al's approach. Then, he "use[s] these compensation data, and [his] estimates of hours of work cross-tabulated by industry, sex, age, education, and class of workers, to estimate the incomes of employees and the implicit labor income of employers, unpaid family workers, and the self employed, under the assumption that the latter earn an implicit labor wage equal to the hourly wage of employees with similar sex, age, educational, and industrial characteristics." (p.655) Next, he multiplies the sectoral compensation of employees data reported in the national accounts by one plus the estimated implicit to explicit ratio. Finally, the resulted estimated labor income of sub-sector is used to estimate the share of each labor sub-input in total payments to labor by sector. On the other hand, the capital share equals to one minus labor share under the assumption of perfect competition and constant returns to scale. The labor share Young reported is in the table III below:

Table III: Labor share reported by Young (1995)

Sector	*Labor Share*
Economy excluding agriculture	0.743
Economy excluding agriculture and official public sector	0.702
Economy excluding agriculture, including military	0.709

Applying Jorgenson et al's approach needs to adjust multiple-job-holder to avoid bias. However, the detailed methodology is not reported in Young's paper; thus I cannot infer from the paper if his estimation is accurate. Moreover, even assume that he follows carefully the method suggested by Jorgenson et al., the labor share Young estimated still overestimate the real value. As he admitted in his paper, Young (2000) argues, " Multiplying the unadjusted share of labour (compensation of employees over GDP at factor cost) in the national accounts by one plus the ratio of implicit to explicit labour income yields an estimate of the "true" share of labor. This is the procedure [he] used in [his] 1995 analysis of the NICs. Unfortunately, it systematically overstates the share of labour." (p. 39) It overestimated the share because that the compensation of employees in the national account already adjusted for self-employed and resulted in double counting when apply this method. In other word, using explicit and implicit conversion ratio for estimating the compensation to employees for Taiwan may overestimate

the labor share. Therefore, based on the above analysis, I assume that the labor share of the Taiwanese economy is 2/3. In addition, because the results are sensitive in one case to the labor share, I include sensitivity analysis for the share equal to [0.6, 0.7, 0.8] for that case. The corresponding capital share is 1/3, and [0.4, 0.3, 0.2].

3.3. Capital Input

3.3.1 Capital Stock and Investment

The Taiwanese Capital stock data is available in "The Trends in Multifactor Productivity, Taiwan Area, Republic of China" by Directorate-General of Budget, Accounting and Statistics (DGBAS), Executive Yuan, Republic of China. They adopted the benchmark extrapolation method to estimate the capital stock. The benchmark years are designated as the point of time when commercial census, which has been conducted once every five year, and 1988 Wealth Survey took place.

In addition to the officially published capital stock for services and industries, I requested the capital stock series (1961 to 2002) from DGBAS directly. I was provided with an unpublished time series of capital stock excluding land using the 1988 Wealth Survey[5].

I also estimate Taiwanese capital stock using perpetual inventory technique to the sub-category of fixed capital formation and adopt the sub-category depreciation rate assumed in Young (1998): "1.3% for residential structure, 2.8% for non-residential structure, 3.4% for other construction, 18.3% for transportation equipment, and 14.0% for machinery." (p.30) To estimate the initial capital stock, I follow the equation $I_t = (\delta + \gamma)K_{t-1}$. To avoid random bias, I take the average of the gross fixed capital formation in real term for 1952-1954 and use it for I_{1953}; δ is the depreciation rate for it sub-category and γ is the average GDP growth rate during 1952 – 1954. The underlying assumption is: different capital stocks grow at the same rate as GDP in the initial years and are representative of the investment prior to the time series[6]. I choose three years rather than five year for the average so to minimize the use of data and allow longer period before the initial year, 1961. Though the investment and GDP time series starts from 1951, I use 1952 to 1954 to estimate initial capital stock because I do not have the growth rate of GDP in 1951. As Young (1995) mentioned, "Given positive rate

[5] I would like to acknowledge Ho, Chin-Sheun, Senior Researcher at Bureau of Statistics, DGBAS, Taiwan, Republic of China.

[6] The method is used in Harberger (1978).

of depreciation and a sufficiently long investment series prior to the first date of the analysis, the perpetual inventory approach is fairly insensitive to the level of capital used to initialize the series." (p.652) For my cases, I allowed 8 years for the case starts from 1961 and 20 years for the case starts from 1973. Finally, I do not include inventory[7].

In addition to domestic capital formation, I add in net foreign investment in my capital stock series because the ratio of net foreign investment to gross national investment on average equals 20% from 1951 to 2002. To take care of the early mass capital outflow in the 1950s and 1960s, I assume that the initial foreign capital stock is 2.2 times that of the domestic non-residential capital stock. The multiplier is to take care of the early unstable political environment: in 1945, Japanese government returned Taiwan to China; and in 1949, the KMT retreated to Taiwan from the mainland[8] with subsequent migration to and from the island[9].

Figure 6 shows Taiwanese net capital stock excluding land at constant price of 1996 from 1961 to 2002. Both published and unpublished are from DGBAS while the Estimate is obtained from fixed capital formation. As can be seen, the two official series are almost parallel to each other in trend. However, the unpublished series were 10 times of the published series in 1961 and roughly twice in 2002. It is not surprising to have discrepancy between two series since one excludes agricultural sector whereas the other includes it. However, the discrepancy is too big.

My estimated series is in-between the two DGBAS series: closer to the lower one in the early 1960s and matches the higher one in around 1990s and afterward. Regardless of which time series chosen for analysis, Taiwanese capital stock has been steadily increasing since 1961.

To choose a time series for my analysis, I generate Table IV and compare the growth rate of all the series with Young's (1995.) As can be seen, my estimate excluding agriculture

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[7] Young (2000) argues, "in [his] experience, the 'change in stocks' figures reported in the national accounts of developing countries are frequently a residual, fabricated, item used to conceal large discrepancies between the production and expenditure sides of the accounts. In addition, the proper measurement of inventory changes, is technically more challenging than the measurement of the flow value of investment in fixed capital. … For these reasons … as in past work [Young 1995], [he] exclude inventories from [his] measure of capital stock, and focus on gross capital formation alone." (p. 32)

[8] As reported in the EIU country profile 1996, " The island remained under Japanese occupation until the end of the Second World War, when it was restored to Chinese sovereignty and the rule of Generalissimo Chiang Kai-shek's Kuomintang. … [In] 1949, Chiang Kai-shek gave up his struggle with the Chinese Communist Party led by Mao Zedong and retreated to Taiwan from the mainland with the remnants of his army and government, bringing the total number of mainlanders arriving on the island to around 2 million." (Political Background: historical background)

[9] The classification is only for simplifying the analysis. The "foreign" is broadly defined as capital from resources not produced with the factor inputs of the economy.

(11.71%) is closest to Young's raw estimate (11.80%) for period 1966 – 1990, whereas the official statistics fall far behind. Therefore, I choose my estimate as the capital stock in my analysis. .

Table IV: Growth Rate of Capital Stock, 1961 - 2002 and 1966-1990 vs. Young (1995)

	1961 - 2002				
Source	Published	Unpublished	Estimated	Estimated Excluding Agriculture	Young
Annual Growth Rate	7.61%	3.58%	9.14%	9.47%	N.A.
	1966 – 1990				
Source	Published	Unpublished	Estimated	Estimated Excluding Agriculture	Young
Annual Growth Rate	8.67%	3.11%	11.19%	11.71%	11.8%

3.3.2 Capital Returns

There are at least two methods to calculate capital returns. One method is to assume constant return to scale technology and then the marginal return to capital equals to the average return to capital. For example, think of a Cobb-Douglas production function, capital return equals capital share multiply by the output-to-capital ratio. The other method relies on the data from National Income[10]. Since Taiwanese National Income does not report the entrepreneur income, I adopt the first method to calculate the return on capital. As mentioned earlier, since the result is sensitive to capital share, I conduct sensitivity analysis for labor share which equals to 0.6, 0.67, 0.7, and 0.8.

Figure 7 shows the Taiwanese return on capital. As can be seen, the rate of return is high in the 1960s, rolls slowly down the hill to the valley in the early 1980s, and remains roughly constant within a band of less than 2%. For the case that labor share equals 2/3, the gross return on capital reaches the zenith (22.5%) in 1965 and attains its nadir (12.87%) in 1990. Given that the capital stock has been monotonically increasing since 1961, it is surprising that the return on capital does not decline as fast as expected. For example, from 1982 to 1987, capital stock grew at the rate of 11.08% annually (in average) while the return on capital only drops from 14.24% to 13.33%. Think of a Cobb-Douglas production function:

[10] The alternative method calculates the return on capital in the following steps: first, assume the capital and labor contribution to entrepreneur income the as the corporate income. Second, sum up the property income and the partial entrepreneur income and divided the summation by capital stock.

based upon the property of constant return to scale, the marginal return equals the average return to capital ($ARK = MRK = \frac{\partial Y}{\partial K} = \theta \cdot Z \cdot (\frac{L}{K})^{1-\theta}$). Such a property, combined with the assumption that the capital share is relatively constant over time, implies that capital returns remain roughly constant as capital increases are not usual if all other things are held constant. The unusual phenomenon may be attributed to either an increase in total factor productivity or in labor input. If the former explains such a phenomenon, one would expect increasing TFP in the Taiwanese economy. On the other hand, if the latter explains the phenomenon, one would expect a greater positive impact on growth from the labor markets during the period so that it induces people to work harder to cancel out the decreasing trend of the marginal return on capital. I will discuss this again in the section 6 after I set up the model in section 4.

Recall that in section 3.2 I discuss how to determine the labor share. I use the monthly wages reported since 1973 to construct the compensation to employees. As a result, I can estimate the capital share using one minus the labor share for each year and present the return to capital using those varying shares. The result is shown in Figure 8. In addition, I calculate the return on capital for the U.S. from 1929 to 2002 and present the results in Figure 9. As can be seen, fixing capital share at 1/3 results in less volatile capital returns for both Taiwan and the U.S. For Taiwan, the return on capital using fixed share fluctuates around 13% while that for the U.S. fluctuates around 10%. The difference between the return on capital in the U.S. and in Taiwan may explain why the capital in the U.S. has been growing at the average rate of 2.9% annually while that in Taiwan has been growing at the average rate of 9.14% annually from 1961 to 2002. For Taiwan specifically, the results of the return on capital using these two measurements coincide in the early 1980s and late 1990s.

3.3.3 Nominal Interest Rate and Real Interest Rate

Data for interest rates were obtained from the web page of Central Bank of China. Figure 10 shows the nominal interest rates in Taiwan from 1961 to 2003. As can be seen, the nominal interest rates have been declining. Figure 11 shows the real interest rates in Taiwan for the same period. As is shown, the real interest rates were higher in the 1960s than the rest of the period. In addition, the economy faced negative real prime rates in 1974, and 1981 to 1982. One possible factor affecting agents' investment decisions in the Taiwanese capital

markets was economic regulation. Taiwan was highly regulated in the 1960s and 1970s and began deregulating in the 1980s. For example, prior to 1986, there were foreign exchange controls and restrictions on foreign investment[11]. In addition, interest rate controls were not abandoned until 1989. Therefore, the negative real interest rate may have arisen from the fact that the capital market was regulated and were not free to adjust when there were big shocks.

3.3.4 Area of Cultivated Land

Figure 12 shows the area of cultivated land in Taiwan from 1952 to 2003. As can be seen, the cultivated area does not change much since 1952 and slightly decreases in the 1980s. Therefore, omitting land value when evaluating capital stock in the economy for all sectors only scales down the capital stock at a constant term and scales up the growth rate of capital input. This will become an issue only if I eventually find the growth in capital stock is the crucial sources of Taiwanese growth.

3.4 Labor Input

3.4.1 Labor Hour vs. Employment

Data for labor hour in Taiwan begins in 1973. Figure 1 shows the average monthly working hours for Taiwan. As can be seen, the average monthly working hour has been declining. On the other hand, as shown in Figure 24, the total labor hour has been increasing. Therefore, I conclude that the labor supply in term of labor hours has increased since 1973 (no data for the period prior to 1973) despite the fact that the average working hour has been declining.

On the other hand, data for employment starts from 1961. Figure 15 shows the employment volume and the growth rate in Taiwan. As can be seen, the total employed rises significantly from 1965 to 1977 and the growth rate fluctuate downward to around 1% in 2002. Furthermore, Figure 16 shows the ratio of number of workers to working age population. As is shown, the ratio fluctuates within a narrow band between 57% and 62%, remains below 58% from 1966 to 1972, and rises above 59% from 1983 to 1990.

I would like to use employment as the proxy for labor input when labor hour data are not available. However, one should keep in mind that using employment as labor input may

[11] The deregulation for foreign investment for influx and out flux is on March 1986. The foreign exchange controls were eliminated on July 15, 1987. In 1987, Taiwan abolished Martial Law and allows indirect investment in China.

mitigate the impact of labor market distortions on agents' equilibrium decisions in the labor markets since labor participation rate is a stickier variable to adjust than labor hours. Therefore, I will use labor hour as my labor input in principle and use employment volume as supplement to my analysis when labor hour data are not available.

3.4.2 Human capital accumulation in terms of quality

In addition to the absolute number of employees or labor hours, an increase in the quality of human capital may mark up the "effective" labor input for Taiwan. Therefore, I examine the education statistics for Taiwan.

Figure 17 shows the education of employees from 1978 to 2002. As can be seen, the numbers of college and high school educated employees have been steadily increasing since 1978. The growth rates are 7% and 5% respectively. Thus, based upon the simple statistics, one should keep in mind that when adopting either employment or labor hour as the labor input, this is likely to underestimate the value that the labor force can create.

Moreover, Bils and Klenow (2000) shows the impact of schooling on growth does not necessary explain the growth. Their additional table shows the Taiwanese human capital stock relative to the U.S. and the corresponding growth rate from 1960 – 1990. The numbers show that the Taiwanese human capital stock is above the Latin American and European average in both 1960 and 1990 and the growth rate is below Latin America but slightly above Europe. Therefore, the average world trend of growth may be enough to take care of this part of impact on Taiwanese growth.

3.4.3 The Issue of Intersectoral Transfer of Labor

Figure 18 shows the percentage of labor in each sector relative to the total employed persons. The biggest decline is from 1965 to 1979. This observation is similar to Young's argument that there is rapid intersectoral transfer during the 1970s. Thus, excluding the agricultural sector in the analysis of Taiwanese growth will definitely augment the growth of the labor input, and then overestimate the contribution of labor growth as the source of growth.

Young (1995) argues, " Intersectoral transfers of labor have been important. Thus, removing agriculture from the analysis lowers the growth rate of output per worker in Taiwan … by 0.6 percent per annum, reflecting the rapid decline in the share of agricultural

employment in total employment." (p.644) Then, a further question should be ask why there is an increase in agricultural marginal product of labor given the decline in the share of agricultural employment in the total employed.

The increase of marginal agricultural productivity of labor can attribute to increase in total factor productivity, increase in capital input or decrease in labor input[12]. The two-sector model by Ranis and Fei may be useful in explaining the phenomena during the surplus labor phase.

In addition to the model, Fei, Ranis and Kuo empirically study Taiwanese economy from 1920 to 1972 argue,

> *"[T]he industries that grew fastest during the 1960s were such light consumer goods as textiles and such intermediate goods as electronics. Both were internationally competitive because of the use of technologies extremely intensive in unskilled labor. Concurrently, the productivity of agricultural labor – supported by earlier investments in rural infrastructure, an increasingly favorable policy environment, and new technologies and crops – increased at 6.6 percent a year during the 1960s, compared with 4.9 percent during the 1950s. The gains kept the prices of foodstuffs low, despite the pattern of rapid industrialization, and prevent a premature sharp rise in real wages. … By about 1968 the rapid pace of labor reallocation had led to the end of labor surplus and the beginning of labor scarcity."*
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> (Fei, Ranis and Kuo, 1979, p. 31- 32)

Therefore, based upon Fei et al's observation in 1979 and Figure 18, if there were no agricultural technological improvement in Taiwan in the 1970s, one should expect the prices of agricultural goods to rise and gradually decrease the intersectoral transfer of labor from the agricultural to the industrial sector. This is because the economy reached full employment in 1971 and any further transfer of labor away from agricultural after 1971 should have increased the price for agricultural goods (Kuo, 1983). However, the price of major agricultural products in Taiwan, e.g. the rice price, remained stable through the development process prior to 1987 (as shown in Figure 19). Consequently, it is very likely that there was technological improvement in the agricultural sector in the early stage of Taiwanese economic growth.

In conclusion, analyzing the economic growth in Taiwan while ignoring the agricultural sector may distort the growth rate of output per worker by wrongly attributing no growth to the agricultural sector. Therefore, I will initiate a one sector model which includes agricultural sector to study the source of the Taiwanese growth.

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[12] When one assumes surplus labor in agricultural sector, decreasing agricultural labor input will lead to increasing marginal product of labor.

3.4.4 Labor wages

The positive growth of the labor force did not drive down the compensation of employees in Taiwan; instead, wages have been increasing since 1973. Figure 20 shows the average monthly earning of an employee; the data starts from 1973. As revealed by the graph, wages steadily increase and the wage rate in 2002 is five times of that of 1973. Consequently, one may conclude that the labor demand increased as did the labor supply. From another perspective, if the wage rate fully reflects the marginal productivity of labor, given that the capital share is relatively constant, to explain the increase in labor wages there should be a more rapid increase in capital relative to labor input or relative to improvements in total factor productivity.

3.4.5 Statistics for Labor Input

I summarize the raw data I use for Taiwanese labor input in Table V. As can be seen, excluding agricultural sector overestimates the growth rate of labor input (in view of the entire economy). Moreover, when I use per working capita employment or hours as labor input, the statistics shows completely different sign for labor growth. The former results in positive growth while the latter results in negative growth. This is because the average growth of the working age population is higher than that of workers. (As Table I shows, the average growth of workers is 2.45% while average growth of working age population is 2.63%).

Table V: Average of annual labor growth

	66 - 90	*52-02*	*61-02*	*73 – 02*	*66– 90(Young)*
Total Employment	3.16%	2.34%	2.42%	1.98%	N.A.
Agricultural	-1.99%	-1.68%	-2.14%	-2.78%	N.A.
Industry	5.58%	3.81%	3.67%	2.50%	N.A.
Service	4.73%	3.84%	3.98%	3.78%	3.8%
Industry +Service	5.10%	3.83%	3.86%	3.23%	4.6%
Labor Hour	N.A.	N.A.	N.A.	1.26%	N.A.
Total hour/working age	N.A.	N.A.	N.A.	-0.99%	N.A.
Employed/working age	0.14%	N.A.	-0.21%	-0.27%	N.A.
Worker/working age	0.07%	N.A.	-0.18%	-0.13%	N.A.

3.5 Capital Intensity

Net capital intensity is defined as net capital stock divided by labor input (the number of employees). Figure 21 shows the capital intensity of Taiwan. As is shown, the capital to labor ratio has been increasing since 1961. This implies that there have been technological changes in the economy. The average annual growth rate (from 1961 to 2002) of capital intensity in Taiwan is 3.5% in domestic dollars and 6.98% in US dollars. Compared with the U.S., such a growth rate is significant since that of the U.S. is 1.6%. In addition, the U.S. capital intensity ratio was 29.0 times that of Taiwan in 1961 and 3.3 times in 2002. Based upon the evolution in capital intensity from 1961 to 2002, there should be technological improvements from less capital-intensive industries to more capital-intensive industries in Taiwan. However, it remains unclear whether or not capital intensity improvements differentiate Taiwanese growth from other developing countries based on the changes of the ratios.

TFP improvement can be an explanation for Taiwanese growth. Consider that Cobb-Douglas production function: If there were no TFP improvements, the increasing capital intensity can well explain the increase in the wage rate. However, the relatively stable return on capital remains a puzzle. Base upon the discussion above, I would still keep TFP as a candidate for explaining the growth of Taiwan.

4. The Model for Neoclassical Diagnoses

In the literatures on the U.S. Great Depression, Cole and Ohanian (1999), and Chari, Kehoe and McGrattan (2004) suggest a methodology to diagnose the cause of the economic downturns. Similarly, such an approach can be adopted to diagnose the causes of economic booms. In the following section, I follow closely the method suggested by Cole and Ohanian (1999), and Chari, Kehoe and McGrattan (2004). First, I define the economy and the equilibrium conditions for an undistorted economy. Second, introduce wedges to measure the distortions. Third, I calibrate the parameters for the economy assuming no distortion except productivity improvements. Finally, assuming the agents in the economy have perfect foresight, I mimic the growth path for Taiwan when some of the wedges are introduced in the model, show the model can well represent the dynamics in the economy, and identify the source of growth.

4.1. The Economy

The economy of the model is composed of a representative family, and producers in a perfect foresight environment. Individuals may face shocks but the shock only lasts for one period.

4.1.1 The Representative Family

I adopt a special form of the CES utility function for the family in this economy. Agents value leisure. There is one unit of labor available each period. In addition, they are infinitely lived. Hence, the preferences are as follows:

$$\text{Max} \left\{ u(C) = \sum_{t=0}^{\infty} \beta^t \{\log(C_t) + \phi \log(1 - \hat{h}_t)\} \right\}$$

In addition, β represents the discount factor.

Finally, the population grows deterministically at rate ν, thus population n at t can be express as follows: $n_t = (1+v)^t$

4.1.2 Production Sector

Firms in this economy adopt labor augmented Cobb-Douglas production technology. For a single firm, $y_t = k_t^{\theta}(x_t l_t)^{1-\theta}$, $x_t = (1+\gamma)^t x_0$, where y is output, k is capital input, and l is labor input. In addition, θ is capital share and γ is the growth rate of the labor-augmented technology. By property of the Cobb-Douglas production function, the production technology for the whole sector can be expressed as equation (1) below:

$$Y_t = K_t^{\theta}(x_t \hat{L}_t)^{1-\theta} \qquad (1)$$

In equation (1), Y is aggregate output, K is aggregate capital input, and L is aggregate labor input.

4.2 The Equilibrium

A competitive equilibrium is derived as follows (from A to D):

A) Given the population grows deterministically at rate ν, and $n_t = (1+v)^t$, I divide all the variables by $n_t = (1+v)^t$ so to get rid of the growth effect from population.

B) Given the labor-augmented technology which grows at rate γ, I detrend all the variables by $(1+\gamma)^t$.

C) The stationary version of the model as a competitive equilibrium is presented below after defining the detrended per capita variables as follows:

$$\tilde{k}_t = \frac{k_t}{(1+v)^t(1+\gamma)^t}; \qquad \tilde{K}_t = \frac{K_t}{(1+v)^t(1+\gamma)^t}$$

$$h_t = \frac{\hat{h}_t}{(1+v)^t}; \qquad L_t = \frac{\hat{L}_t}{(1+v)^t}$$

$$\tilde{Y}_t = \frac{Y_t}{(1+v)^t(1+\gamma)^t}; \qquad \tilde{C}_t = \frac{C_t}{(1+v)^t(1+\gamma)^t}$$

$$\tilde{I}_t = \frac{I_t}{(1+v)^t(1+\gamma)^t}; \qquad \tilde{w}_t = \frac{w_t}{(1+\gamma)^t}$$

D) To get the competitive equilibrium, I take the steps as follows (from a to f) :

a) Given $\{w_t, r_t\}_{t=0}^{\infty}$, K and L solve the firm's problem:

$$\underset{K_t, L_t}{Max}\left\{Z_t K_t^{\ \theta}(x_t L_t)^{1-\theta} - w_t L_t - r_t K_t\right\}$$

$$\Rightarrow \frac{\partial Y}{\partial K_t} \equiv r_t = \theta \cdot Z_t K_t^{\ \theta-1}(x_t L_t)^{1-\theta} = \theta\frac{Y_t}{K_t}$$

$$\frac{\partial Y}{\partial L_t} \equiv w_t = (1-\theta)Z_t K^{\theta} x_t^{1-\theta}(L_t)^{-\theta} = (1-\theta)\frac{Y_t}{L_t}$$

b) Representative family maximized given $\{w_t, r_t\}_{t=0}^{\infty}$

$$\underset{h_t, k_{t+1}}{Max}\left\{u(C) = \sum_{t=0}^{\infty}\beta^t\{\log(C_t) + \phi\log(1-h_t)\}\right\}$$

$$s.t. \quad C_t + I_t \le w_t h_t + r_t k_t$$

$$I_t = K_{t+1} - (1-\delta)K_t$$

$$F.O.C.: \quad \frac{\partial \bullet}{\partial h_t} : \frac{w_t}{C_t} = \frac{\phi}{1-h_t}$$

$$\frac{\partial \bullet}{\partial \tilde{k}_{t+1}} : \frac{C_{t+1}}{C_t} = \beta \cdot (r_{t+1} + 1 - \delta)$$

c) Market clearance conditions

$$K_t = k_t$$
$$L_t = h_t$$

There are two factor-markets in this economy: capital market and labor market. Therefore, I set two market clear conditions at equilibrium. Capital market clears at price r_t; labor market clears at wage w_t and resource constraint satisfied.

d) Resource Constraint

$$C_t + I_t \le Z_t K_t^{\theta} (x_t L_t)^{1-\theta}$$

e) Law of motion

$$(1+v)(1+\gamma)\tilde{K}_{t+1} = \tilde{I}_t + (1-\delta)\tilde{K}_t$$
$$x_t = (1+\gamma)^t$$

f) The System of Equations

Therefore, a competitive equilibrium for an undistorted system is a sequence of quantities $\{h_t, k_t, Y_t, C_t\}_{t=0}^{\infty}$, and a sequence of prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that the representative family and firm optimize and market clear.

The system of equations characterize the equilibrium in term of the detrended variables is as follows.

$$\tilde{Y}_t = \tilde{k}_t^{\theta} (x_0 h_t)^{1-\theta} \quad (2)$$

$$\tilde{C}_t = \frac{\tilde{w}_t \phi}{1-h_t} \quad (3)$$

$$\{(1+\gamma)(1+v)\frac{\tilde{C}_{t+1}}{\tilde{C}_t \cdot \beta}\} = 1 + r_{t+1} - \delta \quad (4)$$

$$\tilde{Y}_t = \tilde{C}_t + (1+v)(1+\gamma)\tilde{k}_{t+1} - (1-\delta)\tilde{k}_t \quad (5)$$

$$r_t = \theta \frac{Y_t}{\tilde{k}_t} \quad (6)$$

$$\tilde{w}_t = (1-\theta)\frac{\tilde{Y}_t}{h_t} \quad (7)$$

The system of equations (2-7) has 6 equations and 6 unknowns. The system expresses the steady state conditions of the economy along the balanced growth path.

4.3. Define Wedges

System of Equations (2-7) is the general equilibrium of the simplified economic system. If all variables remain the same for an economy (if there is any trend, one can detrend the variables and make it stationary), we say the economy is at the steady states and this trajectory is called the balanced growth path. However, the economy does not always stay on this path. If there are shocks, the economy will deviates away from its balanced growth path and we observe boom and bust. Based upon this system of equations, Cole and Ohanian (1999), and Chari, Kehoe and McGrattan (2004) suggest a methodology to diagnose the cause of the economic downturns and recoveries.

The logic behind the diagnostic tools is: When an economy deviates from the steady state, the right and left hand side of the equation will not equal to each other. Therefore, they define wedges (taxes or gaps) to gauge the right and left hand side of each equation. Then, these wedges quantify the degree an economy deviates away from the balanced growth path and they represent the source of shocks that drives business cycles. They characterize these "wedges" as productivity (Z) for equation 2, labor wages or labor taxes (τ_{lt}) for equation 3, investment wedges or capital taxes (τ_{kt}) for equation 4, and government consumption wedges for equation 5.

These wedges reflect the size of shocks on productivity, labor market; capital market and domestic resources that drive the economy deviate from the balanced growth path. The economy faces positive shock on productivity if Z is greater than one, whereas it faces positive shock on labor and capital market when taxes (τ_{lt} and τ_{kt}) are negative. By construction, introducing all the wedges above will account for the observed trajectory of economic transition. Therefore, the wedges are defined as follows:

$$productivity\ (productivity\ wedges): Z_t = \frac{\tilde{Y}_t}{\tilde{k}_t^{\theta}(x_0 h_t)^{1-\theta}}$$

$$labor\ tax\ (labor\ wedges): \frac{\tilde{C}_t}{\tilde{w}_t}\frac{\phi}{1-h_t} \equiv (1-\tau_{lt})$$

$$capital\ tax\ (investmsnt\ wedges): \{(1+\gamma)(1+\nu)\frac{\tilde{C}_{t+1}}{\tilde{C}_t \cdot \beta} - 1\} \equiv (r_{t+1} - \delta)(1-\tau_{k,t+1})$$

$$government\ consumption\ wedges: gap_t^y = \tilde{Y}_t - \tilde{C}_t - (1+v)(1+\gamma)\tilde{k}_{t+1} + (1-\delta)\tilde{k}_t$$
$$(income\ wedges)$$

Ideally, introducing all the wedges above will well mimic the trajectory of economic transition since I endogenize factor prices in the model.

5. Parameterization

In this section, I describe the parameterization of the model.

For the firm's production function, the capital share is chosen to be half of the labor share (θ=1/3). Since the average working age population grows at the rate of 2.63%, I adopt 0.026 to be the population growth (ν =2.63%) in the model. I assume that the balanced growth rate of the economy equals the average world growth rate (g=2%). This is because the focal point of the diagnosis is to identify the sources of growth that differentiate Taiwan from the rest of the world. I measure how the Taiwanese economy deviates from the world balanced growth path by introducing wedges for labor markets, capital markets and productivity improvements so that I can capture how the economy deviates from the world balanced growth path. Next, I assume the depreciation rate equals the annual average depreciation rate for aggregated capital stock in Taiwan which matches the average deprecation rates from 1953 to 2002 (δ=0.07).

I did two case studies in the part of simulation: one is to use labor hour as labor input from 1973 to 2002, and the other is to use employment as labor input from 1961 to 2002.

To pin down x_0, I assume the productivity shock, z, equals one in the initial year. Therefore,

$$Z_{initial} = \frac{\tilde{Y}_{initial}}{\tilde{K}_{initial}^{\theta}(h_{initial}x_0)^{1-\theta}} \equiv 1.$$

In addition, I assume the productivity shocks from 2002 on are the same as that of 2001 detrended.

To pin down ϕ, I assume the labor tax is zero in 2002 and so forth; thus,

$$\phi = (1-L_{2002})\frac{(1-\theta)\tilde{Y}_{2002}/L_{2002}}{\tilde{C}_{2002}}$$

To pin down β, I assume the capital tax is zero in 2002 and so forth; thus,

$$\beta = (1+\nu)(1+\gamma)/(r_{2002}+1-\delta).$$

Table VIII shows the results of the calibration. Notice that the discount factor is 0.9862, which is above 0.95, the standard assumption. The higher discount factor for Taiwanese economy may imply the agents in the economy is more patient than the standard case- such a presumption is reasonable given the high saving rate in the East Asian economies.

Table VI: Results of Calibration

	x_0	ϕ	B
TW Labor Hour (1973 - 2002)	101.1474	0.7126	0.9862
TW Employment (1961 - 2002)	136.8135	0.8383	0.9862

6. The Wedges

In this section, I show Taiwanese wedges, which capture how the economy deviates from the world balanced growth path (which grows at 2% annually). I show two cases in this section. In the first case, I use labor hour as the labor input from 1973 to 2002 (the earliest reported labor hour begins in 1973). Next, to keep the interesting dynamics of the economy in the 1960s, I show the second case which uses employment as the labor input and covers the period from 1961 to 2002. Though employment is only a proxy for labor input, I use that to extend my case keeping in mind that I may underestimate the shocks on the labor markets since the labor participation ratio is a proxy for labor input but less flexible than working hours.

Case I studies the economy from 1973 to 2002 using labor hours as the labor input. The wedges for Case I are shown in Figure 22. As can be seen, the economy experiences productivity improvements since 1976. I assume the productivity wedges (Z) in 1973 equals one in this case. For labor markets, the economy faces positive labor market effects (negative labor tax) for the entire 3o year period. For capital markets, the economy faces positive impacts (negative capital tax in graph) during 1977-1979, 1982-1983, and 1986-1999. Based on the wedges, the combination of productivity improvements, labor and investment wedges together explain the spectacular economic growth in Taiwan since 1973.

Case II is a supplements Case I. The wedges for Case II are shown in Figure 23. As can be seen, the calibrated labor wedges are smaller than those found in Case I and the economy faces greater positive impacts in the 1960s than in the 1970s. In addition, by the assumption of the model, the investment wedges are the same as those in Case I for the period the two cases overlap. Furthermore, the economy faces negative capital market effects in the 1960s. Since the economy faces negative capital market effects prior to 1976, these cannot be the source of growth during that period. The negative effects from the capital market may result from the underdeveloped financial markets. As a result, in the early stage of development, productivity improved, labor participation increased but investment was suppressed. Finally, for productivity wedges, the maximum annual growth rate of Z is 7% in

case II while that in case I is 5% and the average is around 2% for both cases. The differences between the two cases in the productivity growth rates may arise from the reality that employment is less flexible than labor hours to adjust when facing shocks, and by the structure of the model is reflected in TFP.

7. The diagnoses results for the sources of growth (Simulation)

In this section, I identify the growth sources of Taiwanese economy using the model set up in section 4. By controlling the presence of different wedges under different scenarios, the simulation results identify whether capital, or labor market distortions, or exogenous technological improvements can best explain the performance of the economy.

The underlying algorithm is as follows: Without any of the wedges, the economy is on the balanced growth path, which grows at 2% annually. Since the model presented is for detrended variables, the simulated data should show no growth at all if the economy is initially at the steady state and remains on the balanced growth path. If there are any wedges that specifically impact the economy and make it deviate from the balanced growth path, the scenario that includes those specific wedges will result in a transition path similar to the data. For example, if TFP improvements are the only force that drives the economy to grow at a rate faster than 2%, the scenario which only incorporates productivity improvements (i.e. scenario with Z) will result in a simulated path that matches the statistics in the data.

I show the Output, Labor, consumption to output ratio (C/Y), and investment to output ratio (I/Y) for different scenarios under Case I in Figure 24 to Figure 32. Figure 24 shows the scenario with no wedges at all. As is shown, the initial levels of these variables are below the steady states. Therefore, the fact that the economy grew fast in the early stages can simply due to the fact that the economy was converging to its steady states. Figure 25 and Figure 26 show the results of the scenarios with labor wedges (L taxes) and investment wedges (K taxes) respectively; and Figure 27 shows the scenario with both L taxes and K taxes. As can be seen, the model cannot replicate the long-term trend of the output growth.

Figure 28 shows the simulation results for the scenario with Z. As can be seen, productivity wedges are crucial in explaining Taiwanese long-term growth. However, other wedges are also important in explaining the exact output level that Taiwan achieved. Figure 29 shows the scenario with Z plus K taxes. As is shown, the simulated transition path under the scenario with both K taxes and Z can increase the level of output but still cannot fully explain

its level in 2002. Figure 30 shows the results of the scenario with Z and L taxes. As is shown, the transition path mimics the economy's output and labor until the early 1980s. Figure 31 shows the results of the scenario with Z, K and L taxes. As can be seen, adding in K taxes in addition to Z and L taxes can almost mimic the dynamics of the economy for the entire period. Therefore, in addition to the continuous productivity improvements since 1976, one cannot exclude positive labor market effects on the economy in the 1970s and positive capital market effects on the economy in the 1980s in accounting for Taiwan's long-term growth. Finally, in Figure 32, I show the results of the scenario with all the wedges: Z, L taxes, K taxes and income wedges. As can be seen, the simulation results under this scenario fit the data by the assumption of the diagnostic approach. Thus, the previous experiments show the sources of growth for Taiwan are productivity improvements and positive impacts from labor and capital markets.

In addition to identifying the sources of growth using wedges, I compare factor prices in the data with factor prices generated from different scenarios. One may recall from section 3 that if there were no TFP improvement and if it were assumed that the labor share is roughly constant, there still remains the puzzle of why wages have been increasing whereas the return on capital has been almost constant for a substantial length of time. Figure 33 shows the factor prices of the scenario with Z, K taxes and L taxes[13]. As can be seen, the time series for the factor prices in the graphs demonstrate the same pattern observed in the data.

To explain the puzzle, I introduce Z, K taxes and L taxes separately into the model to identify how these three wedges can individually explain the factor prices (return on capital and wages): the return on capital for Taiwan is relative constant while wages in 2002 are three times their 1973 levels.

Figure 34 shows the factor prices under the scenario with Z. Figure 35 shows the factor prices under the scenario with L taxes. Finally, Figure 36 presents the factor prices generated under the scenario with K taxes. Among the three graphs, only Figure 34 (the factor price generated by the model with productivity shocks) can replicates the observed trend for factor prices in the economy: the wage in 2002 is around 3 times that of 1973 and the return on capital is within the band of 13% to 18%. The return on capital matches the trend in data (it falls for a couple years and then remains constant). In addition, the wage

[13] The ratio remains the same as introducing income wedge in the model in addition to Z, K and L wedges.

matches well the increasing trend in the data. On the contrary, the other two graphs cannot even replicate doubling wage rate in the economy for the entire period. Therefore, if factor prices fully reflect the conditions of an economy (in light of the factor price equilibrium), the TFP is a strong candidate for explaining Taiwan's catch-up with the developed countries since 1973.

I also show the Output, Labor, consumption to output rate (C/Y), and investment to output ratio (I/Y) for different scenarios under Case II in Figure 37 to Figure 45. Figure 37 shows the results from the scenario with none of the wedges; Figure 38 and Figure 39 show the results from the scenarios with L taxes and K taxes respectively; and Figure 40 shows scenario with both L taxes and K taxes. As can be seen, the model cannot replicate the long-term trend of output growth in absence of Z. Figure 41 shows the result of simulation with Z. As can be seen, this scenario not only replicates the trend of growth for the entire period but also the level until the 1980s. In other words, under Case II, Z is important in explaining Taiwanese growth.

Figure 42 shows the scenarios with Z and L taxes. As is shown, the simulated transition path raises the transition path above the data until the early 1980s. Therefore, extending the case starting from 1973 to the case starting from 1961 and use employment as a proxy for labor input shows labor wedges are important in the 1960s to the 1970s.

Figure 43 shows the results of the scenario with Z and K taxes. As can be seen, the model can mimic the transition in data very well in the absence of L taxes. Such results suggest that the combined effects of productivity improvements and investment wedges are important. This conclusion is slightly different from what is suggested in Case I. This is because the labor inputs are different in these two cases and the labor market effects on growth are smaller when using employment (Case II) rather than labor hours (Case I) as the input. Finally, to complete the analysis for Case II, I show Figure 44 and Figure 45 reporting the results of the scenario with Z, K L taxes and Z, K L plus income wedges and show the model fits the data well when all the wedges are introduced into the model.

Comparing the preliminary diagnoses with Young's (1995), the observation above is similar to his sub-period results. I replicate Young's table for the growth rate of output, capital, labor, and TFP and add in the percentage contribution in Table VII. As is shown below, labor in the 1970s and TFP in the 1980s account much of the growth in terms of percentage contribution. This is consistent with my results using the diagnostic tool.

However, there are some small differences: First, I demonstrated that investment wedges are not the origin of rapid growth in the 1960s because the wedges have negative effect on economic growth; however, since the model shows that the initial capital stock is below the steady state level, there is naturally rapid capital accumulation. Therefore, my results are in harmony with Young's conclusion based upon the sub-period results.

Second, I showed that improvements in total factor productivity is the momentum that enables Taiwan to achieve the output level today, whereas Young showed growth in labor input is the major contributor to the Taiwanese growth from 1966 to 1990. The discrepancy may be due to the sampling: Young's study is from 1966 to 1990 whereas mine is either from 1973 to 2002 or from 1961 to 2002. Figure 46 shows the growth rate of the exogenous TFP series I feed in the model. As can be seen, the detrended TFP shows that the growth rate is above 1.5% from 1962 to 1967, and 1986 to 2000, whereas only 10 out of 20 years from 1966 to 1985 exhibit such a level of growth.

Therefore, with a longer period of study, the results of this paper show that the productivity improvements are crucial in explaining the long-term growth in Taiwan. Furthermore, the persistent positive labor market effects and the persistent positive capital market effects on the economy in the late 1980s together create a case of a development miracle on the island.

Table VII: Young's Table for Taiwanese Growth Accounting (1995, p. 661)

Period	*G_Y*	*G_K*	*G_L*	*G_TFP*
1966-1970	11.1%	17.1%	4.4%	3.4%
	(100.00%)	(40.21%)	(29.29%)	(30.63%)
1970-1980	10.3%	14.40%	6.80%	1.50%
	(100.00%)	(36.49%)	(48.79%)	(14.56%)
1980-1990	7.8%	8.30%	3.20%	3.30%
	(100.00%)	(26.71%)	(30.73%)	(42.31%)
1966-1990	9.4%	12.30%	4.90%	2.60%
	(100.00%)	(33.63%)	(38.73%)	(27.66%)

8. Conclusion

In this paper, I introduce business cycle accounting (e.g. Cole and Ohanian, 1999; Chari, Kehoe and McGrattan, 2004) to identify the major sources of the Taiwanese growth from 1961 to 2002. Compared with the traditional growth accounting used in the literature (which focus on input and output in production), the new method identifies the sources of growth by analyzing the dynamics of the economy, which takes into accounts agents' and firms' decisions at equilibrium in addition to the production function.

After the preliminary diagnoses for the source of growth of Taiwan, I conclude that productivity improvement is crucial in explaining the long-term growth in Taiwan. In addition, there are persistent positive labor market effects on growth in the 1960s and 1970s and positive capital market effects on growth starting from the 1980s. The combined effects of productivity improvements and positive effects from the labor and capital markets have enabled Taiwan to continue its trajectory of catching up with the developed countries since 1961.

The results of the diagnoses imply possible further research on the sources of growth of Taiwan. A few puzzles remain in terms of the causes of the forces driving the economy to deviate from the world balanced growth path. For the productivity to catch up, it will be interesting to decompose the origin of the productivity improvements. One example of this is examining the extent to which the economic transitions from agriculture to manufacturing to services have contributed to productivity improvements. Setting up a two-sector or three-sector model may be helpful for analyzing this issue.

For the capital market, a topic for future research will be to find out the source of the negative effects in the 1960s and the source of the positive effects in the 1980s. There are two possible explanations for the effects from the capital markets: interest rate and capital controls. The strict interest rate controls before the 1980s may reduce the function of banks as effective intermediaries of funds between savers and investors. On the other hand, the financial development and liberalization of the late 1980s may explain the big positive impact of the capital markets on growth. Thus, modifying the model to reflect financial development may shed light on the origin of the impact on growth attributes to capital market development.

In the labor market, there is a puzzle about why the big positive impacts on growth in the early stage of the development diminished over time. This diminishment may be due to

natural fade out of the shocks, or may due to the implementation of the Labor Law[14]. Developing a model to take care of the impact of the implementation of new law may explain some of the bizarre agents' decisions in the labor markets.

Finally, since total factor productivity is one of the main sources of Taiwanese growth, another interesting topic to study will be sectoral TFP growth to identify whether there is any Balassa-Samulson effect in Taiwan. Finally, extending the same study to other East Asian NICs may clarify if improvement in total factor productivity a universal feature to continued economic prosperity in the second half of the twentieth century.

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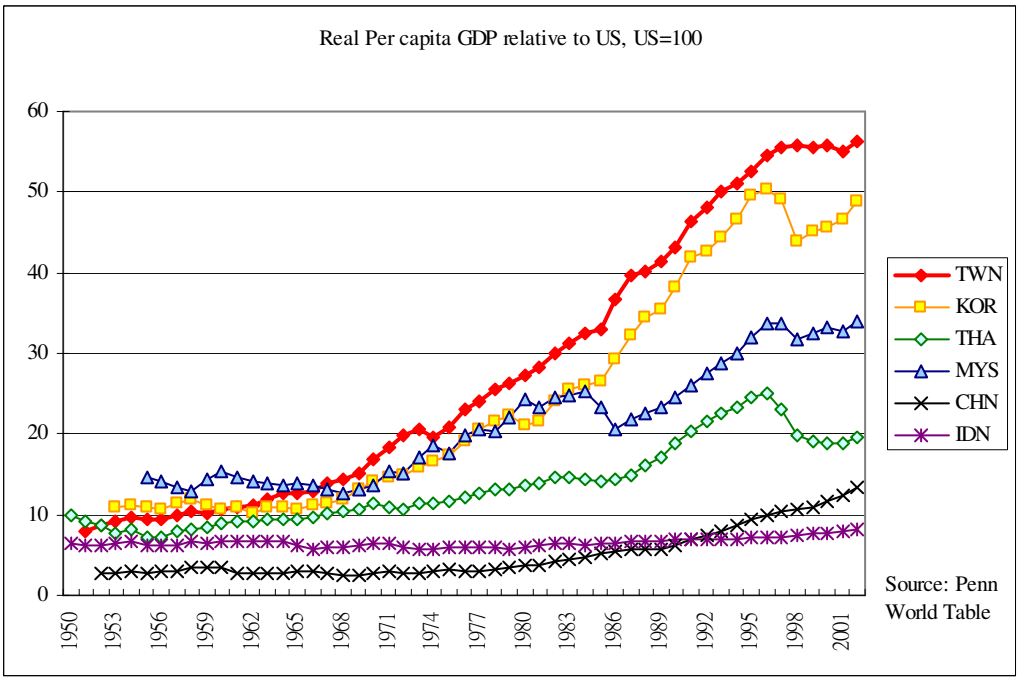

Figure 1: Real GDP per capita relative to U.S., 1950 – 2002, Taiwan vs. Asian Countries

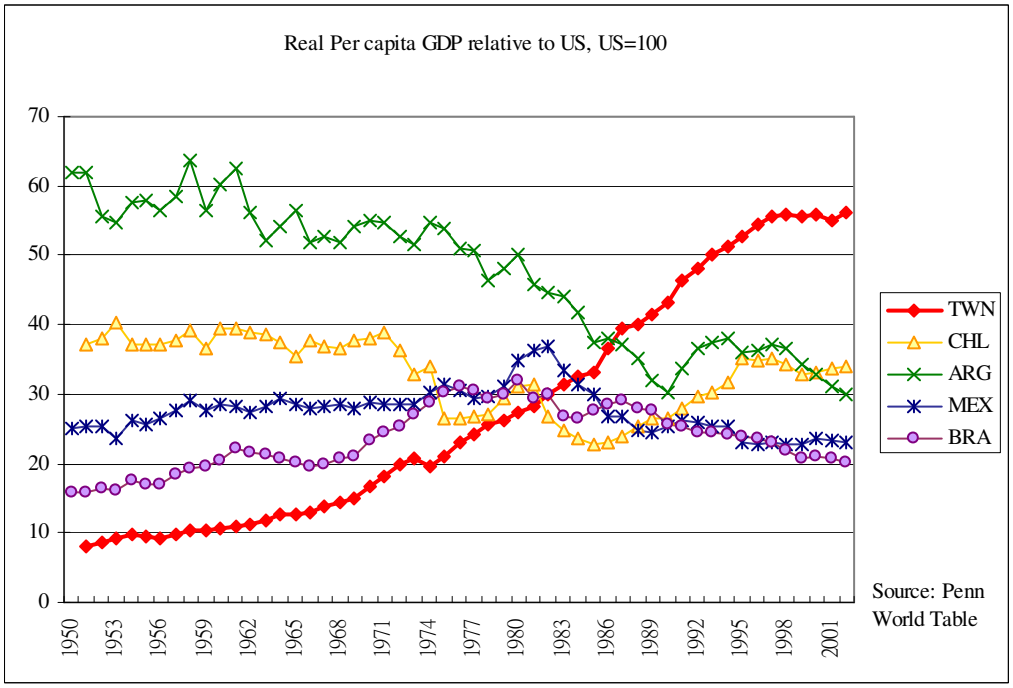

Figure 2: Real GDP per capita relative to U.S., 1950 – 2000, Taiwan vs. Latin American Countries

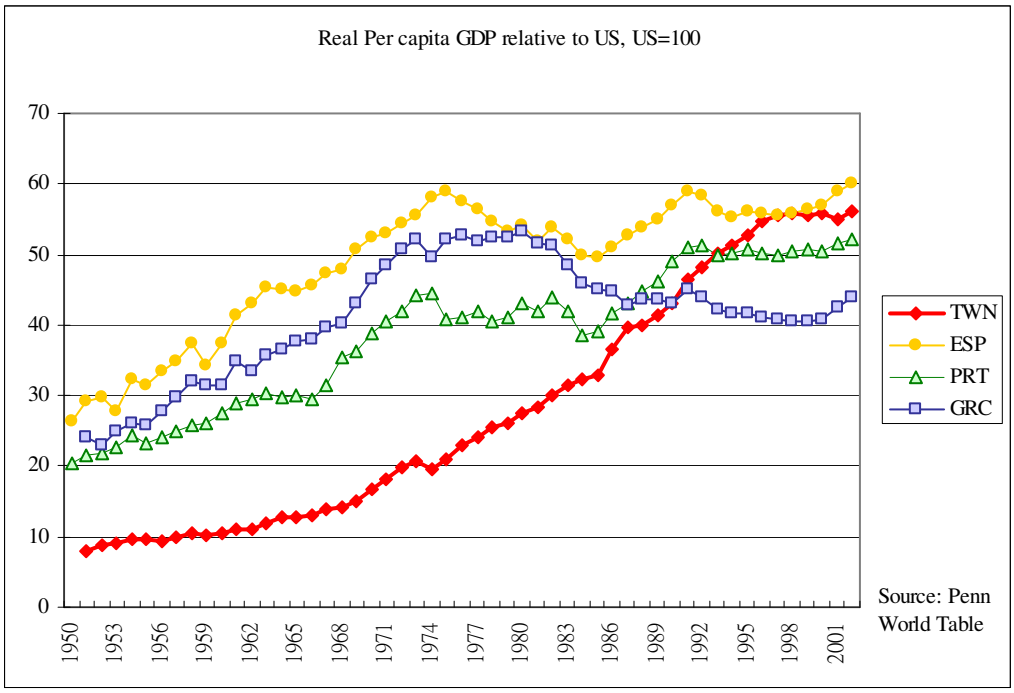

Figure 3: Real GDP per capita relative to U.S., 1950 – 2000, Taiwan vs. European Countries

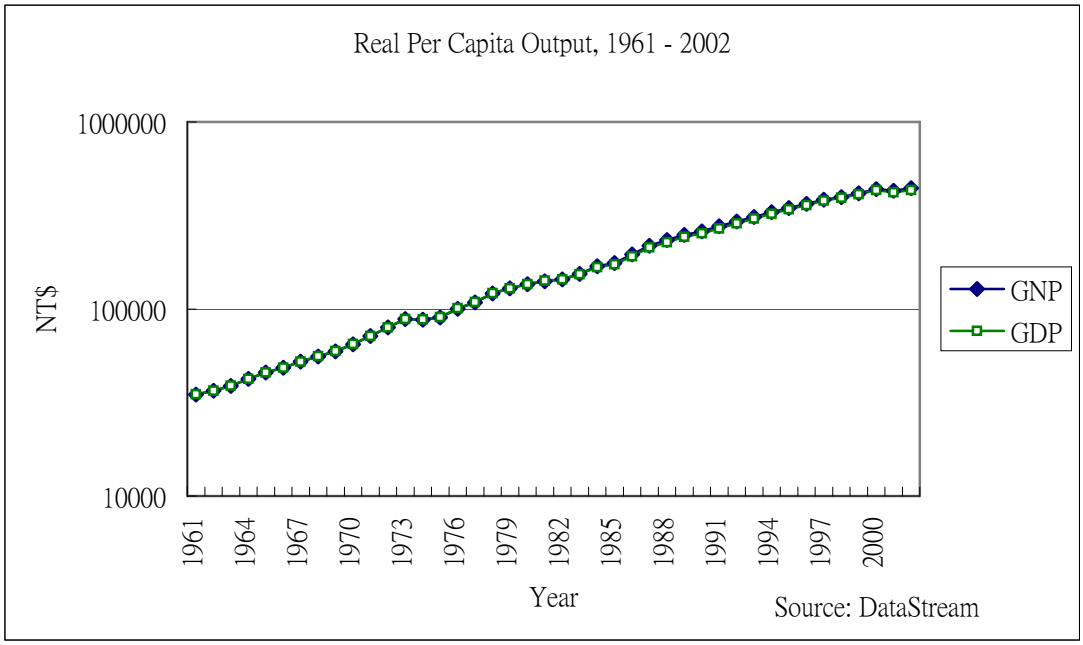

Figure 4: Real per capita output, 1961 – 2002

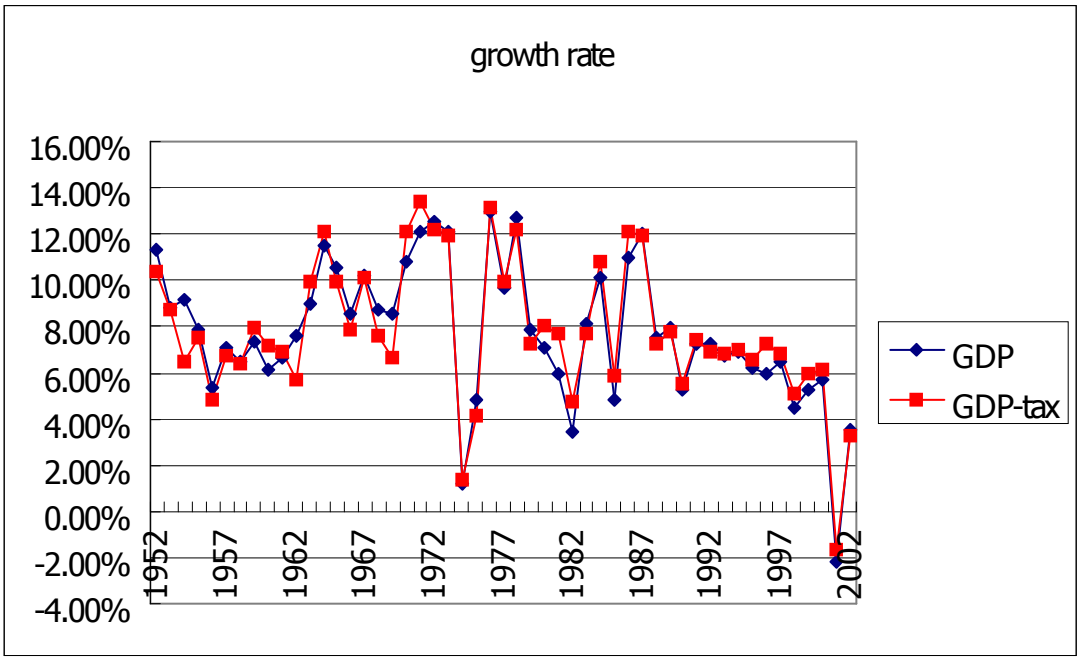

Figure 5: Growth rate for GDP vs. GDP minus net indirect tax, 1951– 2002

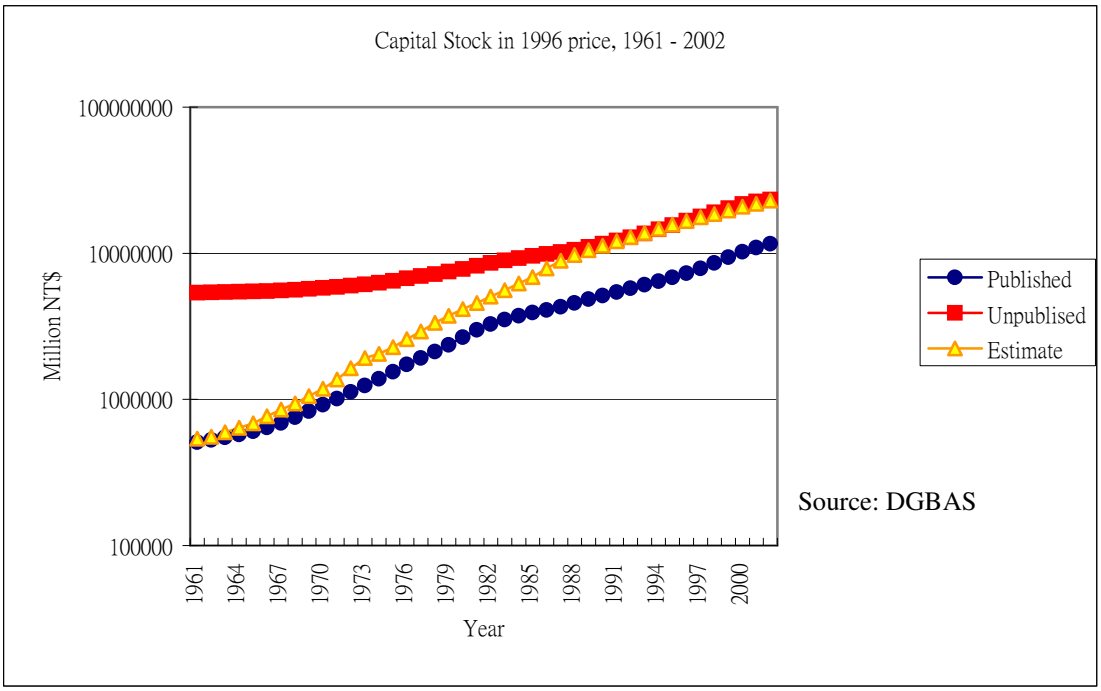

Figure 6: Net Capital Stock excluding land at 1996 price, 1961 – 2002

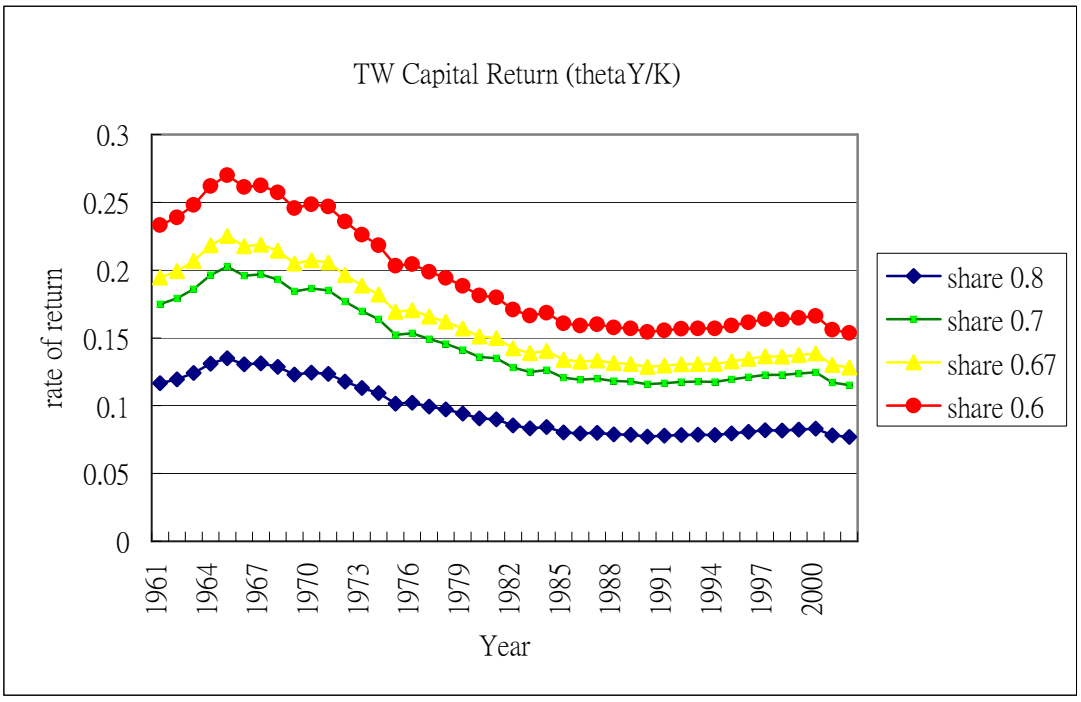

Figure 7: Taiwanese Capital Returns, fixed labor share, 1961 - 2002

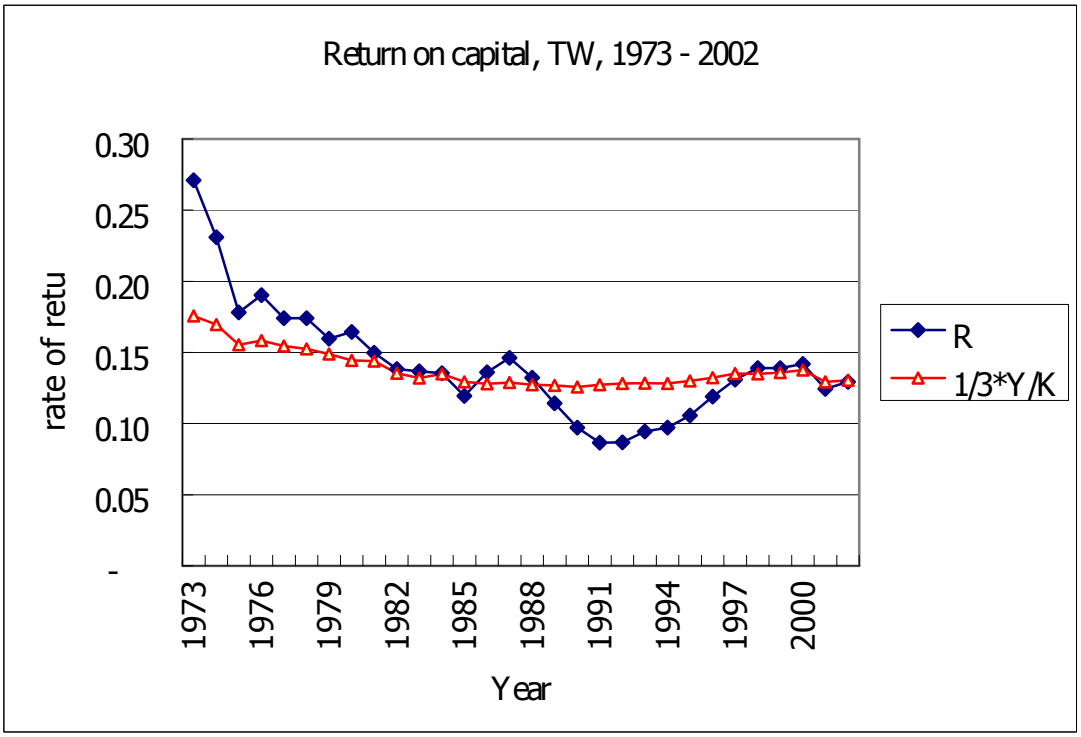

Figure 8: Taiwanese Return on Capital, 1973 - 2002

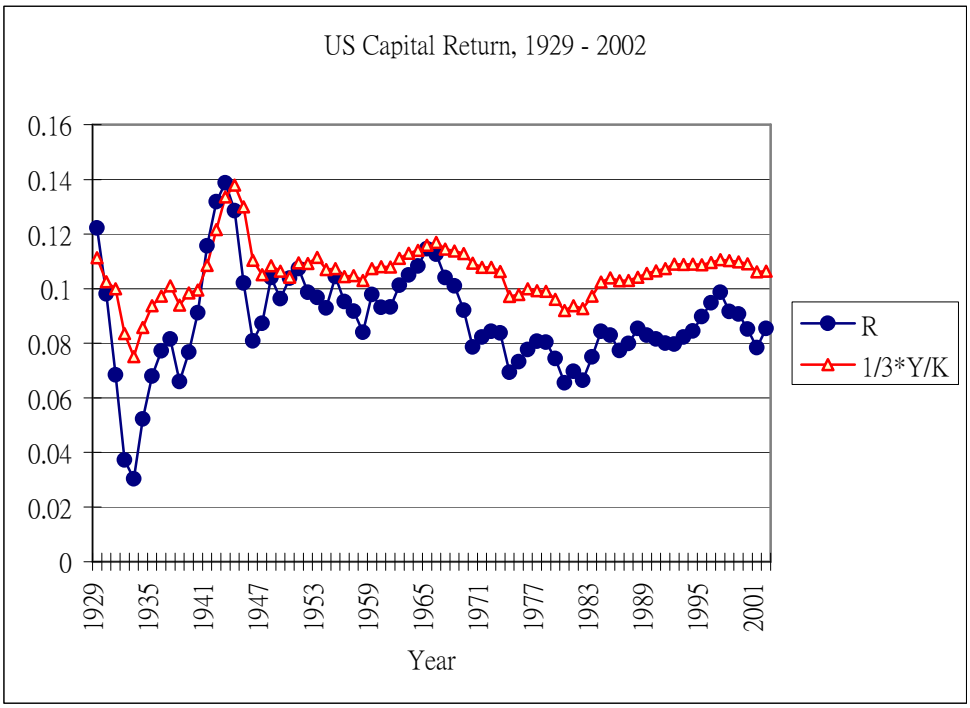

Figure 9: US return on capital, 1929 – 2002

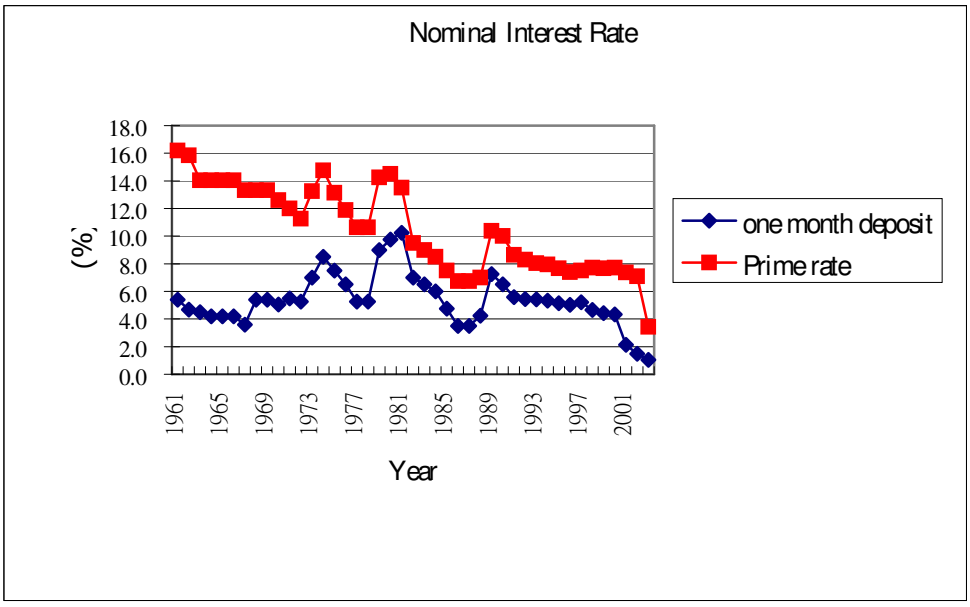

Figure 10: Nominal deposit and prime rate, 1961 - 2003

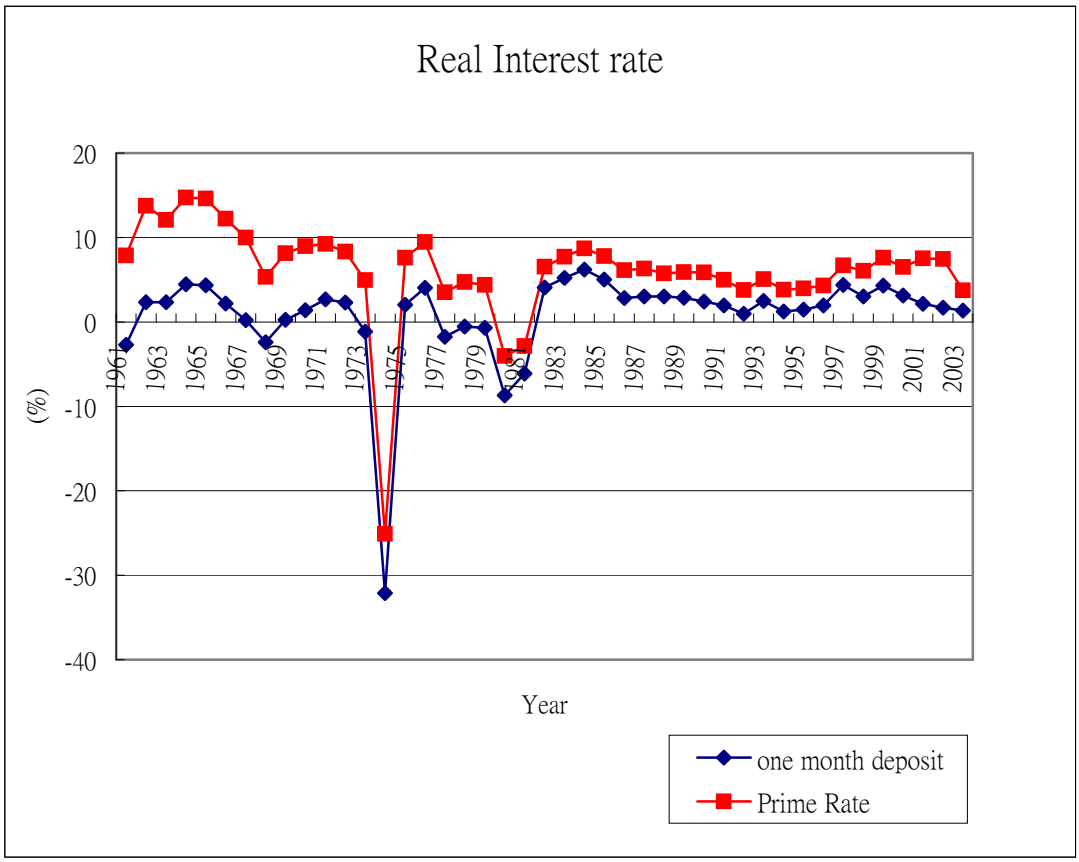

Figure 11: Real deposit and prime rate, 1961 - 2003

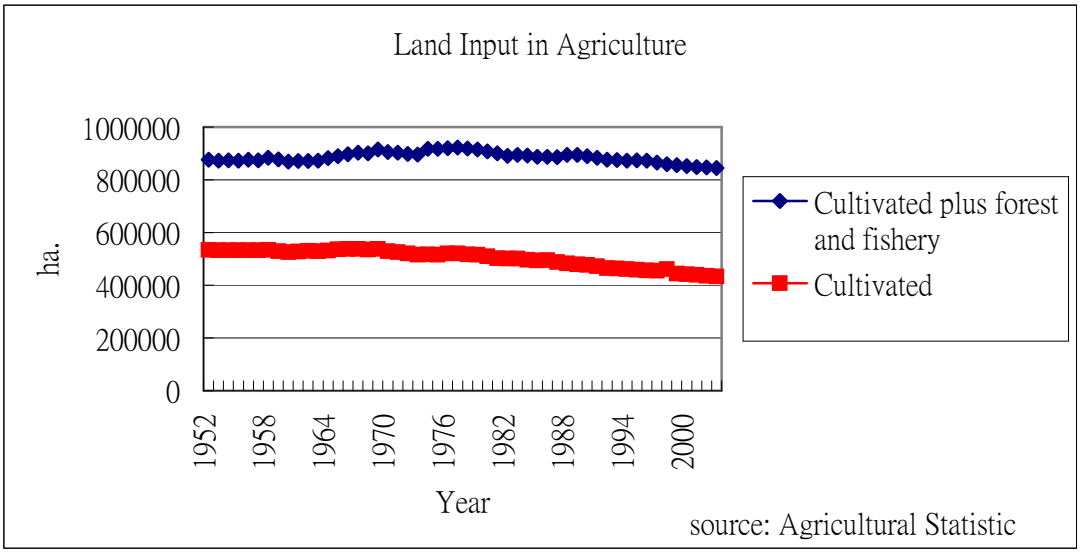

Figure 12: Area of cultivated land, forest and fishery

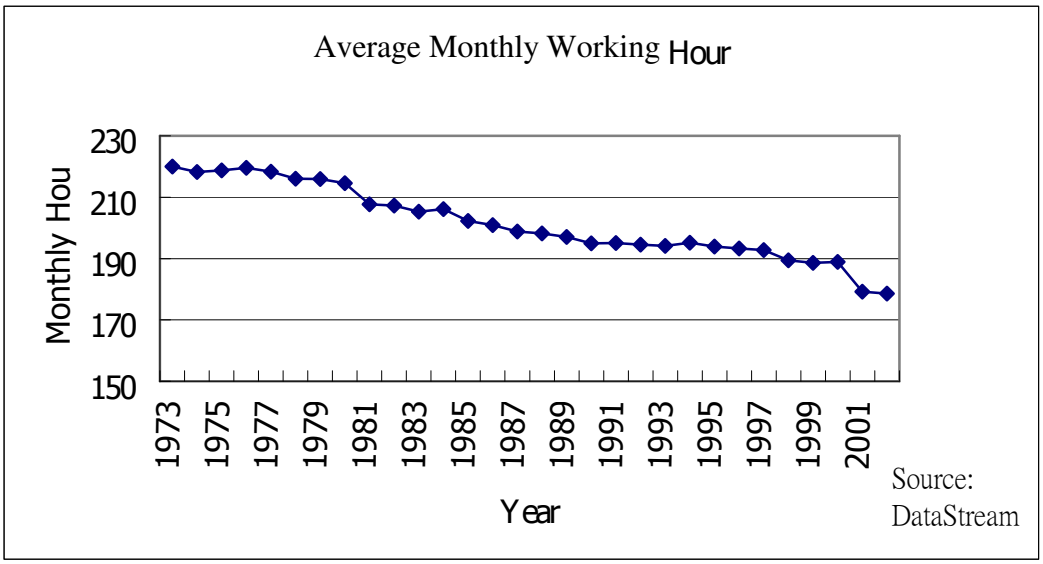

Figure 13: Average monthly working hour, 1973 - 2002

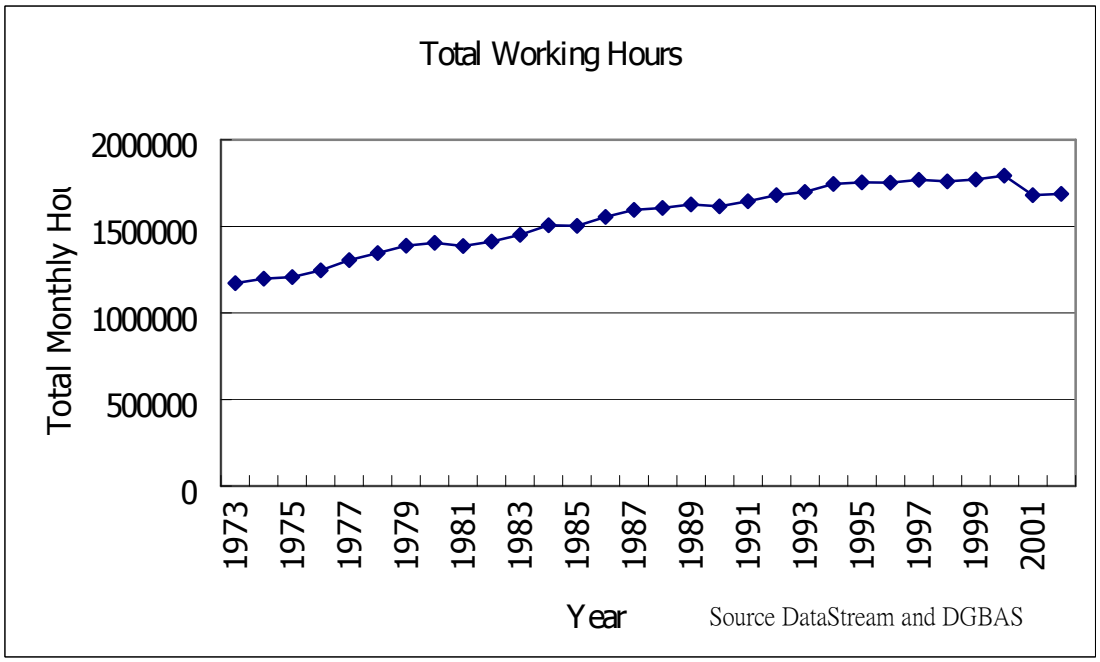

Figure 14: Total labor hour, 1973 – 2002

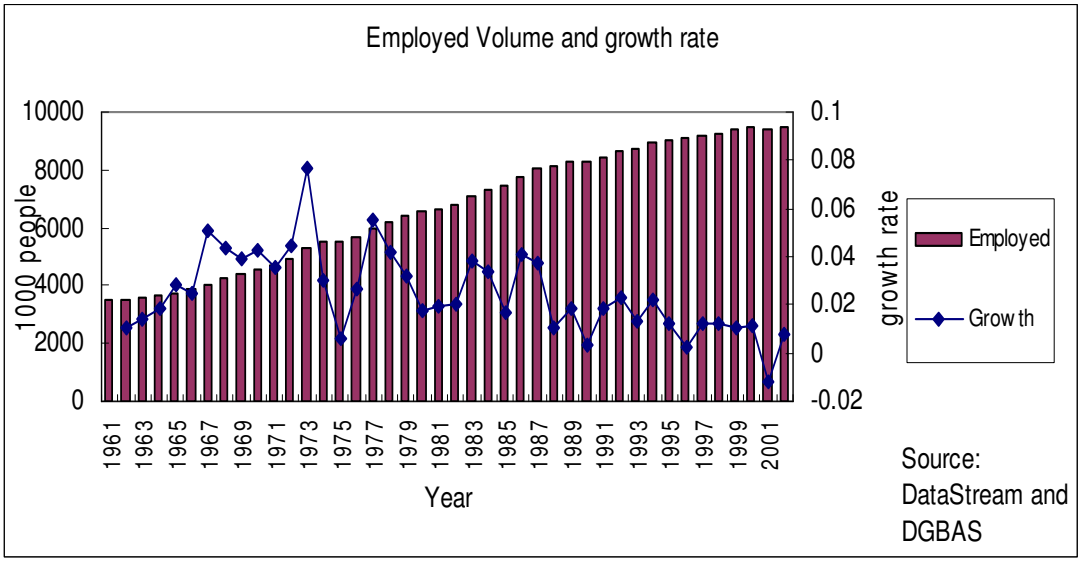

Figure 15: Employed volume and growth rate, 1961 - 2002

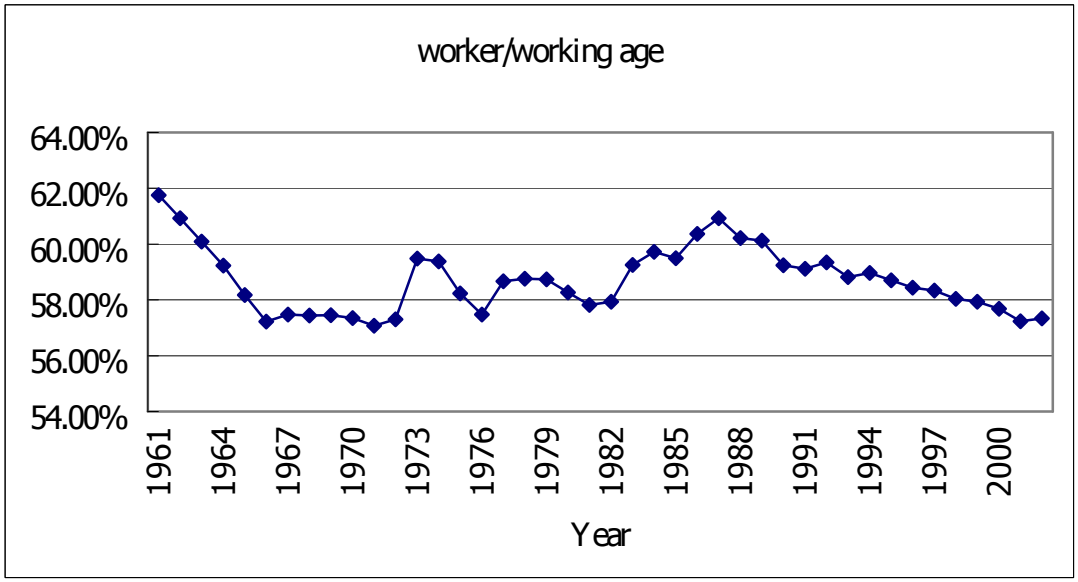

Figure 16: Labor participation ratio, 1961 - 2002

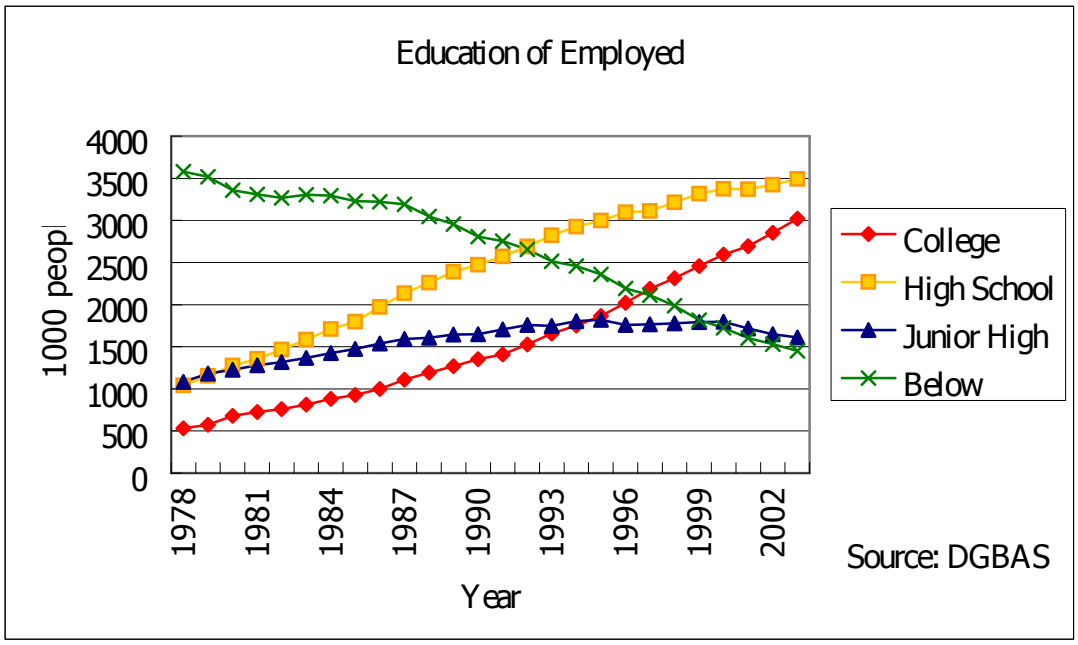

Figure 17: Education of employed, 1978 – 2002

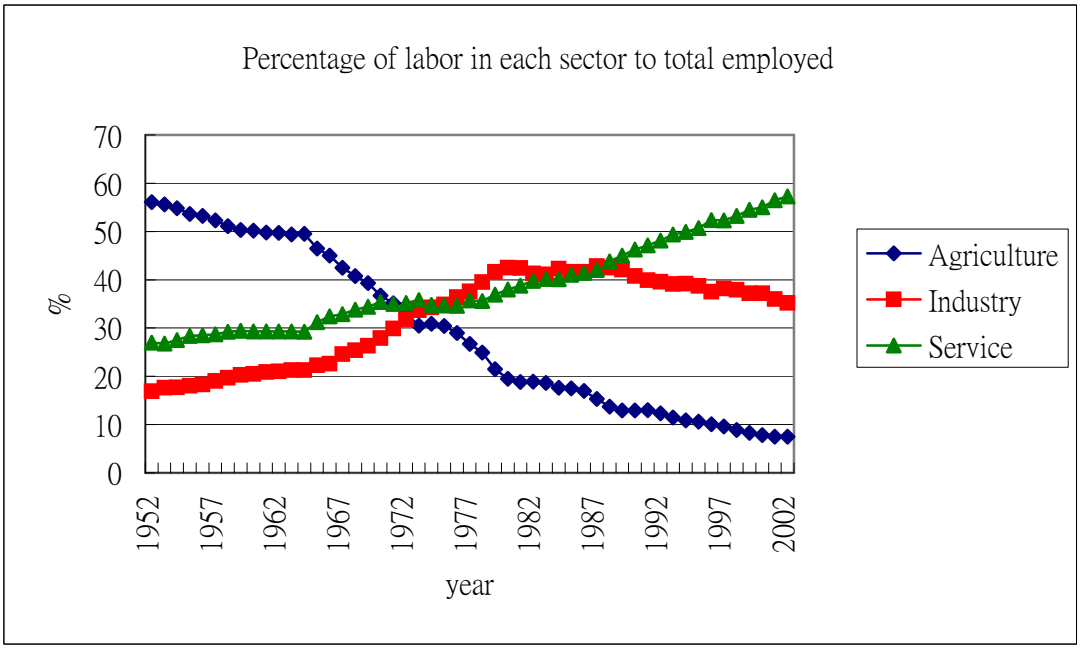

Figure 18: Percentage of labor in each sector relative to the employed, 1952 - 2002

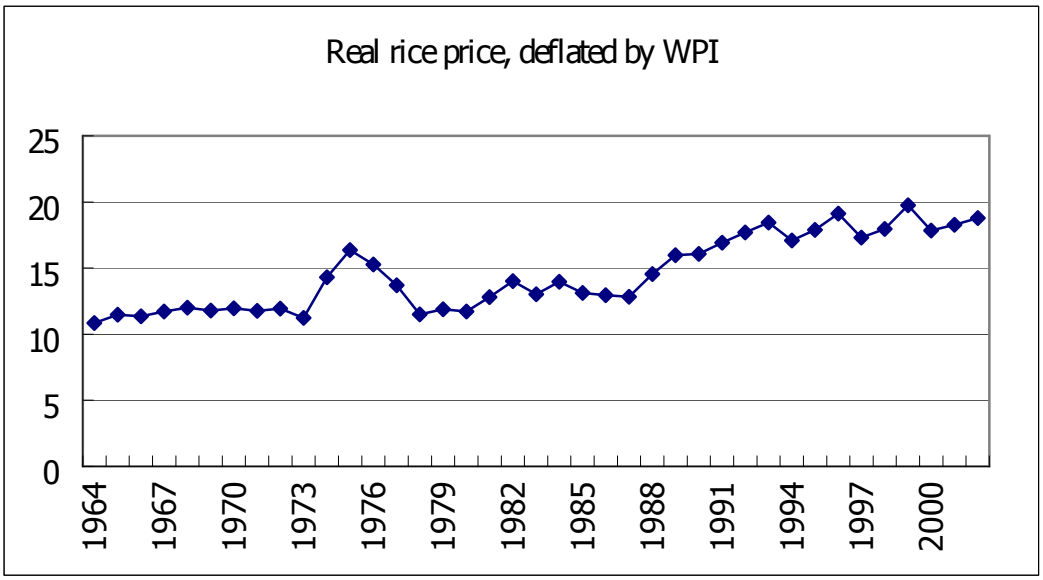

Figure 19: Real rice price, 1964 – 2002

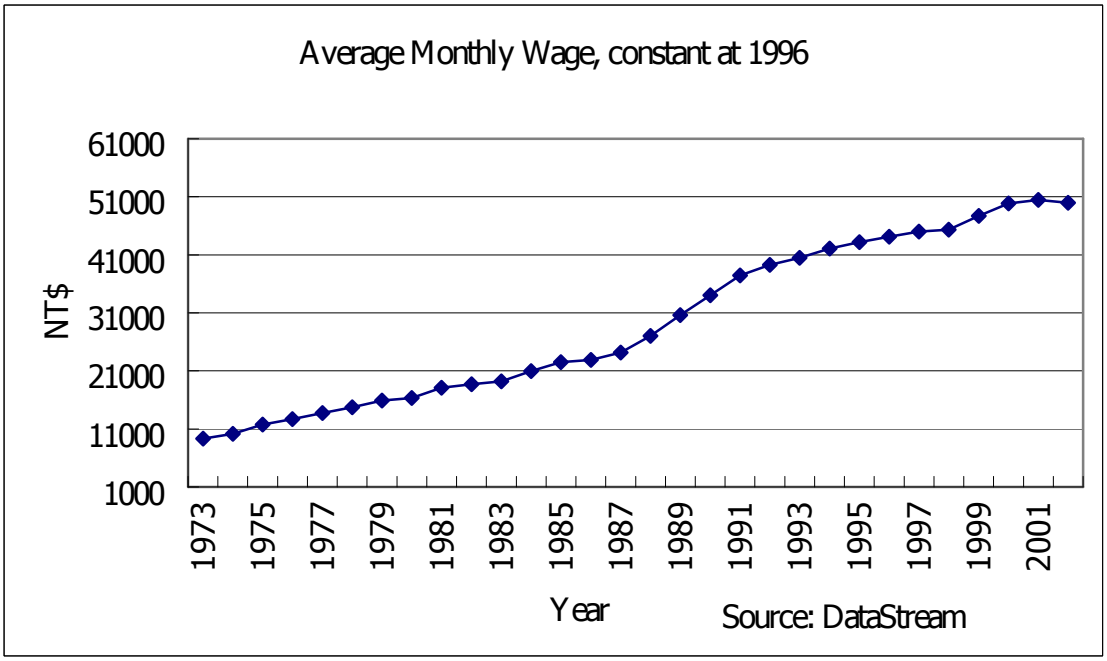

Figure 20: Average monthly earning, 1973 – 2002

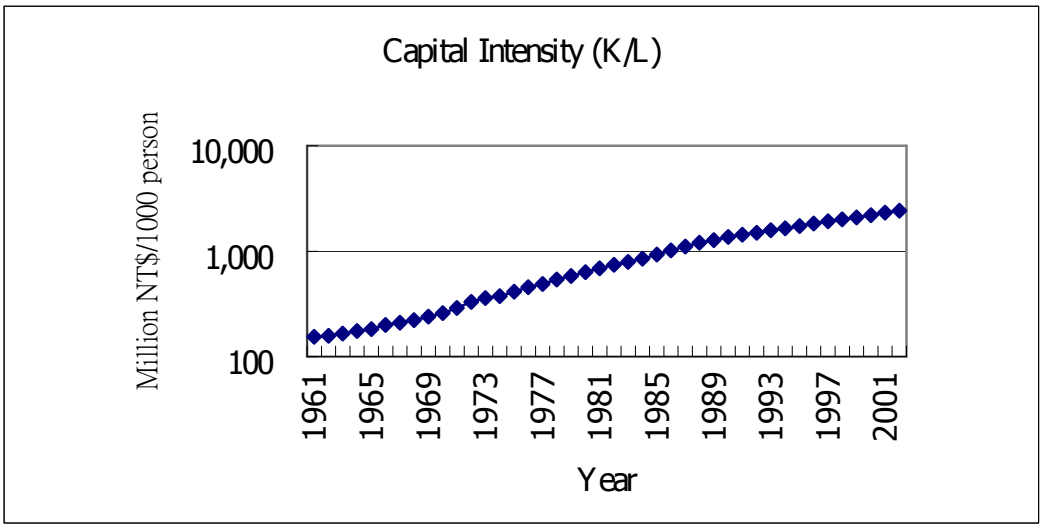

Figure 21: Capital intensity

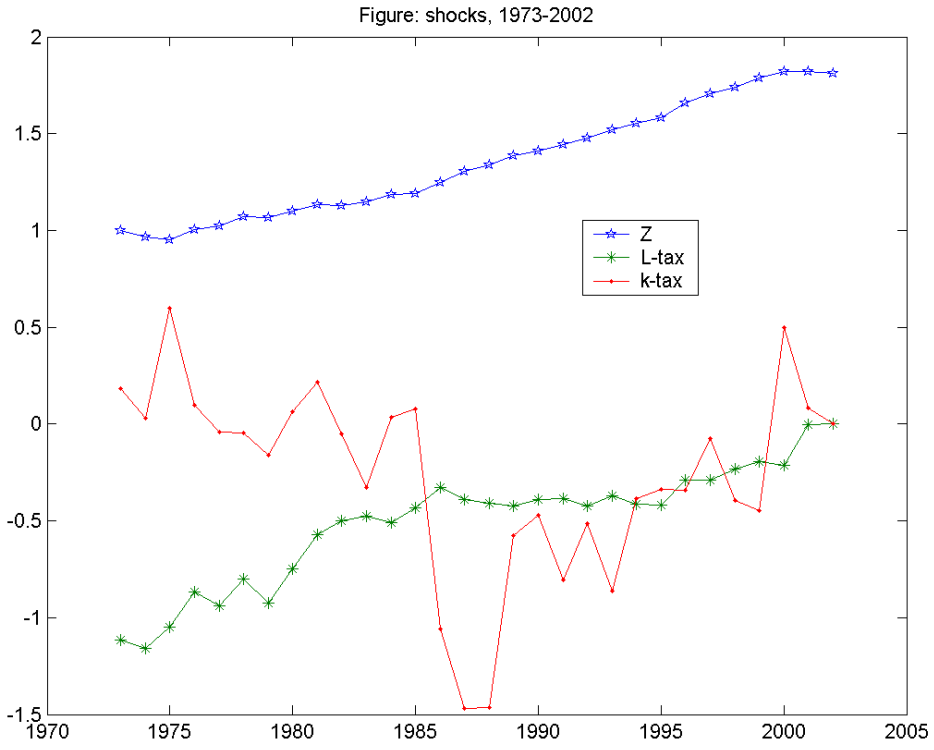

Figure 22: Wedges, 1973 to 2002, Case I

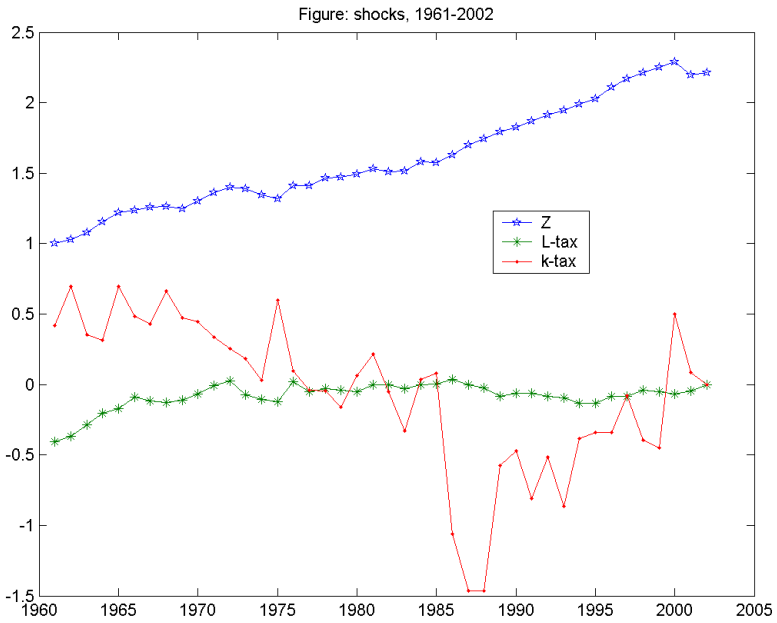

Figure 23: Wedges, 1961 – 2002, Case II

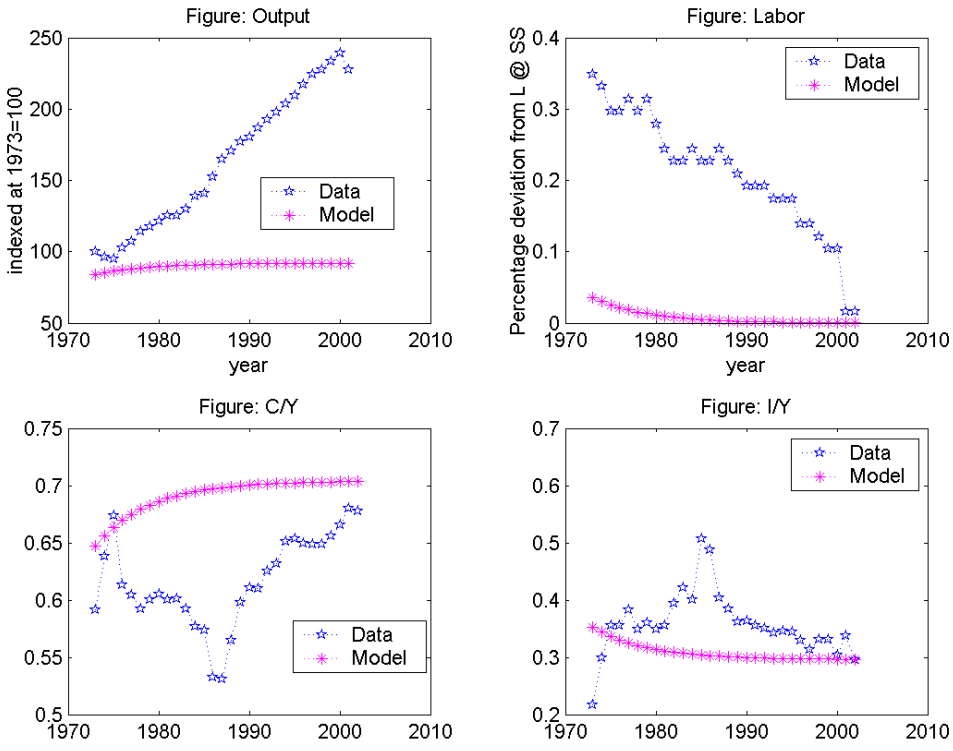

Figure 24: Output, labor, C/Y, and I/Y for model in Case I with none of the wedges

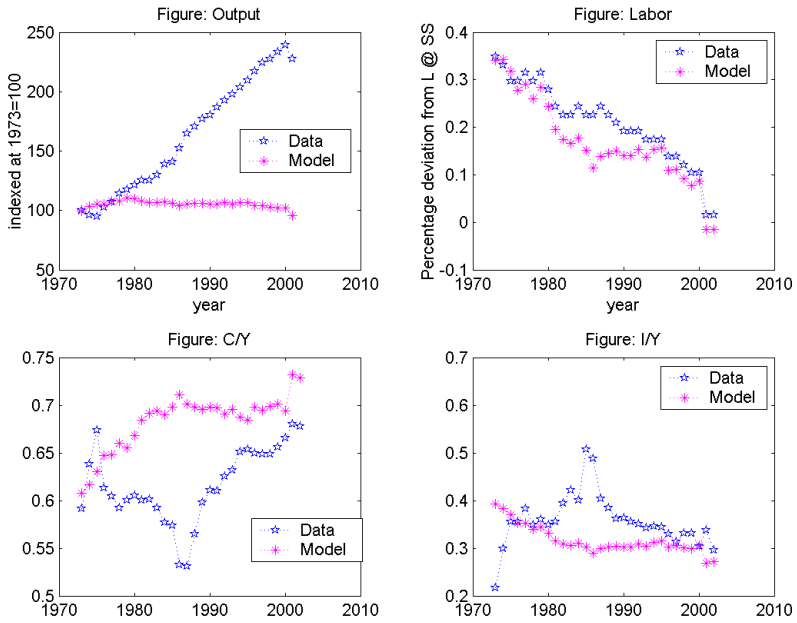

Figure 25: Output, labor, C/Y, and I/Y for model in Case I with L taxes

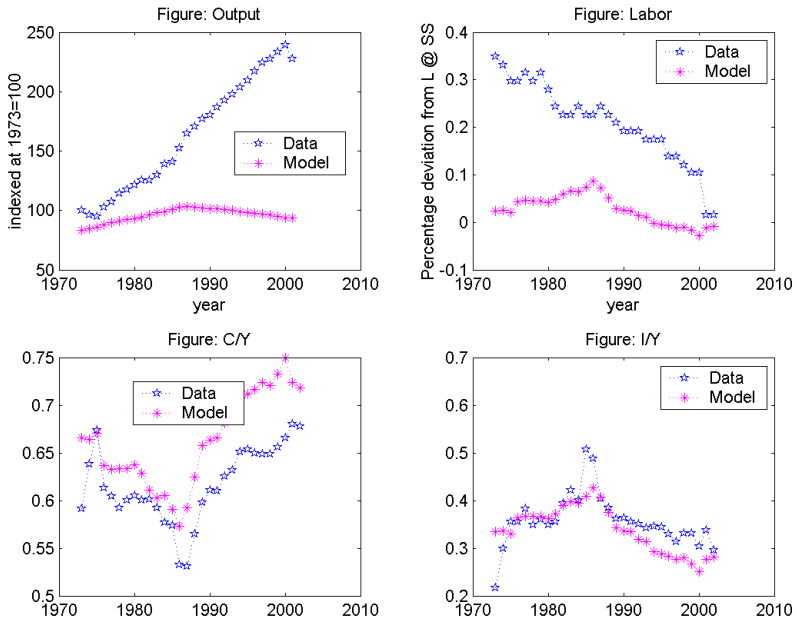

Figure 26: Output, labor, C/Y, and I/Y for model in Case I with K taxes

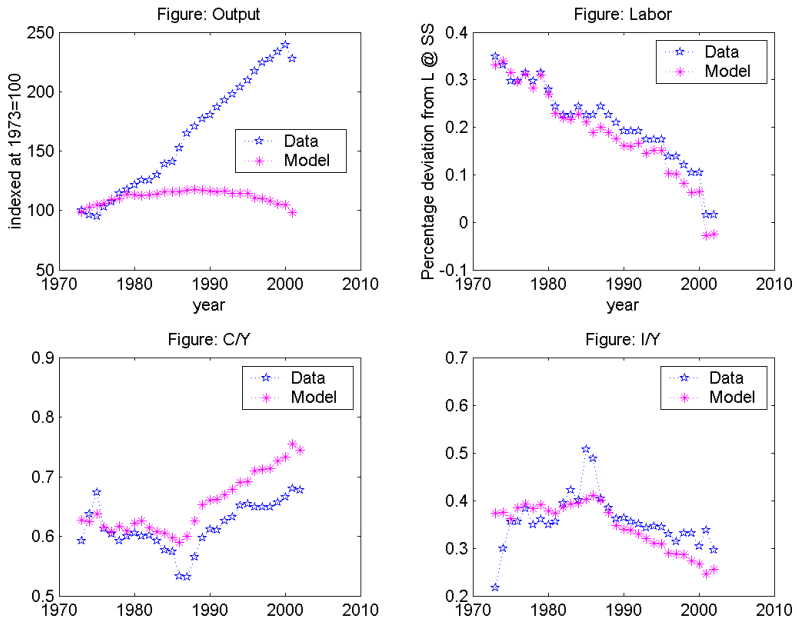

Figure 27: Output, labor, C/Y, and I/Y for model in Case I with L and K taxes

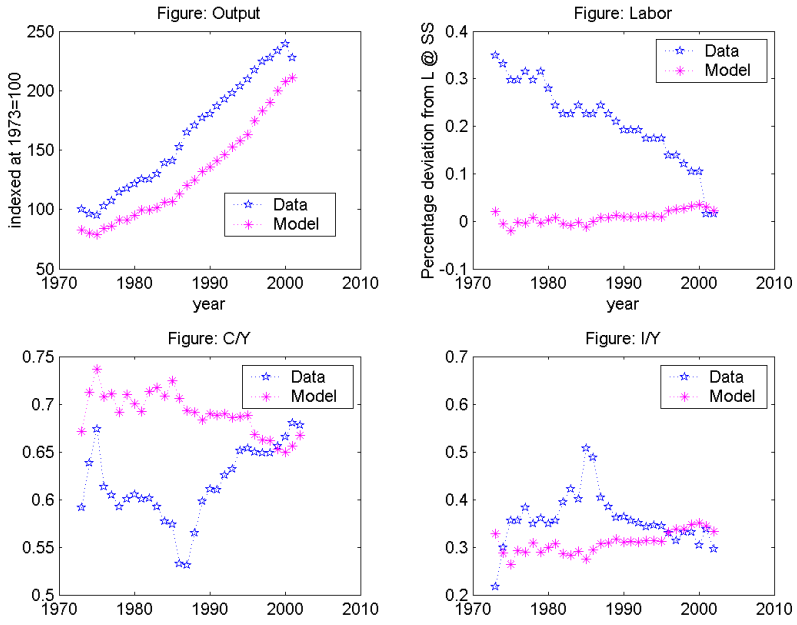

Figure 28: Output, labor, C/Y, and I/Y for model in Case I with Z

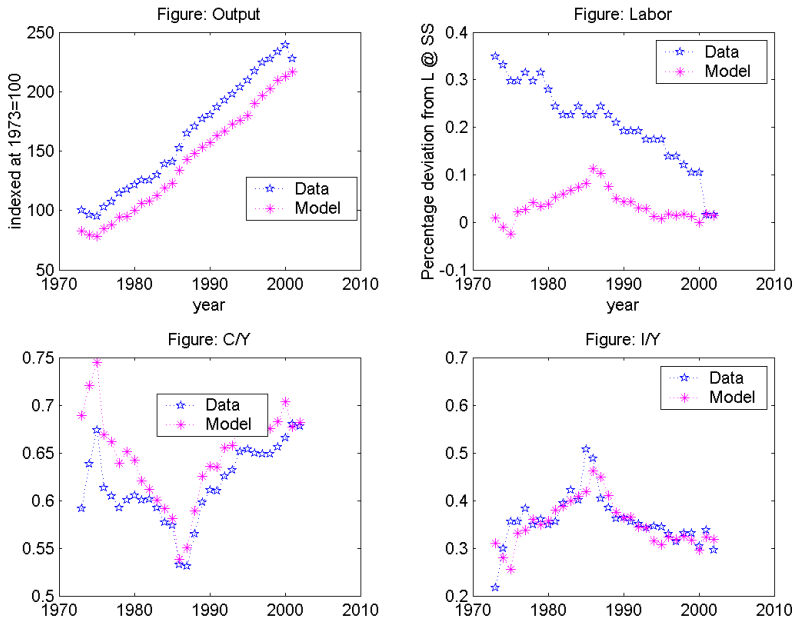

Figure 29: Output, labor, C/Y, and I/Y for model in Case I with Z and K taxes

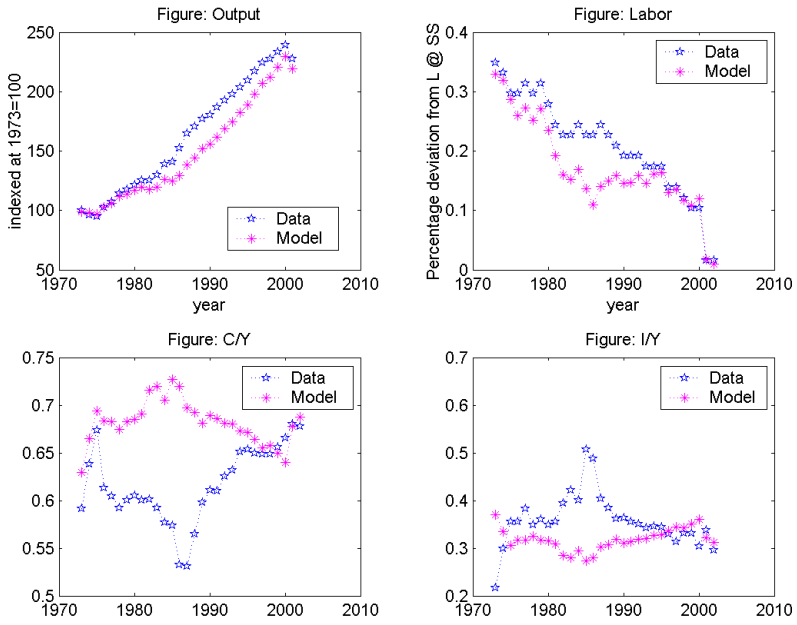

Figure 30: Output, labor, C/Y, and I/Y for model in Case I with Z and L taxes

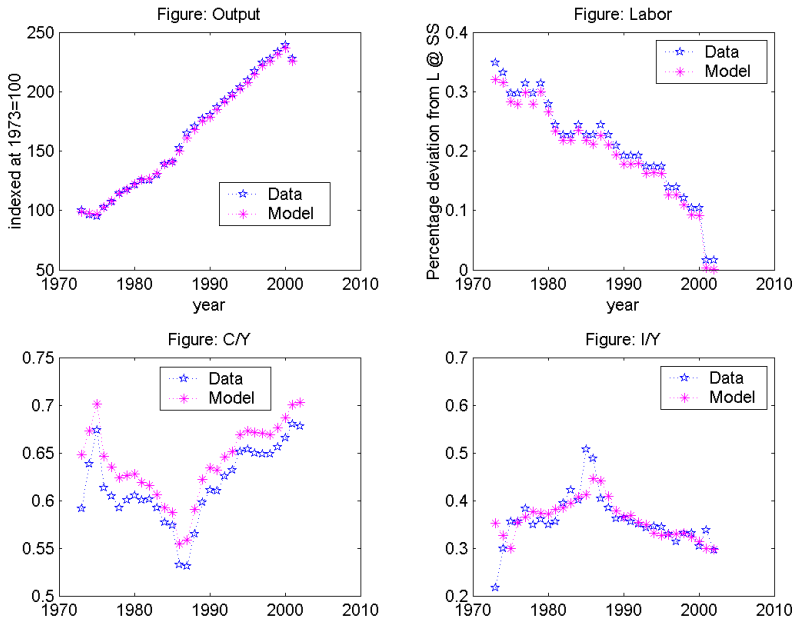

Figure 31: Output, labor, C/Y, and I/Y for model in Case I with Z, K and L taxes

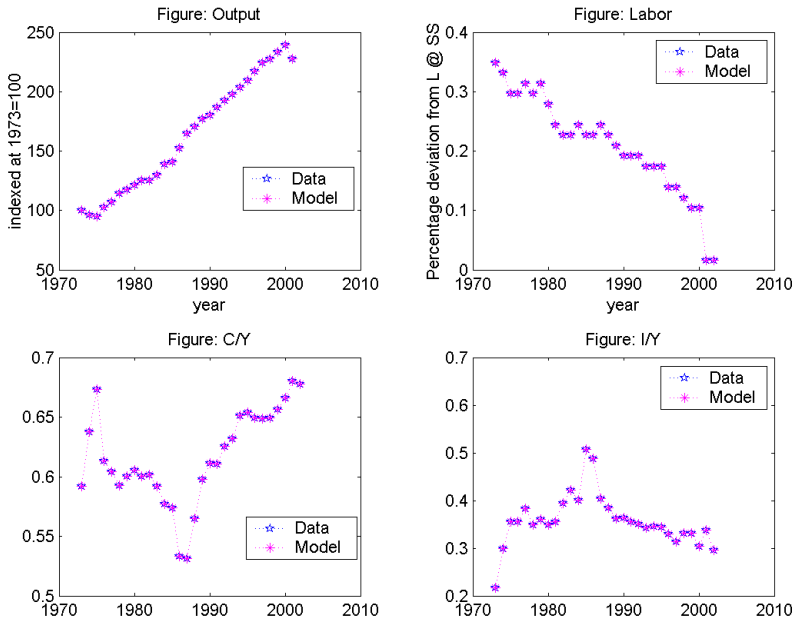

Figure 32: Output, labor, C/Y, and I/Y for model in Case I with Z, K and L taxes and income wedges

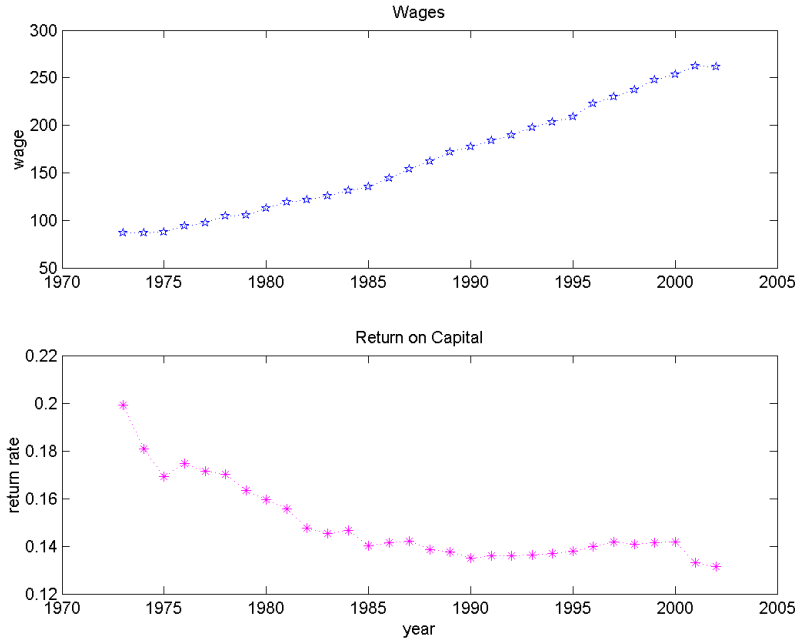

Figure 33: Factor prices generated by model with Z, K, L taxes, Case I

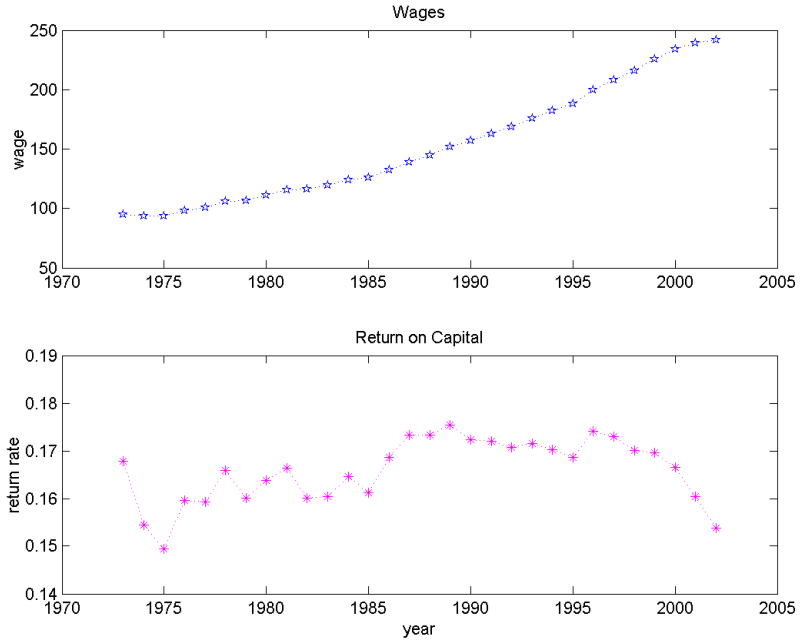

Figure 34: Factor prices generated by model with Z wedges, Case I

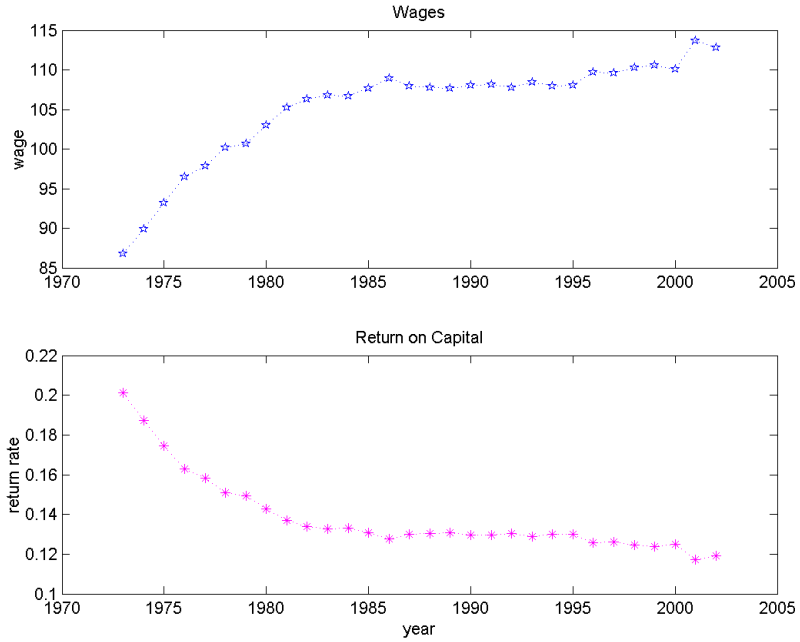

Figure 35: Factor prices generated by model with L taxes, Case I

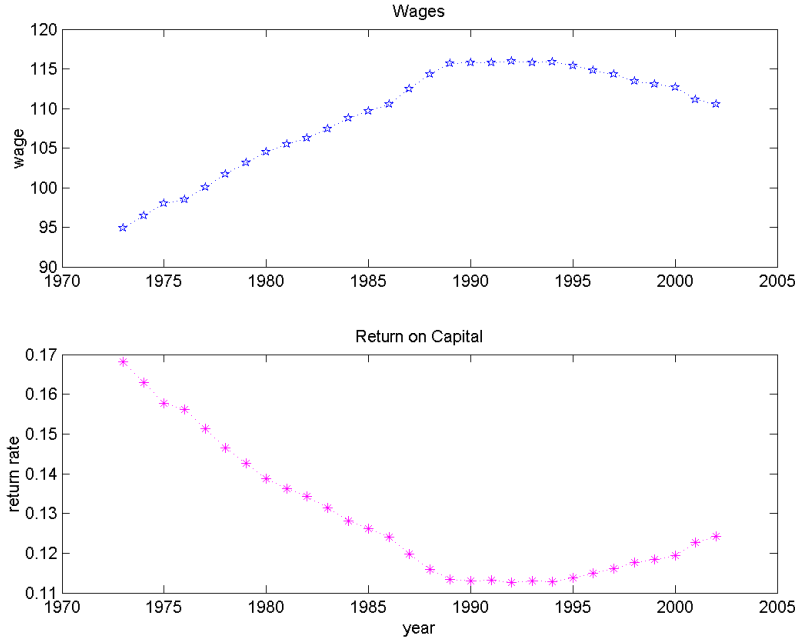

Figure 36: Factor prices generated by model with K taxes, Case I

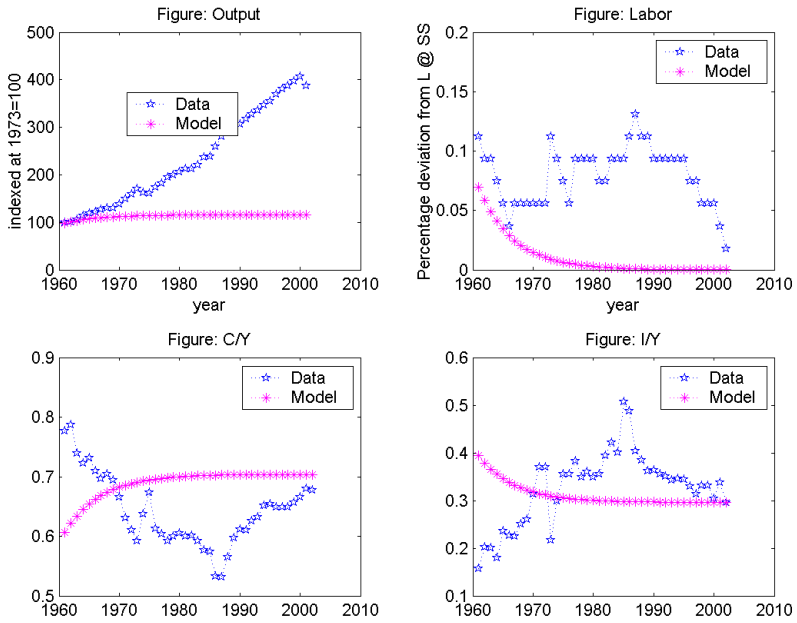

Figure 37: Output, labor, C/Y, and I/Y for model in Case II none of the wedges

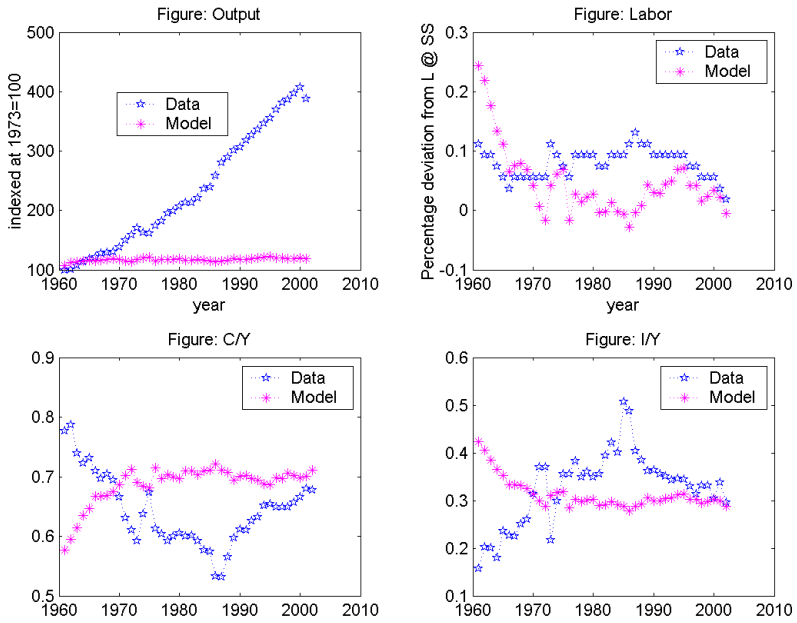

Figure 38: Output, labor, C/Y, and I/Y for model in Case II with L taxes

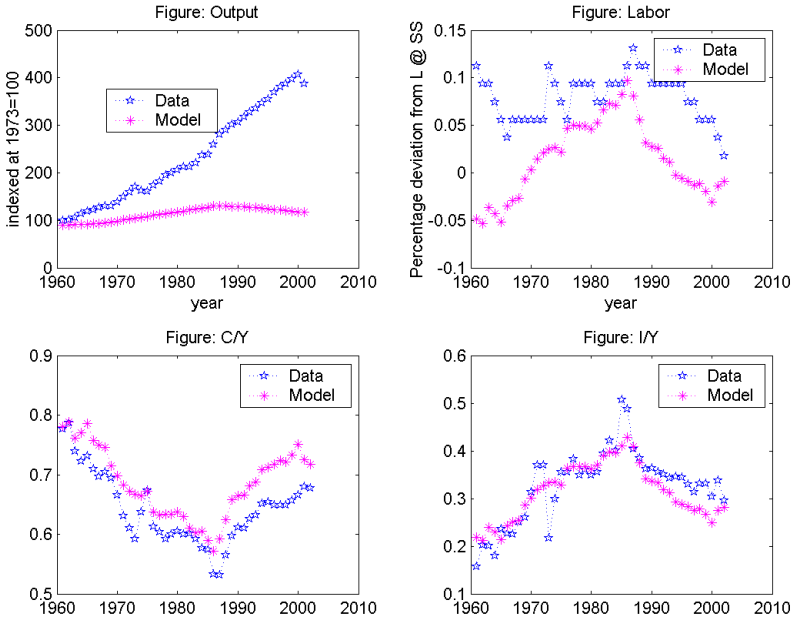

Figure 39: Output, labor, C/Y, and I/Y for model in Case II with K taxes

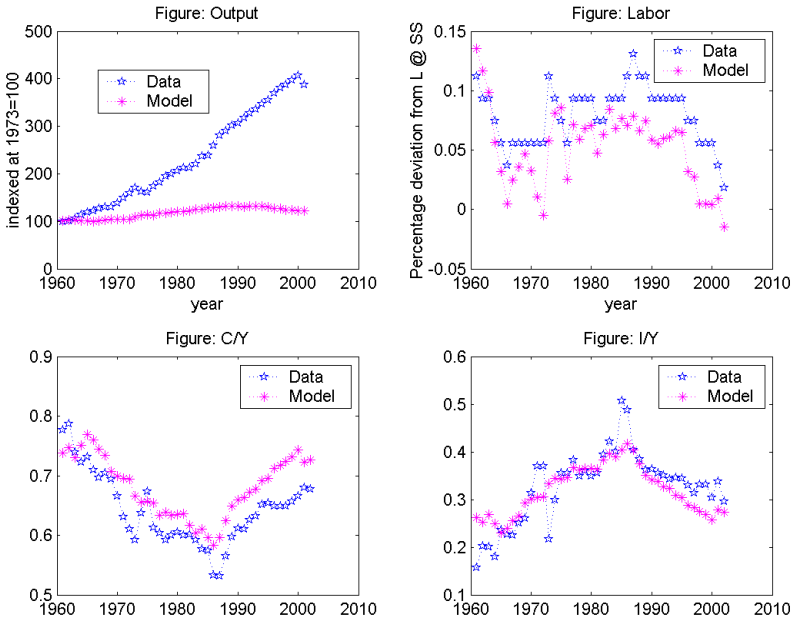

Figure 40: Output, labor, C/Y, and I/Y for model in Case II with L and K taxes

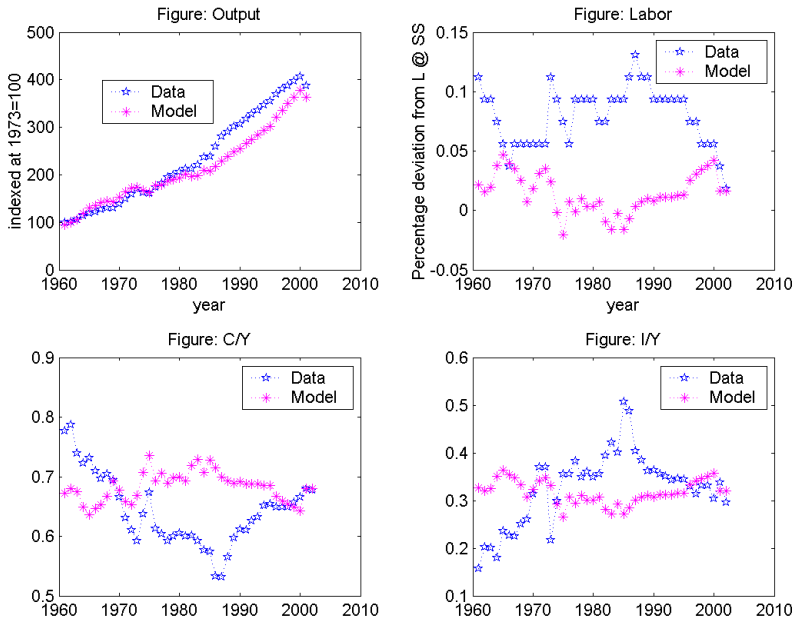

Figure 41: Output, labor, C/Y, and I/Y for model in Case II with Z

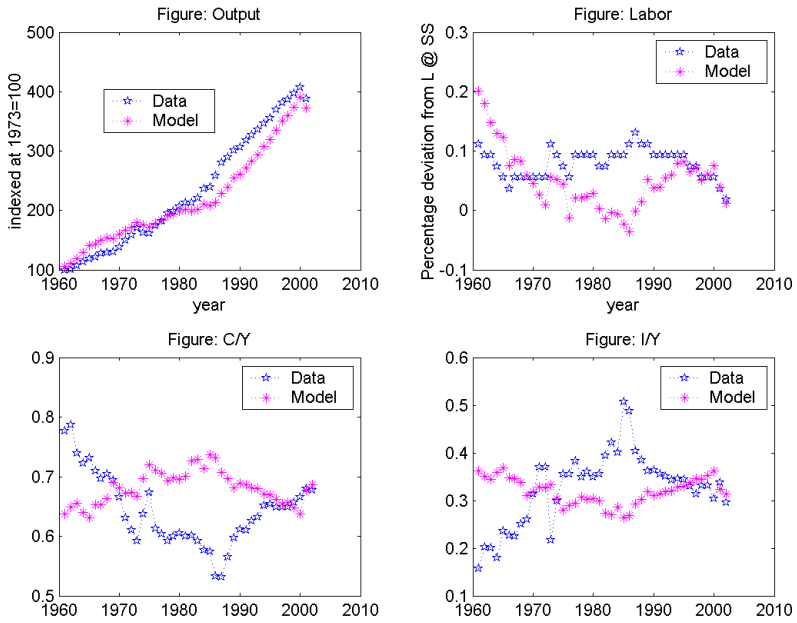

Figure 42: Output, labor, C/Y, and I/Y for model in Case II with Z and L taxes

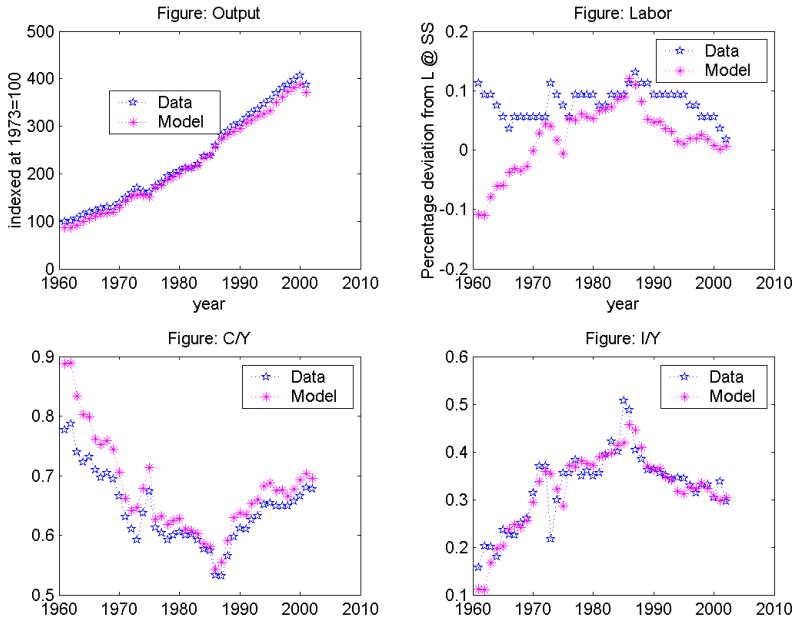

Figure 43: Output, labor, C/Y, and I/Y for model in Case II with Z and K taxes

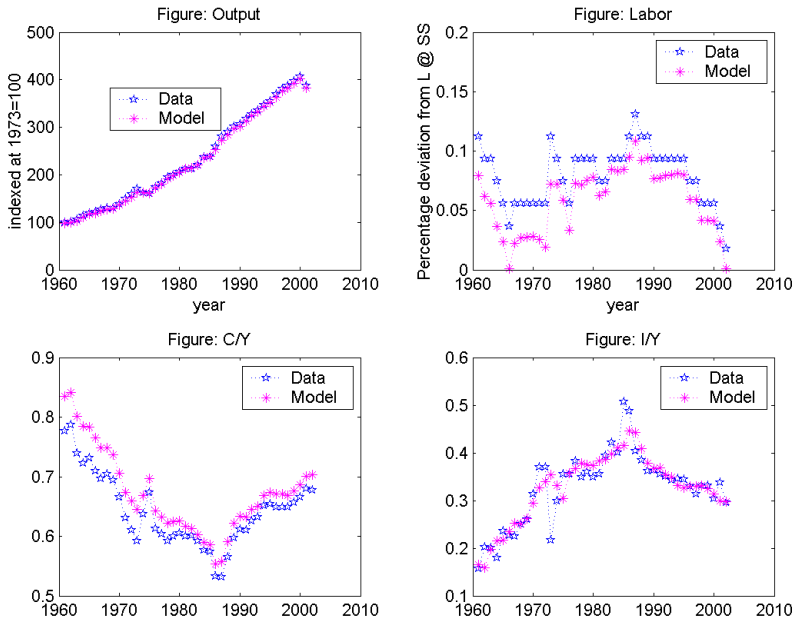

Figure 44: Output, labor, C/Y, and I/Y for model in Case II with Z, L, K taxes

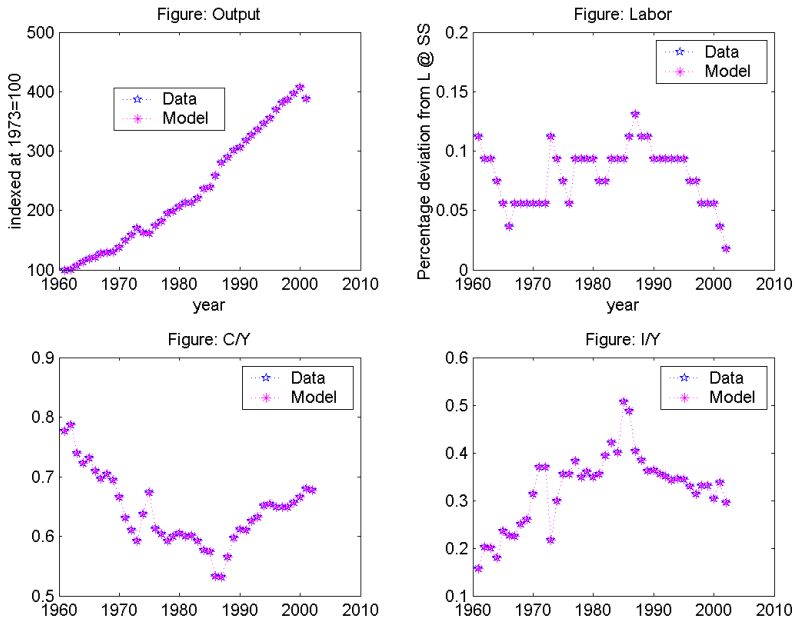

Figure 45: Output, labor, C/Y, and I/Y for model in Case II with Z, L K taxes and income wedges

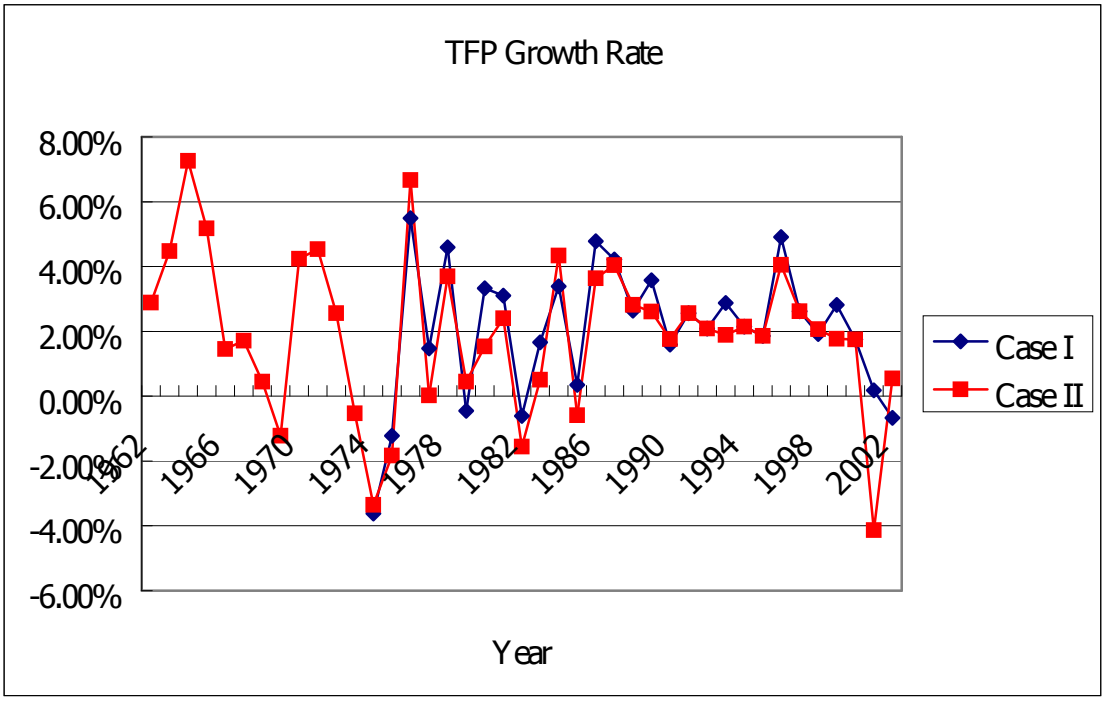

Figure 46: The growth rate of TFP series