How Does Arithmetic Demystify Growth Success?

The Taiwanese Case

Shu-shiuan Lu*

University of California, Los Angeles

October 2006

Abstract

This paper studies the productivity improvement in economies experiencing rapid structural transformation, i.e. resource reallocation from a low to a high productivity sector. In particular, it measures the productivity growth that is attributed to reallocating labor from the farm to the non-farm sector in Taiwan between 1951 and 2003. Examining productivity under a two-sector rather than a one-sector framework reduces the measured productivity growth by 28% in terms of total factor productivity. In other words, the results show that resource reallocation, especially that of labor, from a low to a high productivity sector plays a substantial role in accounting for the significant productivity improvement in an economy experiencing rapid structural transformation.

Keywords: Source of Growth, Sectoral Transformation, and Taiwanese Economy

JEL Classification: O11, O41, O53

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*I am extremely grateful to my advisor, Lee Ohanian for advice and support. I also thank Andrew Atkeson, Harold Cole, Matthias Doepke, Roger Farmer, Gary Hansen, Giovanni Peri, Kenneth Sokoloff, and the participants at the UCLA Proseminar in Monetary and Macroeconomics for helpful comments. All the remaining errors are mine. Please direct correspondence to Shu-shiuan Lu, 8283 Bunche Hall, Box 951477, Los Angeles, CA 90095-1477. Email: shusanlu@ucla.edu Webpage: http://shusanlu.bol.ucla.edu

1. Introduction

This paper uses a multi-sector concept to identify the role of resource reallocation from low productivity to high productivity sectors to account for the rapid economic development of Taiwan. I employ simple arithmetic to analyze economic growth under a two-sector model concept rather than a one-sector concept. Moreover, I demonstrate that in the second half of the 20th century efficient reallocation of resources resolves part of the mystery of high productivity growth in Taiwan.

While the literature on growth shows tremendous work on the adjustment of capital and labor qualities, one still cannot exclude the fact that improvements in productivity are important in explaining the success of Taiwan[1] and its abnormally high rate of convergence to the developed world. Jorgenson and Yip (2001), Maddison (2001), and Young (1995) provide abundant numerical results of productivity growth post Second World War and enable cross-country comparison for productivity. However, the productivity improvement in Taiwan is comparatively high and remains a puzzle under their careful accounting.

The focal point of this paper is to show how using simple arithmetic to look into productivity growth under a multi-sector framework can elucidate an understanding of the growth miracle in Taiwan. The macroeconomic data show that the percentage of the population working in the agricultural sector fell sharply. Meanwhile, the overall economy grew rapidly. This raises the question of whether rapid growth and structural transformation are connected. To address this question, I begin by comparing productivity growth across East Asian, Latin American and OECD countries. The results show that those countries that grew quickly also experienced rapid labor reallocation from the farm to the non-farm sector. Using Taiwan as a detailed case study, I show that applying simple arithmetic to examine productivity under a two-sector rather than a one-sector framework reduces the measured productivity growth by 28% in terms of total factor productivity.

The rest of the paper is organized as follows: First, I review the empirical literature on the comparison of productivity growth across economies and show that Taiwan had a high productivity growth rate relative to the rest of the world. Second, I show the arithmetic

[1] Though Young (1995) emphasized that faster factor accumulation rather than total factor productivity in Taiwan explains why Taiwan able to catch up with the developed economies from 1966 to 1990, the growth rate of total factor productivity remains comparatively higher than the rest of the world for the same period, especially when look into the sub-periods: 1980-1990. I will articulate this point in detail in section 3.

framework I adopt to capture the importance of efficient reallocation of factors in accounting for growth in terms of average labor productivity and total factor productivity. Third, I show the empirical evidence that the economies with rapid growth, e.g. Japan, South Korea, and Taiwan, experienced rapid structural transformation along their growth path. Then, I take Taiwan as the case study for this paper, analyze how structural transformation affected its growth from 1950 to 2002, and show how the growth rate in total factor productivity reflects in part a move of factors. In the last section, I offer some concluding remarks.

2. Literature Review for Productivity Growth across Countries

Productivity can refer to either average labor productivity (ALP) or total factor productivity (TFP). I clarify two concepts of TFP here: one is to view TFP as the residual of the quantity of factor inputs (broad TFP); the other is to view TFP as the residual of all the explainable factors (narrow TFP). The latter implies that TFP is an unexplainable term.

Maddison (2001) conducts a cross-country study on ALP in terms of GDP per person employed in 1990 US$. He shows that Taiwan is one of the fastest growing economies in terms of ALP. Table I replicates the table in the book[2]. As can be seen, the average labor productivity in Taiwan in 1998 was 13.7 times that of 1950. This number is higher than any of the selected economies in Europe, Western offshoots, Latin America and Asia. Furthermore, South Korea ranked the second. The corresponding value in 1998 was 11.25 times that of 1950. Finally, Japan ranked the third and the corresponding value in 1998 was 8.79 times that of 1950. Therefore, Taiwan, South Korea and Japan have a faster productivity improvement than all other economies in terms of average labor productivity; among them, Taiwan is the fastest.

Table I: Average Labor Productivity in 1990 International Dollars

	1950	*1973*	*1998*	*1998/1950*
Canada	20,311	35,302	43,298	2.13
United States	23,615	40,727	55,618	2.36
France	11,214	31,910	50,680	4.52
Germany	9,231	26,623	40,452	4.38
Italy	8,739	25,661	42,534	4.87
Japan	4,511	23,634	39,631	8.79
United Kingdom	15,529	26,956	40,875	2.63

[2] I do not report the same data for Hong Kong and Singapore since they have missing data for 1950 and 1973.

South Korea	2,516	8,689	28,315	11.25
Taiwan	2,569	11,924	35,198	13.70
Argentina	12,538	21,349	25,598	2.04
Brazil	5,060	12,111	14,491	2.86
Chile	10,316	10,316	26,038	2.52
Colombia	6,492	12,202	16,187	2.49
Mexico	7,685	18,399	20,810	2.71
Peru	6,170	12,685	10,135	1.64
Venezuela	23,792	37,856	26,495	1.11

(Maddison 2001, p. 349 &350)

Barro and Sala-I-Martin (2003) summarize the literature on TFP growth. They summarize works from Jorgenson and Yip (2001), Elias (1990) and Young (1995). Their table shows that the TFP growth in Taiwan (1966 to 1990) is relatively high compared with the rest of the world. Table II replicates the tables from Barro and Sala-I-Martin (2003), and Jorgenson and Yip (2001). The table summarizes the TFP growth rates for OECD, Latin American and East Asian countries. As can be seen, Taiwan, South Korea, Japan, and Hong Kong grew faster than the other economies. Since Hong Kong is a city-state, I choose South Korea and Japan as fast growing economies in addition to Taiwan[3].

Table II: Growth in TFP from 1940 to 1990, Assorted Economies

1960-1995 OECD Countries						
Canada	France	Germany	Italy	Japan	UK	US
0.0057	0.013	0.0132	0.0153	0.0265	0.008	0.0076
1960-1989 OECD Countries						
Canada	France	Germany	Italy	Japan	UK	US
0.0080	0.0167	0.0162	0.0186	0.0316	0.0115	0.0086
1940-1990 Latin American Countries						
Argentina	Brazil	Chile	Colombia	Mexico	Peru	Venezuela
0.0054	0.0114	0.0138	0.0084	0.0113	-0.0062	0.0011
1966-1990 East Asian Countries						
	Hong Kong	Singapore	South Korea	Taiwan		
	0.023	0.002	0.017	0.026		

Table III & IV replicate the tables in Young (1995) which show the sub-period productivity growth for Taiwan and South Korea. The numbers in brackets are the percentage contribution of growth in labor, growth in capital, and growth in TFP to the output growth

[3] In addition, if we look at the TFP growth for OECD countries for the period 1960 to 1989 rather than the period 1960 to 1995, Italy also has high TFP growth compared with other OECD countries. Finally, when one compare across Latin American economies, Brazil and Mexico have higher TFP growth than the other economies within the group.

rate. As is shown, the total factor productivity is high for Taiwan during 1966-1970 and 1980-1990. In addition, the total factor productivity for South Korea (1980 to 1990) is high as well. In other words, though Young carefully adjusted quality improvements on factor inputs, the contribution of TFP to growth remains as high as 42% in Taiwan (between 1980 and 1990). Therefore, it is clear from his work that the fast growing East Asian economies do realize some high productivity growth in addition to rapid capital and labor accumulations.

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

Period	*G_Y*	*G_K*	*G_L*	*G_TFP*
1966-1970	0.111	0.171	0.044	0.034
	(100.00%)	(40.21%)	(29.29%)	(30.63%)
1970-1980	0.103	0.144	0.068	0.015
	(100.00%)	(36.49%)	(48.79%)	(14.56%)
1980-1990	0.078	0.083	0.032	0.033
	(100.00%)	(26.71%)	(30.73%)	(42.31%)
1966-1990	0.094	0.123	0.0490	0.026
	(100.00%)	(33.63%)	(38.73%)	(27.66%)

Table IV: Young's Table for Korean Growth Accounting (1995, p. 660)

Period	*G_Y*	*G_K*	*G_L*	*G_TFP*
1960-1966	0.077	0.070	0.072	0.005
	(100.00%)	(28.18%)	(64.52%)	(6.49%)
1966-1970	0.144	0.194	0.103	0.013
	(100.00%)	(41.76%)	(49.35%)	(9.03%)
1970-1975	0.095	0.118	0.055	0.019
	(100.00%)	(42.11%)	(38.27%)	(20.00%)
1975-1980	0.093	0.178	0.052	0.002
	(100.00%)	(58.57%)	(38.80%)	(2.15%)
1980-1985	0.085	0.099	0.047	0.024
	(100.00%)	(31.56%)	(40.31%)	(28.24%)
1985-1990	0.107	0.108	0.072	0.026
	(100.00%)	(26.34%)	(49.73%)	(24.30%)
1966-1990	0.103	0.137	0.064	0.017
	(100.00%)	(39.50%)	(43.68%)	(16.50%)

In sum, in terms of productivity, Taiwan, South Korea and Japan have been growing rapidly relative to the rest of the world. Among them, Taiwan's growth is the fastest. Consequently, I would like to use Taiwan as the main case study for this paper and supplement my study with South Korea, Japan and Italy to support the argument that there is a positive relationship between rapid growth and fast structural transformation.

3. The Arithmetic Frameworks for Identifying Reallocation Effect in Productivity Growth

In the following section, I will decompose productivity growth (in terms of ALP and TFP) into two parts: one is the contribution of efficient resource reallocation to productivity growth; and the other is the contribution of productivity improvement to growth. The contribution of efficient resource reallocation measures the proportion of growth that results from reallocating resources, such as labor or capital, from a less productive sector to a more productive sector. Such a shift of resources can contribute to growth in total output without any productivity improvement in either high or low productive sectors. On the other hand, the contribution of productivity improvement measures the proportion of growth that results from technological improvement assuming no reallocation of resources.

3.1 Decomposition of Average Labor Productivity

Average Labor Productivity (ALP) is defined as total output divided by total employment. When ALP is expressed in terms of a two-sector framework, ALP is composed of productivity in the farm sector multiplied by the share of farm labor plus productivity in the non-farm sector multiply by the corresponding share of labor in that sector. The decomposition is shown as follows:

$$\frac{Y_t}{L_t} = \frac{q_t \cdot Y_t^F + Y_t^{NF}}{L_t^F + L_t^{NF}} = \frac{q_t \cdot Y_t^F}{L_t^F} \cdot \frac{L_t^F}{L_t^F + L_t^{NF}} + \frac{Y_t^{NF}}{L_t^{NF}} \cdot \frac{L_t^{NF}}{L_t^F + L_t^{NF}}$$

$$= \frac{q_t \cdot Y_t^F}{L_t^F} \cdot F_t + \frac{Y_t^{NF}}{L_t^{NF}} \cdot (1 - F_t) \qquad where\ F_t \equiv \frac{L_t^F}{L_t^F + L_t^{NF}}$$

F: Farm Sector; NF: Non-Farm Sector;
Y: Output; L: Labor;
q: Relative Price (Price of non-farm output equals one)

Therefore,

Equation 1:

$$\frac{\frac{Y_t}{L_t}-\frac{Y_0}{L_0}}{\frac{Y_0}{L_0}} \equiv \quad X\cdot\left[A\cdot B-C\cdot D\right]+Y\cdot D\cdot(C-1)+Z\cdot B\cdot(A-1)$$

$$=\left(F_0-F_t\right)\cdot\left[\frac{\frac{Y_t^{NF}}{L_t^{NF}}}{\frac{Y_0^{NF}}{L_0^{NF}}}\cdot\frac{\frac{Y_0^{NF}}{L_0^{NF}}}{\frac{Y_0}{L_0}}-\frac{\frac{q_t\cdot Y_t^F}{L_t^F}}{\frac{q_0\cdot Y_0^F}{L_0^F}}\cdot\frac{\frac{q_0\cdot Y_0^F}{L_0^F}}{\frac{Y_0}{L_0}}\right]$$

$$+F_0\cdot\frac{\frac{q_0\cdot Y_0^F}{L_0^F}}{\frac{Y_0}{L_0}}\cdot\left(\frac{\frac{q_t\cdot Y_t^F}{L_t^F}}{\frac{q_0\cdot Y_0^F}{L_0^F}}-1\right)+(1-F_0)\cdot\frac{\frac{Y_0^{NF}}{L_0^{NF}}}{\frac{Y_0}{L_0}}\cdot\left(\frac{\frac{Y_t^{NF}}{L_t^{NF}}}{\frac{Y_0^{NF}}{L_0^{NF}}}-1\right)$$

where

X = reallocation;

A= % change in non-farm average labor productivity

B = initial non-farm average productivity relative to the aggregated

C= % change in farm average labor productivity

D = initial farm average productivity relative to the aggregated

Y = % of labor in farm sector

Z = % of labor in non-farm sector

As a consequence, the aggregated average labor productivity increment that results from the reallocation effect is X[AB-CD], whereas the increment that results from productivity improvement is the sum of YD(C-1) and ZB(A-1).

3.2 Decomposition of Total Factor Productivity

Total factor productivity (TFP) can also be represented as the weighted average of TFP in the farm and the non-farm sectors. Under a two-sector model, aggregated TFP is composed of α, β, TFP in farm and TFP in non-farm sector.

$$TFP_t = \frac{Y_t}{K_t^{\theta} L_t^{1-\theta}} = \frac{q_t \cdot Y_t^F + Y_t^{NF}}{K_t^{\theta} L_t^{1-\theta}}$$

$$\begin{aligned}
&Define: Y_t \equiv q_t \cdot Y_t^F + Y_t^{NF} \\
&\qquad K_t \equiv K_t^F + K_t^{NF} \equiv \alpha \cdot K_t + (1-\alpha) \cdot K_t \\
&\qquad L_t \equiv L_t^F + L_t^{NF} \equiv \beta \cdot L_t + (1-\beta) \cdot L_t \\
&where \quad \alpha \equiv \%\ of\ capital\ in\ farm\ \text{sec}tor \\
&\qquad \beta \equiv \%\ of\ labor\ in\ farm\ \text{sec}tor
\end{aligned}$$

Thus,

Equation 2:

$$\begin{aligned}
TFP_t &= \frac{q_t \cdot Y_t^F}{(\alpha_t K_t)^{\theta} (\beta_t L_t)^{1-\theta}} \cdot \alpha_t^{\theta} \cdot \beta_t^{1-\theta} + \frac{Y_t^{NF}}{\left[(1-\alpha_t)K_t\right]^{\theta}\left[(1-\beta_t)L_t\right]^{1-\theta}} \cdot (1-\alpha_t)^{\theta} \cdot (1-\beta_t)^{1-\theta} \\
&= TFP_t^F \cdot \alpha_t^{\theta} \cdot \beta_t^{1-\theta} + TFP_t^{NF} \cdot (1-\alpha_t)^{\theta} \cdot (1-\beta_t)^{1-\theta}
\end{aligned}$$

In other words, I can decompose the TFP into two terms: TFP of the farm sector and TFP of the non-farm sector, weighted by the percentage of the factors in each sector.

Therefore, to obtain the TFP without reallocation effect (from pure productivity improvement), one could set α_t and β_t constant and equal to the initial value (α_0 and β_0) over time. For the case "if there were no labor reallocation", one could set β_t constant and equal to the initial value β_0. Similarly, for the case "if there were no capital reallocation", one could set α_t constant and equal to the initial value α_0. Finally, for the case "if there were no TFP^F_t improvement in the farm sector", one could set TFP^F_t constant and equal to the initial value TFP^F_0; for the case "if there were no TFP^{NF}_t improvement in the non-farm sector", one could set TFP^{NF}_t constant and equal to the initial value TFP^{NF}_0. Finally, for the case "if there were no TFP improvement, one could set both TFP^F_t and TFP^{NF}_t respectively and constantly equal to TFP^F_0 and TFP^{NF}_0 over time.

4 Contribution of Efficient Resource Reallocation to Productivity Growth

In section 2, I show that Japan, South Korea and Taiwan experienced relatively high productivity improvement after the Second World War. To argue that rapid development coincides with rapid structural transformation, I compare the speed of structural transformation of Japan, South Korea and Taiwan from 1960 to 2002 with the experiences in the U.S. and Canada in this section. First, I show the speed of transformation in the U.S. and Canada. Second, I compare the speed of structural transformation of various economies after the Second World War with historical data from the U.S. and Canada

4.1 The Speed of Transformation: U.S. and Canada

The percentages of employment in the agricultural sector in the U.S. and Canada from 1880 to 2002 are shown in table V. For the Canadian data, those starting from 1881 to 1940 are from the census of Canadian Historical Statistics; those starting from 1950 to 1960 are from the annual data of Canadian Historical Statistics; and those starting from 1970 to 2002 are from the International Labor Organization.

As can be seen, it took the US and Canada roughly the same length of time, 50 to 60 years, to experience farm sector employment dropping from 23% to 3%.

Table V: Percentage of Employment in Agricultures, 1880 - 2002, US and Canada

			US		
Year	1880	1890	1900	1910	1920
%					
Year	1930	1940	1950	1960	
%	22.74%	20.08%	12.15%	8.30%	
Year	1970	1980	1990	2000	2002
%	4.40%	3.39%	2.86%	2.56%	2.55%
			Canada		
Year	1881	1891	1901	1911	1921
%	48.1%	45.8%	40.2%	34.3%	32.7%
Year	1931	1940	1950	1960	
%	28.8%	25.8%	22.89%	13.25%	
Year	1970	1980	1990	2000	2002
%	9.09%	7.28%	5.63%	4.40%	3.91%

The other measurement to show the percentage of labor force in the farm sector is by the percentage of the economically active population in the agricultural sector. The values for the U.S. and Canada are tabulated in Table VI. The data for the US is from 1880 to 1990 and taken from the US Bureau of Labor Statistics reported in the Statistical Abstract of the United States 2003; whereas those for Canada is from 1950 to 1990 and taken from the International Labor Organization. According to the publication of the International Labor Organization,

"The economically active population comprises all persons of either sex who furnish the supply of labour for the production of economic goods and services as defined by the United Nations systems of national accounts and balances during a specified time-reference period.

…

Two useful measures of the economically active population are the usually active population measured in relation to a long reference period such as a year and the currently active population or equivalently the "labour force" measured in relation to a short reference period such as one week or one day.

…

usually active population may be subdivided as employed and unemployed in accordance with the main activity

…

The labour force or "currently active population" comprises all persons who fulfil the requirements for inclusion among the employed or the unemployed as defined. "

(http://www.ilo.org/public/english/bureau/stat/res/ecacpop.htm)

Table VI: Percentage of Economically Active Population in Agricultures, US (1880- 1990) and Canada (1950-1990)

			US			
Year	1880	1890	1900	1910	1920	1930
%	50.06%	42.84%	37.56%	31.55%	27.40%	22.01%
Year	1940	1950	1960	1970	1980	1990
%	17.57%	12.32%	6.64%	4.29%	3.48%	2.84%
			Canada			
Year	1880	1890	1900	1910	1920	1930
%						
Year	1940	1950	1960	1970	1980	1990
%		19.84%	13.19%	7.79%	6.66%	3.37%

As can be seen, it took the US and Canada 40 to 50 years to experience their economically active population in the farm sector drop from 23% to 3%.

In sum, the US and Canada display roughly similar speeds of structural transformation from a society mainly focused on agriculture to industry and services. Therefore, I take the number of years the US or Canada took to transform from one level of labor in agriculture to another as the standard number of years of transformation required for an economy.

4.2 Measuring the Speed of Transformation

In order to measure how fast economies transform, I compare each economy's structural transformation with that of the US and Canada. I do not compute a direct annual rate of structural transformation because the process of transformation is likely to be nonlinear over time: one would expect transformation to be more rapid in early stages of development and slow down as the economy matures. To overcome this issue, I take the following steps. First I obtain the percent of farm labor for each of the analyzed economies in 1960 and 2002[4]. Second, I compare these values to the data for the US and Canada and compute the number of years it would have taken for the US or Canada to undertake the identical transformation (both in level and percent change) in farm labor. Third, I divide the number of years the US or Canada took to achieve the transformation by the number of years the analyzed economy took. I term this ratio as the "ratio of standard to actual." This ratio represents how fast an economy transforms. For example, if it takes the U.S. 50 years to have the percentage of farm employees to drop from 20% to 10% and if it takes Japan 25 years to drop from 20% to 10%, I argue the structural transformation in Japan is twice the speed of the U.S. The corresponding "ratio of standard to actual" equals two. Therefore, the higher the ratio, the faster an economy transforms from an agricultural economy to an industrialized economy. The results[5] are in Table VII.

In view of the employment in the farm sector, Japan, Italy[6], South Korea and Taiwan experienced the fastest structural transformation. These economies also experienced higher TFP growth in Table II. Note that I did not report the employment data for Latin American countries because employment data are not a good measurement to compute the speed of structural transformation in these economies. Instead, an economically active population rather than employment serves as a better measurement. That is because employment is

[4] Except where indicated in table VII.

[5] The employment data for the developed economies are obtained from the US Bureau of Labor Statistics, Foreign Labor Statistics webpage. The data for S. Korea are from the International Labor Organization, and the data for Taiwan is from its Agricultural Statistic Abstract located on the web.

[6] Italy also has high TFP growth during 1960-1989, as shown in table II, OECD Countries, 1960-1989.

subject to business cycles and the unemployment rate is relatively high and volatile in Latin America.

Table VII: Percentage in Farm, in terms of Employment, OECD Countries, S. Korea and Taiwan

Countries	*1960*	*2002*	*Equivalent Standard Year*	*Ratio of* $\frac{\text{Standard}}{\text{Actual}}$
Japan	29.51%	4.49%	70 Years	1.67
France	22.48%	3.66%	45 Years	1.07
Germany	13.78%	2.52%	55 Years	1.30
Italy	32.47%	3.53%	80 Years	1.90
Netherlands	10.25%	3.10%	30 Years	0.71
Sweden	15.75%	2.47%	55 Years	1.31
Countries	% in farm (date)	% in farm (date)	*Equivalent Standard Year*	*Ratio of* $\frac{\text{Standard}}{\text{Actual}}$
United Kingdom	4.73% (1960)	2.67% (1983)	30 Years	1.30
South Korea	48.6% (1974)	8.9% (2003)	90 Years	3.10
Taiwan	46.5% (1965)	6.56% (2004)	95 Years	2.44

In view of the economically active population[7] from 1950 to 1990, Korea and Japan's percentage in agriculture dropped more than 40%, which was the largest decline among 45 countries[8]. (The table for 45 countries is reported in Appendix 1.) Japan dropped from 48.83% of population in agricultures to 7.28%; such a transition took the U.S. approximately 70 years. Similarly, Korea had 76.9% of the employed in agricultures and dropped to 18.11% by 1990, which is a process that took the U.S. more than 70 years.

[7] I collect the data from the International Labor Organization. Taiwan did not report economically active population. Therefore, I use the South Korea Case, which I have data for both measurements, to show the two measurements, employment and economically active population can both show the speed of transformation is fast for the growth miracles in Japan, South Korea and Taiwan.

[8] Taiwan does not report economically active population.

Finally, within the group of Latin American economies, Brazil, Colombia and Mexico are the top three economies with the biggest percentage of change in terms of percentage of the economic active population in the farm sector. Except Colombia, which was not included in Table II, Brazil and Mexico are also the economies with relatively higher TFP growth in the region.

In sum, compared with the group consisting of OECD, Asian and Latin American countries, Japan, South Korea and Taiwan experienced relatively high productivity improvement after the Second World War. Meanwhile, all of these economies experienced rapid structural transformation. Therefore, economies with higher productivity growth also show relatively fast structural transformation.

Among them, Taiwan experienced a fast rate of industrialization in the second half of the 20th century. One key feature of industrialization is a shift of labor from an agricultural (farm) to a non-agricultural (non-farm) sector. Based upon the coinciding rapid economic growth experiences and rapid efficient labor reallocation, I would like to use Taiwan[9] to show that, once the resource reallocation of labor is taken into account, the rapid growth in the economy becomes less mysterious (in section 5 and 6).

5. The Economic Structural Transformation in Taiwan

The data used in this section is downloaded from DataStream, World Penn Tables and assorted Taiwanese government web pages and statistical data books. The period covered is 1952 to 2003 (1952 is the earliest I can obtain the data). Sometimes the data may start at later time or end at earlier time due to the availability of the data.

The structure in this section is as follows: First, I show the structural transformation in Taiwan in terms of GDP and employment. Then, I show the reason why it makes sense to conduct the analysis under a multi-sector framework rather than a one-sector framework.

5.1 Structural transformation in GDP

Figure I shows the sectoral GDP relative to the aggregate in terms of percentage from 1952 to 2004. As can be seen, the percentage of GDP that comprises the agricultural sector is 32.22% in 1951 and falls to 1.74% in 2003; in addition, the percentage attributed to the

[9] I use Taiwan as my example because the Taiwanese labor productivity improvement (both ALP and TFP) is the most significant[9] among the three economies.

manufacturing sector is 19.69% in 1952, reaches its peak (47.11%) in 1986 and drops back to 29.54% in 2004. Finally, the percentage attributed to services remains around 46%, starts to takeoff rapidly in 1987, and reaches 68.72% in 2004. In other words, the GDP share in agriculture has declined monotonically since 1952, whereas the aggregated share of the other two sectors (manufacturing and services) increased in importance to the economy during this period.

5.2 Structural transformation in employment

Figure II shows the sectoral employment relative to the total employed population in terms of percentage from 1952 to 2004. As can be seen, the percentage of the employed working in the agricultural sector is 56.1% in 1952 and falls to 6.56% in 2003; in addition, the percentage of the employed working in manufacturing sector was 16.9% in 1952, reaches its peak (42.8%) in 1987 and drops back to 35.21% in 2004. Finally, the percentage of the employed working in services is 27% in 1952 and reaches 58.23% in 2004. In other words, the number of the workers in agricultures has sharply declined since 1952, whereas the aggregated number of workers in the other two sectors has increased.

In sum, Taiwan experienced rapid industrialization from the 1950s to the end of the 20^{th} century. During this period, in terms of labor and output, the service sector became the largest sector in Taiwan.

5.3 How Structural Transformation Matters: One Sector vs. Multiple Sectors

Form 1952 to 2003, Taiwan transformed from an agricultural society to an industrialized economy; then to a society where the majority of the labor force was employed in the service sector. If the productivity differentials among the three sectors are very large, a multi-sector analysis with at least three sectors is better able to capture the transition dynamics. At the other extreme, if the productivity among sectors is close, a multi-sector analysis is redundant and the efficient transfer of resources (in particular, labor) from one sector to the other does not matter for growth.

I compare the productivities of agriculture, industry and services in terms of average labor productivity and marginal labor productivity. If the productivity differential among any of these sectors is small, the two sectors can be aggregated into one. On the other hand, if the productivity differential among any of these sectors is large, two of them must be viewed as distinct sectors.

Figure III shows the labor productivity index, which is taken from the Productivity Statistics provided by Directorate-General of Budget, Accounting and Statistics Executive Yuan (DGBAS.) I transformed the index so that the base year is 1981. The index is in terms of average labor productivity, which is defined as

$$\frac{\text{Real Gross Domestic Product}}{\text{L}abor\ input(Labor\ hour,.Employed)}.$$

As can be seen, from the productivity relative to the base year, industries and services have a productivity index close to each other over time, whereas the farm sector is further apart from the other two. In other words, in view of average labor productivity, I combine industry and service sectors as a non-farm sector and the agricultural sector as a farm sector.

Now I turn to look at productivity in terms of marginal labor productivity. Presumably, if the marginal labor productivities are not equal across sectors, laborers have a tendency to move from one sector to the other; such a shift leads to higher growth since the resources are moved from a less productive sector to a more productive sector.

To measure marginal labor productivity, I estimate the per worker wage rate in each sector, assuming that the wage rate could be a proxy for marginal labor productivity in each sector. I look at the cost side instead of the production side so that I do not need to assume the form of the production function.

The wage rates for the industries and services are taken from the Earning and Productivity Statistics provided by Directorate-General of Budget, Accounting and Statistics Executive Yuan (DGBAS.) The wage rate for agricultural workers is my estimate. I estimated the real wage for the farm worker as farm family income from agricultural activities divided by the number of farmers per farm household. The original data for agricultures are from the Farm Statistics.

Figure IV shows the estimated yearly income for laborers in each sector from 1973 to 2003. As can be seen, the annual wage income for workers in industries and services are roughly the same and increase hand in hand, whereas that for workers in agricultures remains constant over the period 1996 to 2003, except that it shows a trend of growth after 1987.

Figure V shows the relative ratios for the wages among sectors. As can be seen, the wage ratio between industry and services is roughly around one (it is 1.26 in 1979 and declines to 1.12 in 2003). On the other hand, the ratio of annual wage in industries to agricultures is 3.97 in 1986 and 2.81 in 2003. The wage gap between farm and non-farm sectors is huge compared with the wage gap between industries and services. Finally, the ratio of "non-farm" to "farm" attains the highest level in the late 1980s, and drops to the level roughly equal to that in the late 1970s. However, it still remains above 2.5. Therefore, the productivity in terms of the real wage, which is a proxy for marginal productivity and average labor output, shows a widening gap in absolute terms between farm and non-farm sectors.

Given that the labor productivity of the agricultural sector is smaller than that of the non-agricultural sector, industrialization enables the economy to reallocate resources from a less productive sector to a more productive sector. Such a shift results in higher labor productivity in terms of arithmetic, even with no productivity improvement in farm or non-farm sectors. Therefore, investigating the overall economic growth at the aggregated level may significantly ignore the reallocation effect and overestimate the contribution of non-factor inputs.

Therefore, based upon the analysis in this section, to illustrate the impact of fast industrialization on the aggregated growth, I use a two-sector framework – farm and non-farm (including industries and services) – to study the effect of transferring resources from a low productivity sector to a high productivity sector, in particular, the economic transition in Taiwan.

6. Empirical Analysis with a Two-Sector Framework: the Taiwan Case

In this section, I use a two-sector framework and the equations derived in section 3 to show how the efficient use of resources, reallocated from a low productivity sector to a high productivity sector, amplifies the productivity growth in terms of average labor productivity and total factor productivity. I use Taiwan as the case study.

First, I show the accumulated productivity differential between farm and non-farm sectors widened over the period of study (1952-2003). Second, I use the decomposition formula for average labor productivity (as in Equation 1) to demonstrate the how efficient labor reallocation contributes to the productivity growth analyzed under a one-sector framework. Finally, I use the decomposition formula for total factor productivity (as in Equation 2) to simulate the productivity growth with six cases, fixing certain variables- e.g. percentage of factors in the farm sector or TFP.

6.1 ALP Differential between farm and non-farm sectors

Figure VI shows the average labor productivity differential between farm and non-farm sectors from 1952-2003. As can be seen, for the farm sector, the ALP in 2003 was 6.28 times what it was in 1952; whereas for the ALP in the non-farm sector, the value in 2003 was 10 times what is was in 1952. In other words, the non-farm sector and the farm sector have different rates of growth in terms of ALP. Consequently, transferring labor from a farm to a non-farm sector takes advantage of this unbalanced rapid growth more than an economy without any structural transformation.

6.2 Percentage contribution from the reallocation effect to ALP growth

Figure VII shows the 10-year moving average of the percentage contribution to growth from the reallocation effect and pure productivity improvement in terms of ALP growth. As can be seen, the impact of productivity improvement on growth followed a downward sloping trend from the beginning and reached its first valley in 1974 (from 84% to 56%). Later on, the contribution of the reallocation effect to growth remains at a relatively high level compared to the early 1950s, fluctuates around 40%, and then reaches its zenith in 1992 (49%). In other words, the reallocation effect is more significant in the later period of my study.

I report the yearly value in Appendix 2. The percentage contribution from productivity improvement and the reallocation effect are listed in the table. As shown, the contribution of "reallocation effect" begins to dominate that of "productivity improvement" more frequently in the 1980s and 1990s: The "reallocation effect" dominates the "productivity improvement" for two out of 27 years (with average contribution of 30% from 1953 to 1979), whereas in eight out of 26 years the reallocation effect dominates the productivity improvement with an average contribution 40% from 1980 to 2003.

Therefore, one can conclude that the labor reallocation effect becomes important when there is a big labor productivity gap relative to the initial aggregate labor productivity. That is one of the reasons why the reallocation effect in the later period of the study is significant, although the shift is more rapid in the earlier periods. It seems that the reallocation of resources may account for the relatively high aggregated TFP growth in the 1980s.

It could be that human capital does not accumulate fast enough to catch up with the productivity gap. Thus, the productivity differential is not fully reflected in the earlier period.

By the 1980s, enough human capital was built up to exploit the productivity gap. As a result, a tiny fraction of the labor transferred out of the farm sector was responsible for a bulk of the productivity growth. The strong reallocation effect in the 1980s resulted from the fact that the productivity gap widened during this time, as shown in Figure VI. Such a result is consistent with Young's (1995) findings that the TFP growth in Taiwan remained high in the 1980s after taking into account quality adjustment.

Therefore, when using ALP as the measurement for productivity, the labor reallocation effect is significant in accounting for high productivity growth in Taiwan, especially in the 1980s.

6.3 Percentage contribution from the reallocation effect to the TFP growth

With respect to TFP growth, I demonstrate the contribution of efficient reallocation of resources in a manner different from the previous section because the decomposition of the reallocation effect lacks a certain degree of freedom to divide the productivity growth into reallocation effect and productivity improvement. Using Equation 2, I ran six simulated cases and I summarize the cases in table VIII.

Table 8: The six cases for the simulation

	Assumption	*Abbreviation*
Case 1*	The TFP in data (the real TFP)	TFP Total
Case 2	No labor reallocation	No L
Case 3	No capital reallocation	No K
Case 4	No TFP improvement	No TFP
Case 5	No TFP improvement in the farm sector	No F TFP
Case 6	No TFP improvement in the non-farm sector	No NF TFP

*: This case takes into account all the TFP improvement and factor reallocation (equivalent to the real data).

The further apart the case value is away from the real data (Case 1), the greater is the contribution of the absent factor in the case. Figure VIII shows six cases. As can be seen, the TFP acquired from "Case 3: no K" or "Case 5, no F TFP" does not reduce the "Case 1: TFP total" much. However, the figure shows in "Case 4: No TFP" or in "Case 6: No NF TFP", the TFP grows in the opposite direction – the TFP declines rather than the increases, whereas the real TFP (TFP total) rises.

Finally, as in "Case 2, no L", the resulting TFP is more than 28% off the "TFP total". In other words, efficient factor reallocation, especially shifting labor from a less productive sector to a more productive sector has a significant positive impact on the "arithmetic productivity improvement." In short, reallocating labor from the farm to the non-farm sector does increase the calculated TFP growth on top of the productivity improvement due to technological advances. Therefore, taking into account the reallocation effect would clear part of the mystery of the rapid growth in Taiwan

7 Conclusion

In this paper, I measure productivity improvement under a two-sector rather than a one-sector framework, moving away from the one-sector framework that traditional growth accounting is based upon. In the first section, I showed empirically that productivity improvement is fast in those low-income economies converging to the developed economies after the Second World War – e.g. Japan, South Korea and Taiwan. Meanwhile, these economies experienced rapid structural transformation, switching from agricultural economies to industrialized societies. Therefore, the paper linked the fast structural transformation with high productivity growth and found that structural transformation is significant in accounting for the growth miracles.

The arithmetic decomposition of the two definitions of productivity - average labor productivity and total factor productivity – shows that the effect of shifting labor from a low productivity sector to a high productivity sector has an undeniable effect in accounting for the high productivity obtained from the analysis based on the one-sector framework.

Therefore, I conclude that the arithmetical high productivity improvement is attributed to the combined results of the structural transformation of the economy and some technological advancement. Sectoral transformation magnifies the growth attributed to technological advancement. In other words, the mystery of high growth in productivity can be resolved when taking into account the effect of efficient reallocation of production factors, especially labor, on an economy experiencing transformation from an agricultural to an industrialized and a post-industrialized economy. Note that I do not argue that the efficient resource reallocation guarantees rapid economic growth but rather explains it.

The decomposition exercise leads directly to one possible area for further research: to study what causes economic transformation. One possible explanation states that productivity differentials and the resulting wage differential among sectors creates an incentive for labor to move from a low productivity sector to a high productivity one. For example, adoption of new technology in the non-farm sector creates jobs in this sector, increasing the factor return in the non-farm sector relative to the farm sector. Thus, laborers are willing to leave the farm and work in the more productive sector.

Based on the neoclassical model, such a transition should be rapid. However, the empirical data show that the productivity gap among the sectors does not decrease immediately. Perhaps this is due to a mechanism or a friction that slows down the immediate closing of the productivity gap between the farm and non-farm sector. Thus, establishing a model that includes such a friction (e.g. model with time to build human capital) can explain: why the East Asian growth successes experienced higher productivity growth than the other successes (e.g. the U.S. and Canada). Moreover, it provides an explanation for why some economies experience the same structural transformation but at a different pace with the result of lower productivity growth.

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Appendix 1: ILO report for economic Active population, (Unit: %)

	1950	*1960*	*1970*	*1980*	*1990*	*40 Year Change*
Australia	15.4	11.32	8.05	6.49	5.52	9.88
Belgium	11.85	7.96	4.83	2.95	2.63	9.22
Canada	19.84	13.19	7.79	6.66	3.37	16.47
Denmark	25.7	17.93	11.18	6.98	5.56	20.14
France	30.89	22.1	13.61	8.26	5.49	25.4
Germany	23.04	15.01	8.71	6.94	3.98	19.06
Italy	43.97	30.8	18.79	12.61	8.6	35.37
Netherlands	17.68	10.76	6.82	5.56	4.57	13.11
New Zealand	18.8	14.77	11.85	11.22	10.36	8.44
Portugal	49.76	44.02	31.75	26.04	17.82	31.94
Spain	51.62	41.14	29	18.44	11.86	39.76
Sweden	20.79	14.1	8.31	6.17	4.41	16.38
Switzerland	16.89	11.29	7.78	6.17	5.52	11.37
United Kingdom	5.48	4.01	2.81	2.6	2.17	3.31
United States	12.32	6.64	4.29	3.48	2.84	9.48
Greece	55.33	52.16	42.25	31.22	22.96	32.37
Hungary	51.77	38.02	25.13	18.42	15.22	36.55
Iceland	36.52	24.67	17.94	10.31	10.97	25.55
Israel	18.47	14.4	9.67	6.11	4.13	14.34
Ireland	40.21	36.58	26.36	18.57	14.34	25.87
Poland	57.77	48.08	38.91	29.79	27.47	30.3
Turkey	87	78.72	70.69	60.47	53.57	33.43
Latin American Countries						
Argentina	25.17	20.61	16.01	12.95	12.15	13.02
Brazil	61.57	55.17	47.24	36.67	23.28	38.29
Chile	32.89	30.33	24.08	20.9	18.78	14.11
Colombia	59.23	52.07	45.14	40.49	26.61	32.62
Costa Rica	57.53	51.25	42.6	34.99	26.03	31.5
Cuba	41.17	35.7	30.1	23.57	18.15	23.02
Ecuador	65.44	59.4	51.49	39.81	33.26	32.18
Honduras	74.68	72.45	67.41	57.18	41.4	33.28
Panama	56.42	51.06	41.62	28.93	26.18	30.24
Peru	57.68	52.32	48.27	40.29	35.58	22.1
Mexico	60.39	55.13	43.82	36.27	27.82	32.57
Uruguay	24.35	21.29	18.68	16.64	14.21	10.14
Puerto Rico	36.84	25.37	13.75	5.79	4.36	32.48
Asian Countries						
Hong Kong, China	12.12	7.77	4.36	1.32	0.89	11.23
Japan	48.83	33.06	19.64	10.95	7.28	41.55
Korea, Republic of	76.9	61.32	49.14	37.12	18.11	58.79
Singapore	8.21	7.4	3.43	1.56	0.36	7.85
China	88.38	83.23	78.34	74.24	72.24	16.14
India	79.55	75.37	72.64	69.53	64.02	15.53
Indonesia	79.01	74.8	66.3	57.84	55.17	23.84
Malaysia	67.35	63.26	53.74	40.78	27.36	39.99
Philippines	71.11	63.64	57.89	52.37	45.78	25.33
Thailand	84.68	83.71	79.78	70.92	64.07	20.61

Appendix 2: ALP

Year	*Productivity Improvement*	*Reallocation Effect*	*Year*	*Productivity Improvement*	*Reallocation Effect*
1953	***94.277%***	5.723%	1979	***60.227%***	39.773%
1954	***85.199%***	14.801%	1980	***53.492%***	46.508%
1955	***78.961%***	21.039%	1981	***58.384%***	41.616%
1956	***83.126%***	16.874%	1982	***146.328%***	-46.328%
1957	***79.332%***	20.668%	1983	***50.982%***	49.018%
1958	***61.311%***	38.689%	1984	42.859%	***57.141%***
1959	***81.084%***	18.916%	1985	25.830%	***74.170%***
1960	***103.321%***	-3.321%	1986	***62.043%***	37.957%
1961	***86.588%***	13.412%	1987	***72.042%***	27.958%
1962	***83.096%***	16.904%	1988	***74.194%***	25.806%
1963	***84.533%***	15.467%	1989	***74.366%***	25.634%
1964	***97.098%***	2.902%	1990	13.733%	***86.267%***
1965	***63.546%***	36.454%	1991	36.433%	***63.567%***
1966	***70.546%***	29.454%	1992	***58.515%***	41.485%
1967	49.241%	***50.759%***	1993	***82.120%***	17.880%
1968	***51.123%***	48.877%	1994	***66.626%***	33.374%
1969	28.348%	***71.652%***	1995	***71.226%***	28.774%
1970	***64.142%***	35.858%	1996	49.590%	***50.410%***
1971	***51.184%***	48.816%	1997	11.875%	***88.125%***
1972	***61.578%***	38.422%	1998	***74.199%***	25.801%
1973	***67.454%***	32.546%	1999	***95.233%***	4.767%
1974	***54.841%***	45.159%	2000	11.482%	***88.518%***
1975	***85.625%***	14.375%	2001	***117.320%***	-17.320%
1976	***61.239%***	38.761%	2002	39.002%	***60.998%***
1977	***53.715%***	46.285%	2003	***56.578%***	43.422%
1978	***55.164%***	44.836%			

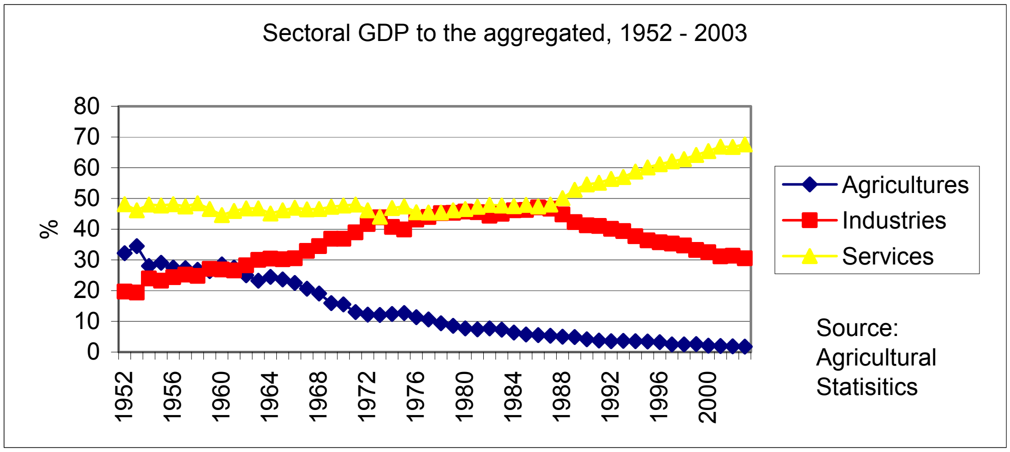

Figure I: Sectoral GDP to the aggregated, 1952-2003

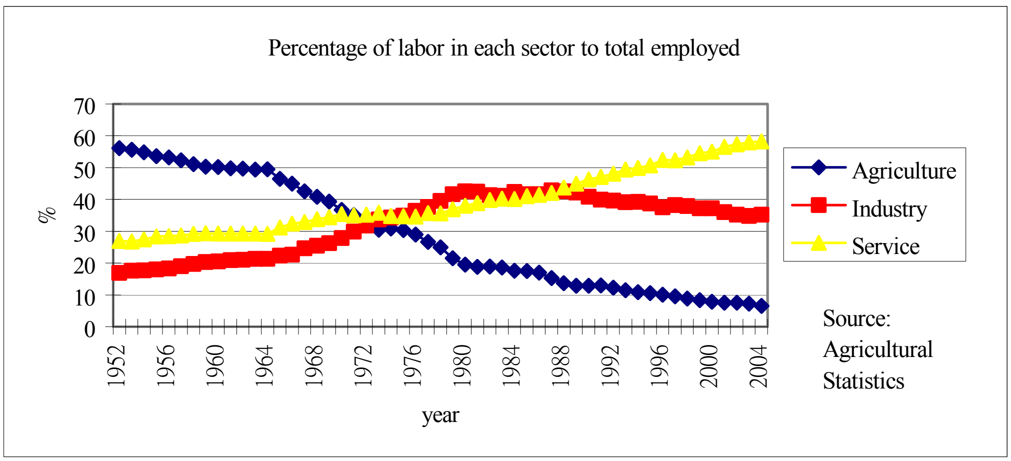

Figure II: Percentage of Labor in Each Sector relative to the total employed, 1952-2003

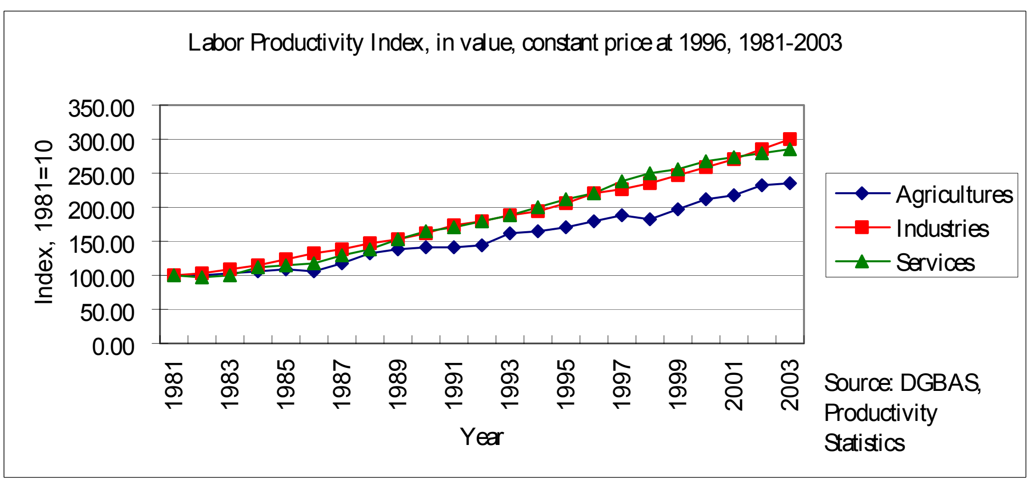

Figure III: Productivity Index, 1981 – 2003

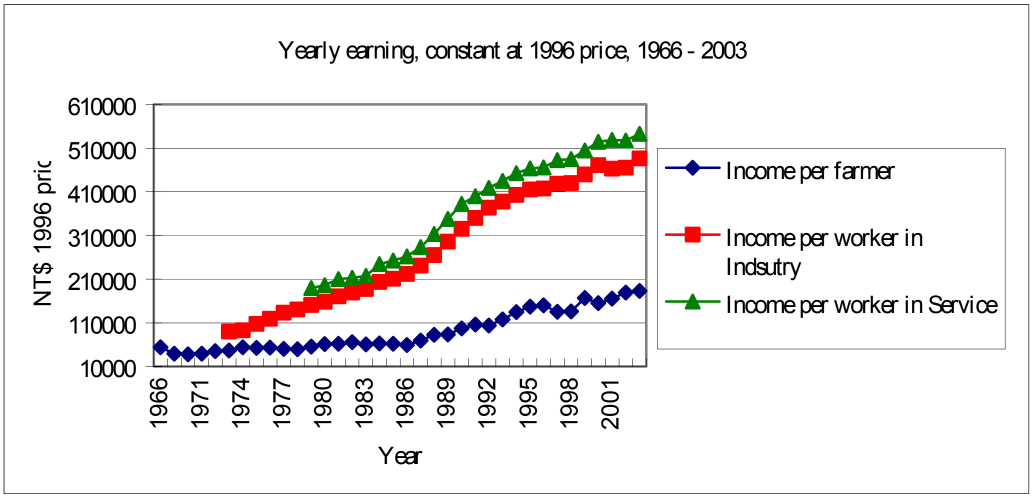

Figure IV: Yearly Earning Per Worker in Each Sector

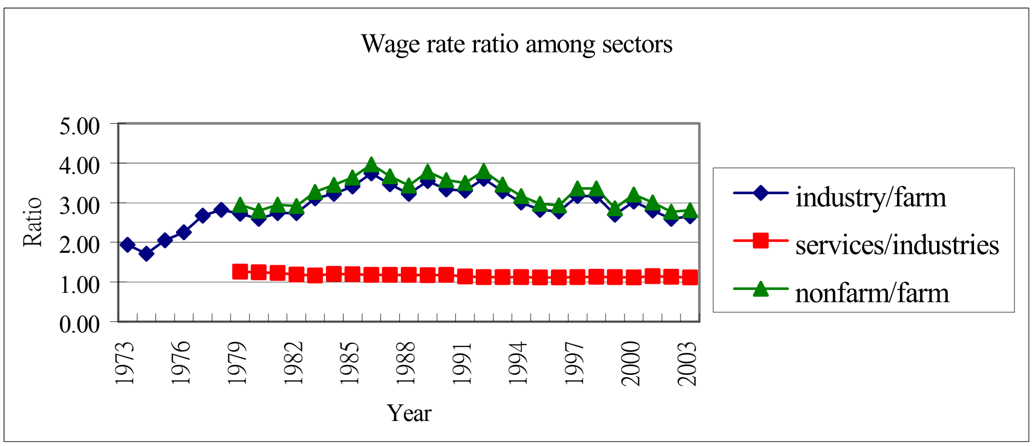

Figure V: Wage Ratio among Sectors

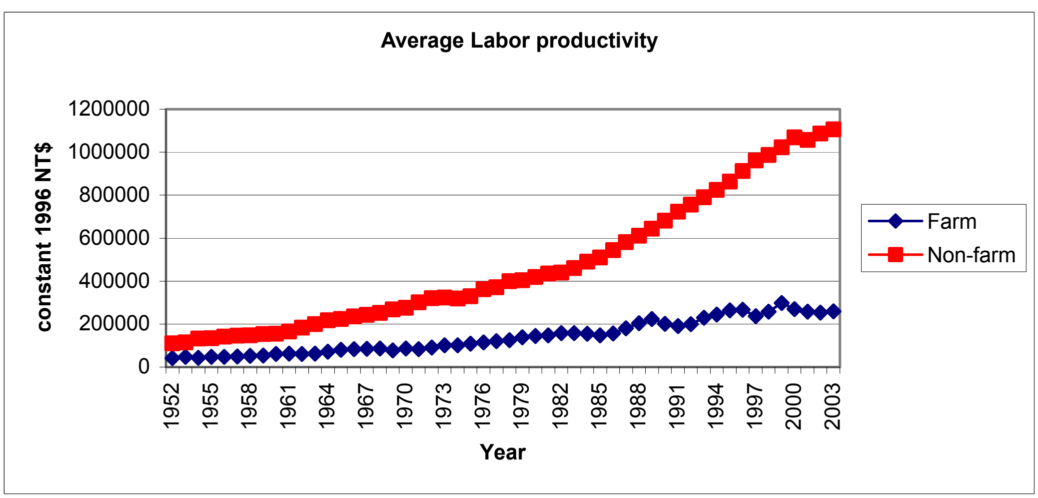

Figure VI: Average Labor Productivity in the Farm and Non-farm Sectors

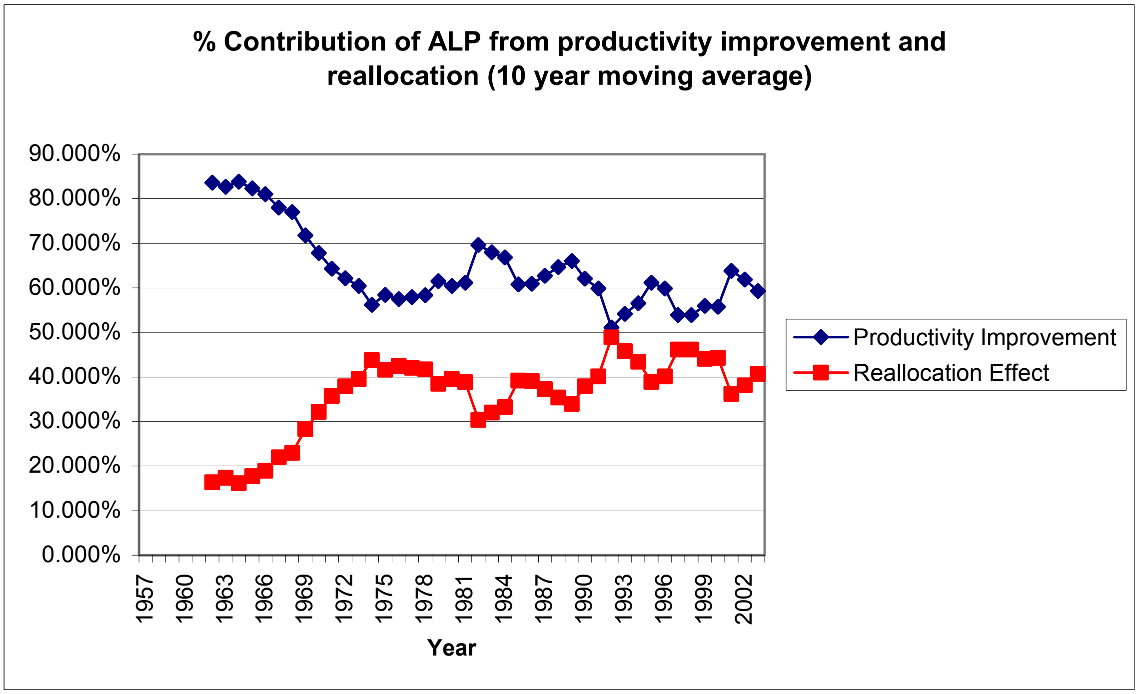

Figure VII: Percentage Contribution of Labor Reallocation Effect on ALP Growth

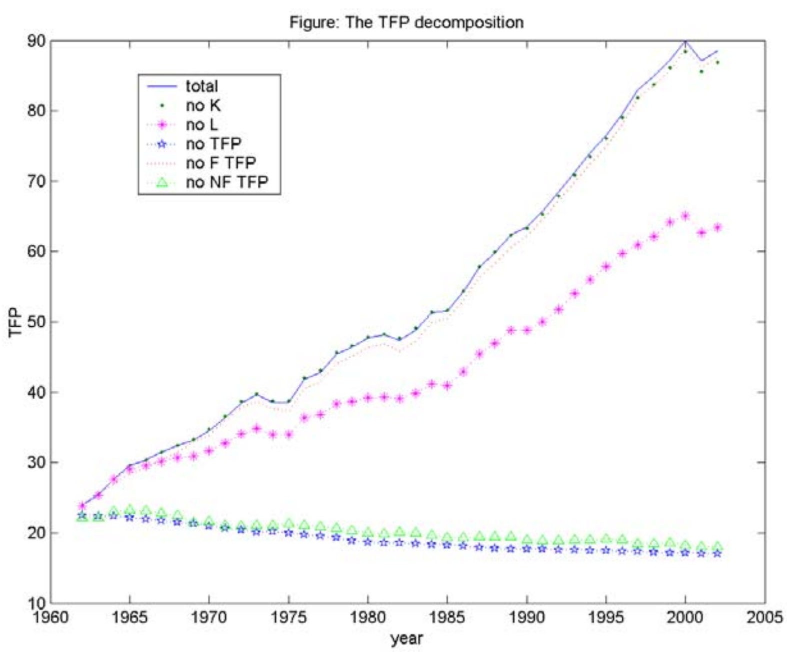

Figure VIII: TFP decomposition